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Public transport use among the urban and rural elderly in China: Effects of personal, attitudinal, household, social-environment and built-environment factors

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Abstract: Public transport brings significant benefits to the aging society by providing essential mobility to the elderly. However, few studies have investigated the factors that impact public transport use among the urban or rural elderly. This study explored the effects of personal, attitudinal, household, social environment, and built environment factors on the public transport trips of the elderly. The research data was collected from 274 urban and rural neighborhoods of Zhongshan, a medium-sized Chinese city. The negative binomial regression models suggest that, all else being equal, living in a neighborhood with a high level of public transport service, abundant green space along walking routes connecting home and bus-stops, or a relatively balanced structure of age or income is strongly connected to more public transport trips of the elderly. The results also indicate that a strong preference for public transport is significantly related to the public transport use among the elderly. These findings facilitate our understanding of the correlates of public transport use while providing insights into achieving an effective design of policies to encourage public transport use among the elderly in China.

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1 Introduction

It is fundamental to provide a basic level of mobility to the general population, especially to the transportation disadvantaged (Giuliano, 2005). The transportation disadvantaged, including the elderly, young, disabled, and low-income, etc., are commonly considered to be either unwilling or unable to drive or who do not have an access to a car (Duvarci, Yigitcanlar, Alver, & Mizokami, 2010; Giuliano, 2005). The mobility of the elderly is highly associated with their accessibility to public transport which ensures their participation in activities at greater distances from their home (Chen, 2010; Hess, 2009; Wretstrand, Svensson, Fristedt, & Falkmer, 2009). Previous research also reveals that public transport use may promote physical activity and health condition with higher levels of transportation-related walking (Day et al., 2014; Musselwhite, Holland, & Walker, 2015; Voss et al., 2016). Encouraging public transport use among the elderly is a crucial component of the efforts to improve mobility and quality of life (Zhang, Yang, Li, Liu, & Li, 2014). China has the world's largest ageing population. Up to year 2015, the population of the elderly (aged 60 or over) in China reached 222 million, accounting for 16.1% of the national population of China and this percentage is expected to rise to 25% by year 2030 (Ge et al., 2017). With the pressure of the ageing trend, it becomes a challenge to provide a public transport service that is safe, reliable, accessible and affordable to the elderly (Banister & Bowling, 2004).

In the past three decades, the level of motorization in both urban and rural areas in China is growing rapidly while the modal split of public transport keeps shrinking (Wu, Liu, Xu, Wei, & Zhang, 2017). In 2005, the State Council of the People's Republic of China launched an initiative of "Public Transport Priority Strategy" aiming to promote the development of varied public transport. However, policies that encourage public transport in the ageing population are scarce as little is known about the barriers and facilitators of public transport use among the elderly.

This study makes an important contribution to the literature. With data collected from Zhongshan, a medium-sized Chinese city, the factors that impact public transport use of the urban and rural elderly are investigated in an effort to better understand the correlations of personal, attitudinal, household, and neighborhood-level social and built environment attributes. Firstly, the study generated five categories of attributes: personal, attitudinal, household, neighborhood-level built environment, and neighborhood-level social environment. Then, negative binomial regression models were applied to examine that how public transport trips of the elderly are related to the social and built environment attributes, together with personal, attitudinal, and household attributes. The public transport trips in the present study are all-purpose bus trips. The elderly population in this study focus on adults aged 60 and over, in line with the definition of elderly population from the Law of the People's Republic of China on Protection of the Rights and Interests of the Elderly. The findings will provide insights for transportation and public health agencies, practitioners, and researchers into the effective design of interventions on health promotion of urban elderly.

2 Literature review

The public health and urban planning fields have mutually contributed to revealing how environmental features are related to the elderly' public transport use in the western context (Hess, 2012; Kim, 2011). The environmental correlates of public transport use are categorized as the built environment and the social environment. The built environment is characterized as the human-made environment where we live and work (Roof & Oleru, 2008; Srinivasan, O'Fallon, & Dearry, 2003). The social environment is constituted by the people who we interact with and the culture that we live in (Barnett & Casper, 2001). With regard to built environment features, walking trips from an origin or destination to the nearest bus-stop is a barrier for older adults to ride a bus (Hess, 2012). Both perceived and actual walking distance to bus-stops demonstrates significant influence on the ridership of the elderly (Broome, McKenna, Fleming, & Worrall, 2009; Chen, 2010; Hess, 2009, 2012). Public transport service, e.g., degree of the service articulation and the level of service, is another significant predictor of public transport use among the elderly (Barnes, Winters, Ste-Marie, McKay, & Ashe, 2016; Burkhardt, 2003; Haselwandter et al., 2015; Hess, 2012). Additional built environment features that showing significant effects could be categorized as: (1) land-use density, e.g., population density and residential density (Hess, 2012; Ryan, Wretstrand, & Schmidt, 2015); (2) street network design, e.g., number of street intersections (Hess, 2012); (3) destination accessibility, e.g., distance to the nearest clinic or hospital (Chen, 2010); (4) aesthetic and safety of pedestrian environment, e.g., greenery, neighborhood crime, and pedestrian infrastructure (Aceves-González, Cook, & May, 2015; Hess, 2012). Social environment factors featuring social norm and social support are significantly correlated to the elderly' judgment and actual use of public transport (Bamberg, Hunecke, & Blobaum, 2007).

The environmental attributes employed in public transport-related studies were typically derived (Siu et al., 2012) by: (1) surveying individuals' perceptions of the social or built environment (Rodríguez, Evenson, Diez Roux, & Brines, 2009); (2) aggregating neighborhood measures from secondary data source, such as Census or Traffic Analysis Zone (Ding, Wang, Yang, Liu, & Lin, 2016); (3) measuring these characteristics within a certain distance of the individuals' residences (Cerin et al., 2013), e.g., by buffer radii (ranging from 100 m to 1 km); or (4) quantifying the built environment attributes objectively at high resolution or used cluster analysis to identify different urban forms (Riva, Gauvin, Apparicio, & Brodeur, 2009). In Ewing and Cervero's research (2010), the built environment variables that influence travel behavior were named with words beginning with D as "five Ds" from five aspects: density, design, distance to transit, destination accessibility, and diversity.

It is worth mentioning that the majority of social and built environment-travel behavior studies were predominantly conducted in the Western contexts, and their findings are not necessarily translatable to the Chinese contexts (Van Cauwenberg et al., 2011). Currently, China is facing a rapid and intense urbanization which also transforms the urban landscape in Chinese cities dramatically (Zegras, 2010). Meanwhile, China is undergoing a drastic motorization, with the vehicle ownership increasing from 32 per 1000 people to 118 (from 2007 to 2016) (Zegras, 2010; Zhang et al., 2017). The joint pressure of urbanization and motorization poses both tough challenges and great opportunities to China's land use and transportation systems (Sun, Zhang, Xue, & Zhang, 2017; Wu, Ma, Long, Zhou, & Zhang, 2016). In the past few years, researchers began to investigate the associations of built and social environment with physical activity and travel behavior of the elderly using data collected from China. (Day, 2016; Ku, McKenna, & Fox, 2007; Ying, Ning, & Xin, 2015; Zhang, Li, Ding, Zhao, & Huang, 2016; Zhu, Chi, & Sun, 2016). For example, in Nanjing, China, older commuters are less likely to access rail transit by public bicycle (Ji et al., 2017); and among Taiwanese elderly, the degree of willingness to make medical trips by bus is associated with socioeconomic and health status, hospital or clinic accessibility, and bus service (Chen, 2010). However, rare among these studies have explored the correlates of public transport use among the urban and rural elderly in China. Revealing the factors which influence public transport use among the elderly is an indispensable step to facilitate interventions to promote physical activity. For this reason, this study will serve as an extended body of literature.

3 Data and methods

3.1 Study area

As stated in a previous study (Zhang, Yang, et al., 2014), the Zhongshan Metropolitan Area was chosen to examine the public transport use of the elderly in the Chinese context. Zhongshan is a medium-sized prefecture-level city in Guangdong Province of southern China (Figure 1). In the three largest coastal urban agglomerations with the most competitive economies in China, there are about 20 medium-sized cities with similar urbanization and motorization level, as well as urban transport characteristics to Zhongshan (Zhang, Yang, et al., 2014). Thus, the research findings in Zhongshan might be typical and informative to this type of cities.

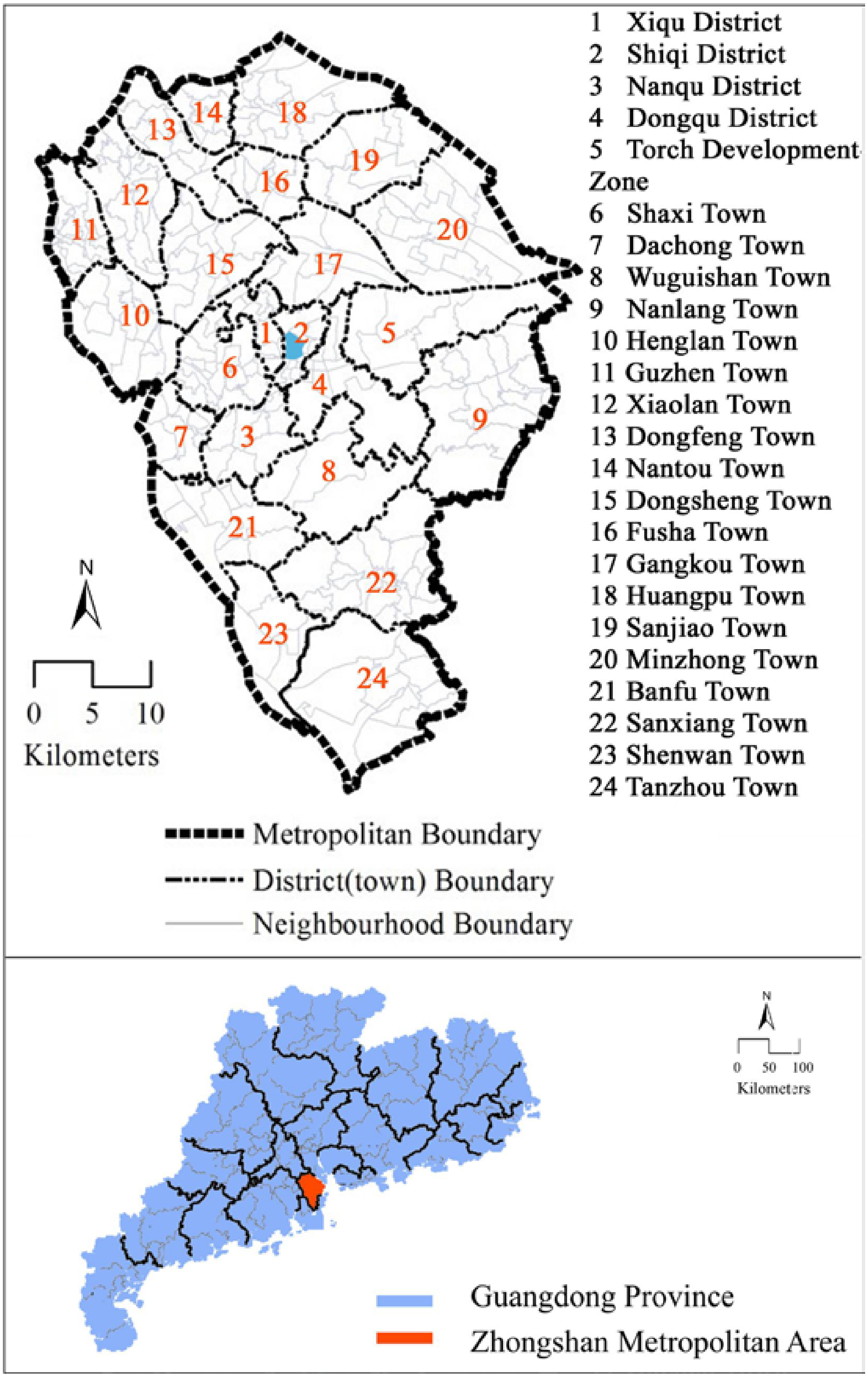

Figure 1: Study area

Note: The upper side of the figure shows the city boundary, district (town) boundary, and the neighborhood boundary of Zhongshan; while the bottom half shows the location of Zhongshan in Guangdong Province.

The public transport system in Zhongshan is run by Zhongshan Public Transportation Group Co., Ltd. It includes 175 lines and 2,056 buses with the entire Zhongshan Metropolitan Area covered. The average modal split of public transport in Zhongshan was 4.7% among the general population (Zhongshan Municipal Bureau of Urban Planning, 2010). In Zhongshan, the elderly made 2.84 trips per day in average, among which 9.5% (0.27 times per day) were public transport trips (Zhongshan Municipal Bureau of Urban Planning, 2010). Since 2010, there are two major policies pertaining to the public transport use among the elderly in Zhongshan. The first one is to extend the bus lines to connect the rural areas where public transport service failed to be satisfying, especially for the elderly with lower mobility. This policy was initiated in 2010 since the implementation of Zhongshan Transportation Development Planning (2010 to 2020). The second policy is to provide a free bus card to the elderly to encourage public transport use, especially among the elderly with low income. Commenced in 2010, this policy covered only registered permanent residence at the beginning. Since 2014, the policy began to benefit temporary resident without household registration in Zhongshan as well.

3.2 Data collection

The frequency of elderly's public transport trips were derived from Zhongshan Household Travel Survey (ZHTS) in 2010 (Zhongshan Municipal Bureau of Urban Planning, 2010). Selected by stratified random sampling covering the whole Zhongshan City, the sample size of the elderly over 60 was 4784 (2905 male and 1879 female) from 274 urban and rural neighborhoods, with a sample rate of 2.0% (Zhang, Li, Liu, & Wu, 2018). The ZHTS provided the self-reported data of one-day public transport trips, together with personal, attitudinal, and household data.

The following data for the characterization of built environment attributes comes from Zhongshan Municipal Bureau of Urban Planning (Zhang, Li, Liu, & Li, 2014): (1) traffic analysis zones' boundaries—proxy for neighborhood boundaries; (2) land use in 2010 with five major types of land use (residential land, commercial and service facilities, industrial and manufacturing, green space, and other types); (3) neighborhood population in 2010; (4) road networks; (5) bus stops; and (6) political boundaries, such as city and zone boundaries. All the data were then integrated into ArcGIS for further analysis.

3.3 Characterization of socioeconomic and attitudinal attributes

The personal-level socioeconomic data includes sex and age. The household-level socioeconomic data includes household size, income level, and ownership of bikes, electric-bikes, motorcycles, and cars. The individual attitudinal data involves the most favorite travel modes for daily trips among walking, bike, electric-bike, public transport, motorcycle, and car.

3.4 Characterization of social and built environment attributes

The social and built environment attributes were characterized on the basis of neighborhoods, which are defined to be spatially equivalent to the traffic analysis zones. As designed to be homogeneous with respect to socio-demographic characteristics and living conditions (Martinez, Viegas, & Silva, 2009), traffic analysis zones share boundaries with administrative divisions in most cases. According to the administrative divisions of Zhongshan Metropolitan Area, a total of 274 traffic analysis zones (neighborhoods) were selected in this study.

With respect to previous literature, social environment is reflected by segments of the population with different socio-demographic characteristics, e.g., age structure, average income, average education level (Bamberg, et al., 2007). A hypothesis is that different social environment is related to differences in elderly' judgment and actual use of public transport. The neighborhood level data of ZHTS provides some support for this hypothesis. In neighborhoods with low, medium or high average income, the public transport trips among the elderly are 0.18, 0.26, and 0.35 respectively. Thus, residents in low-income neighborhoods demonstrate a weaker social norm to ride a bus for everyday trips. Similarly, in neighborhoods with a smaller proportion of elderly population than the average (13.6%), the elderly makes 0.30 public transport trips per day, which is 17.5% higher than their counterparts. In this study, we defined two types of attributes to demonstrate the social environment of the neighborhood where the elderly live, i.e., the proportions of elderly population, and the proportions of high (medium or low)-income households.

Ewing and Cervero suggested (2010) that each D variable of "five Ds" built environment contains a number of attributes that are commonly used in built environment- travel behavior research. Considering the best available data, we identified five neighborhood-level built environment attributes according to the five Ds in this study, which are dwelling units density (density), intersection density (design), land-use mixture (diversity), bus-stop density (distance to transit), and commercial accessibility (destination accessibility). Additionally, we also employed the sixth attribute "the percentage of green space" to represent the aesthetic factor which also influences the public transport use among the elderly (Van Cauwenberg, et al., 2011).

The dwelling unit density, intersection density, bus-stop density, and the percentage of green space are self-explanatory. The land-use diversity was calculated with respect to the context of Zhongshan, as applicable. The land-use diversity represents the degree to which different land uses in a neighborhood are mixed. We calculated the land-use diversity by the Entropy Index (EI) (Kockelman, 1997), wherein 0 indicates single-use environments and 1 stands for the equalization of different land uses in area coverage. EI is defined by:

$$EI=\sum_{i=1}^{n} P_i \log(1/P_i) \qquad (1)$$

where n = number of unique land uses, $n \geq 1$; P_i = percentage of land use i's coverage over total land use coverage (Zhang, Li, Yang, Liu, & Li, 2013). The measure of commercial accessibility describes the ease of access to commercial attractions. The neighborhood-level commercial accessibility is defined by the area of coverage of commercial facilities within one-kilometer distance from the centroid of a neighborhood. This measure relies on the data from the Zhongshan Household Travel Survey (ZHTS) in year 2010. The travel dairy of ZHTS shows that travel distance of one kilometer covers 70% of urban elderly's home-based shopping trips and is a commonly acceptable distance by the elderly. For each neighborhood, we obtained the commercial accessibility by the following two steps. For step 1, we defined the centroid of each neighborhood as the origin, distributed the acceptable travel distance of one kilometer as a buffer to the main roads from the origin, then formed an enclosed area with the endpoints of the acceptable travel distances in ArcGIS. For step 2, we collected the data of area covered by commercial facilities in the enclosed area in ArcGIS, and divided the data by the population of the neighborhood to get the commercial accessibility.

3.5 Model specification

In built environment-travel behavior research, poisson regression and negative binomial regression are extensively used for non-negative count dependent variables (Jang, 2005; Lewsey & Thomson, 2004).

Therefore, we tested the data to choose the proper model from poisson regression models and negative binomial regression models. The poisson process assumes that the conditional variance of the distribution of the elderly's daily public transport trips is equal to the expected value (Long, 1997; Long & Freese, 2006). However, in this study, this assumption could not be met by the dependent variable as the conditional variance is smaller than the expected value. Therefore, we preferred negative binomial regression rather than poisson regression. The percentage of elderly making 0, 1, 2, or 3 and more public transport trips is 86.2%, 3.1%, 9.1%, and 1.6% respectively. Thus, the count of elderly's public transport trips has more zero observations than non-zero ones, indicating a possible over-dispersion. We then tested to determine if a zero-inflated negative binomial regression is more suitable than a standard one. We employed the Vuong model selection test and the results strongly favored a standard negative binomial regression over a zero-inflated one.

Therefore, this study chose a negative binomial regression model to analyze the impact of individual, attitudinal, household, and built environment attributes on the frequency of elderly's public transport trips. We checked for the multicollinearity of all the independent variables by calculating the variance inflation factor (VIF). All the VIFs are smaller than 10, indicating a low degree of multicollinearity. The basic negative binomial regression model specifications were expressed as follow:

$$\begin{aligned}\mathrm{Log}Nr_{\mathrm{frequency}} = {} & \beta_0' + \beta_1' * \mathrm{GENDER} + \beta_2' * \mathrm{AGE} + \beta_3' * \mathrm{PROWALK} + \beta_4' * \mathrm{PROBIKE} \\ & + \beta_5' * \mathrm{PROEBIKE} + \beta_6' * \mathrm{PROBUS} + \beta_7' * \mathrm{PROMOTOR} + \beta_8' * \mathrm{PROCAR} \\ & + \beta_9' * \mathrm{HHSIZE\_1} + \beta_{10}' * \mathrm{HHSIZE\_2} + \beta_{11}' * \mathrm{HIGNINC} + \beta_{12}' * \mathrm{MEDINC} \\ & + \beta_{13}' * \mathrm{BUSDIST} + \beta_{14}' * \mathrm{BIKES} + \beta_{15}' * \mathrm{EBIKES} + \beta_{16}' * \mathrm{MOTORS} + \beta_{17}' * \mathrm{CARS}\end{aligned} \tag{2}$$

where $Nr_{\mathrm{frequency}}$ is the frequency (times/day) of elderly's public transport trips; GENDER denotes whether the respondents is male or female; AGE means the respondent's age in years; PROWALK, PROBIKE, PROEBIKE, PROBUS, PROMOTOR or PROCAR demonstrates whether the respondents favor walking, bicycle, e-bike, public transport, motorcycle, or car over other travel modes in daily travel; HHSIZE_1 and HHSIZE_2 are dummies for the household size of one and two (with a reference category of more than two); HIGHINC and MEDINC are dummies for the household total annual income ranges of above 60,000 Chinese Yuan (Renminbi) (RMB, 6.3 Renminbi ≈ 1 US Dollar) and 20,000-60,000 RMB (with a reference category of 0-20000 RMB); BUSDIST represents the distance of the nearest bus-stop to respondents' home; BIKES, EBIKES, MOTORS, and CARS stand for the number of bicycles, electric bicycles, motorcycles and private cars in a household, respectively.

Along with the basic model presented above, regression of the dependent variables proceeded in an expanded model with three social environment attributes and six built environment attributes added as independent variables. The three social environment attributes are P_ELDERLY, P_HIGHINC, and P_MEDINC, which denote the proportions of the elderly population, the high-income households, and the medium-income households (with a reference category of low-income households) in the neighborhood where the elderly live. The six built environment attributes are DWELLING, INTERSECTION, MIXTURE, COMMERCIAL, BUSSTOP, and GREENSPACE, which demonstrate the dwelling unit density, intersection density, land-use mixture, commercial accessibility, bus-stop density, and the percentage of green space in the neighborhood where the elderly live.

4 Results

4.1 Descriptive statistics

Descriptive statistics provide a general view of the dependent and independent variables (Table 1). The average age of the respondents is 67.05 years old. One-fourth of the elderly choose walking or public transport as their favorite travel mode. Nearly 20% of the respondents live alone while over one-third live with a partner. Nearly two-thirds of the respondents live in medium-to-high-income households. The average distance from home to the nearest bus-stop is 0.5 km. The household ownership of motorcycle and bicycle averaged 0.76 and 0.61, much higher than that of e-bike or car. The standard deviation values of dwelling unit density, intersection density, and percentage of green space among all land uses were larger than their mean values, implying the substantial variations of land-use density, road network design, and aesthetics among neighborhoods in Zhongshan.

Table 1: Descriptive statistics of dependent and independent variables (sample size = 4784)

Variable	Description	Mean	S. D.	Min.	Max.
Dependent Variables					
Frequency	Frequency of the elderly's public transport trips, times per day, count	0.27	0.73	0	6
Personal Attributes (Independent Variables)					
GENDER	1 = Male, 0 = Female, binary	0.61	0.49	0	1
AGE	Age of the respondent in years, count	67.05	6.61	60	95
Attitudinal Attributes (Independent Variables)					
PROWALK	The respondent favors walking over other modes, binary, 1 = yes	0.26	0.44	0	1
PROBIKE	The respondent favors bicycle over other modes, binary, 1 = yes	0.16	0.37	0	1
PROEBIKE	The respondent favors e-bike over other modes, binary, 1 = yes	0.06	0.24	0	1
PROBUS	The respondent favors bus over other modes, binary, 1 = yes	0.24	0.43	0	1
PROMOTOR	The respondent favors motorcycle over other modes, binary, 1 = yes	0.12	0.33	0	1
PROCAR	The respondent favors car over other modes, binary, 1 = yes	0.03	0.17	0	1
Household Attributes (Independent Variables)					
HHSIZE_1	Household size is one person, binary, 1 = yes	0.19	0.39	0	1
HHSIZE_2	Household size is two persons, binary, 1 = yes	0.35	0.48	0	1
HHSIZE > 2	Household size is three or more persons, binary, 1 = yes	0.46	0.50	0	1
HIGHINC	High household income (>60000 RMB/yr), binary, 1 = yes	0.17	0.37	0	1
MEDINC	Medium household income (20000-60000 RMB/yr), binary, 1 = yes	0.47	0.50	0	1
LOWINC	Low household income (<20000 RMB/yr), binary, 1 = yes	0.36	0.48	0	1
BUSDIST	Distance from home to the nearest bus-stop (km), continuous	0.50	0.36	0.1	1.2
BIKES	Number of bikes in a household, count	0.61	0.71	0	5
E-BIKES	Number of electric bikes in a household, count	0.22	0.46	0	4
MOTORS	Number of motorcycles in a household, count	0.76	0.85	0	5
CARS	Number of private cars in a household, count	0.17	0.44	0	4
Sociol Environment Attributes (Independent Variables)					
P_ELDERLY	Proportions of elderly population in the neighborhood, continuous	0.14	0.06	0.01	0.29
P_HIGHINC	Proportions of high-income household in the neighborhood, continuous	0.25	0.43	0	1
P_MEDINC	Proportions of medium-income household in the neighborhood, continuous	0.60	0.49	0	1
P_LOWINC	Proportions of low-income household in the neighborhood, continuous	0.15	0.35	0	1
Built Environment Attributes (Independent Variables)					
DWELLING	Dwelling units density, 1000 units /km2, continuous	3.34	4.32	0.02	17.42
INTERSECTION	Intersection density, number of 5 intersections per km2, continuous	2.79	3.18	0	13.26
MIXTURE	Land-use mixture, Entropy Index, continuous	1.95	0.98	0.04	4.29
COMMERCIAL	Area coverage of commercial establishments within 1 km from the center of a neighborhood, in ha, continuous	33.19	33.08	0	230.46
BUSSTOP	Bus-stop density, number of bus stops per km2, continuous	0.70	0.18	0	1
GREENSPACE	Percentage of green space land use among all land uses, continuous	0.07	0.08	0	0.65

Note: S. D. = Standard Deviation; Min. = minimum; Max. = maximum.

4.2 Negative binomial regression analysis

The results of negative binomial regressions demonstrated how differently that the personal, attitudinal, household, social environment, and built environment attributes were associated with public transport use among the elderly (Table 2). The two hypotheses of the paper are: 1) attitudinal factors are significantly correlated to the daily public transport trips among the elderly, and 2) social and built environment factors are significantly correlated to the daily public transport trips among the elderly.

Table 2: Negative binomial regressions of the frequency of elderly's public transport trips

Category	Variable	Basic Model		Expanded Model	
		Coef.	z	Coef.	z
Personal attributes	MALE	**0.228*****	2.58	**0.229*****	2.60
	AGE	**–0.012***	–1.68	**–0.012***	–1.62
Attitudinal attributes	PROWALK	**–0.506*****	–3.25	**–0.528*****	–3.36
	PROBIKE	**–0.807*****	–4.34	**–0.746*****	–4.00
	PROEBIKE	**–1.137*****	–4.02	**–1.156*****	–4.07
	PROBUS	**1.354*****	10.03	**1.386*****	10.21
	PROMOTOR	**–0.619*****	–3.16	**–0.540*****	–2.73
	PROCAR	**–0.990*****	–2.73	**–0.943*****	–2.59
Household attributes (HHSIZE > 2 and LOWINC are reference categories)	HHSIZE_1	–0.033	–0.21	–0.063	–0.41
	HHSIZE_2	**0.235****	2.00	**0.235****	2.00
	HIGHINC	0.313	2.11	0.081	0.52
	MEDINC	0.020	0.18	–0.125	–1.10
	BUSDIST	**–0.803*****	–5.87	**–0.656*****	–4.59
	BIKES	0.130	2.04	0.145	2.25
	EBIKES	0.171	1.63	0.266	2.51
	MOTORS	–0.076	–1.17	–0.071	–1.05
	CARS	0.009	0.10	–0.006	–0.06
Social environment (P_LOWINC is a reference category)	P_ELDERLY			**–1.727****	–2.12
	P_HIGHINC			**0.386****	2.32
	P_MEDINC			**0.334****	2.32
Built environment	DWELLING			–0.019	–0.80
	INTERSECTION			0.039	1.42
	MIXTURE			**0.178*****	3.48
	COMMERCIAL			0.001	0.98
	BUSSTOP			**–0.512***	–1.80
	GREENSPACE			**1.665*****	2.83
	_cons	–0.807	–1.52	–1.189	–2.05
Summary statistics	Number of obs	4784		4784	
	LR chi2	526.97		575.66	
	Prob > chi2	0.0000		0.0000	
	Pseudo-R2	0.0913		0.0998	
	Log likelihood	-2621.5893		–2597.2441	

Note: ***denotes significance at $p < 0.01$, **denotes significance at $p < 0.05$, and *denotes significance at $p < 0.1$. Blank cells mean variable was not included in that model. Obs = observations; prob = probability.

At the personal level, both age and gender are significant at 90% confidence. Being male or younger was related to more public transport trips. At the attitudinal level, all six attributes showed significant associations. Those who preferred public transport to other modes would make 2.87 times (= exp (1.354)–1) more public transport trips compared with their counterparts. The elderly who favored other modes over public transport would make 39.69% to 67.92% fewer public transport trips.

At the household level, attributes related to household size and the distance between home and the nearest bus-stop were significant at 95% confidence. Those who live with a partner would make 26.46% more public transport trips than those who live in a household with three or more members. As expected, living an extra kilometer away from the nearest bus-stop was related to a 55.19% decrease in the frequency of public transport trips.

At the social environment level, all three variables demonstrated significant correlations. The elderly who live in a neighborhood with the largest proportion of elderly population tend to generate 23.85% fewer public transport trips than their counterparts in a neighborhood with the smallest proportion. More middle-to-high income households in the neighborhood, more frequently the elderly use public transport. Comparing to the elderly in low-income neighborhoods, those who reside in high-income or medium-income neighborhoods would make 47.12% and 39.59% more public transport trips.

At the built environment level, three variables representing land-use diversity, public transport service, and aesthetics were statistically significant at 90% confidence. The elderly who live in the most mixed-developed environment would make 37.71% fewer public transport trips than in the least mixed-developed environment. As expected, denser bus-stops in a neighborhood are related to more public transport use among the elderly in Zhongshan. Compared to the elderly living in the neighborhood with the least bus-stops, the elderly would make 62.86% more public transport trips if they live in the environment with the densest ones. Similarly, with an increase of 20% of green space land use based on the average, the public transport trips by the elderly would increase by 5.69%.

The directions of the effects for the individual and household attributes persisted across both basic and expanded models, and the coefficients showed slight to moderate variation. The LR chi2 and the Log likelihood of each model represent the overall goodness of fit. The changes of Pseudo-R^2, LR chi2 and Log likelihood in expanded models implied that the social and built environment variables contributed to strengthening the explanatory power and enhanced the predictability of the models.

5 Discussion and policy implications

Personal, attitudinal, and household attributes related to gender, age, attitudes towards public transport, and household size, are significantly related to the elderly's public transport use. Specifically, being male or younger-old, or favoring public transport over other modes, or living with a partner is associated with more public transport trips. Male or younger elderly are more physically active to use public transport than their female or older counterparts, which is an important reason for the higher frequency of public transport trips. The findings on the correlation of a strong preference to public transport is in consistency with previous literature, including the Theory of Planned Behavior (Godin & Kok, 1996). This implies the potential effects of the dissemination of an active life style involving positive attitudes towards public transport among the elderly (Ding, Lin, & Liu, 2014).

The correlations of the social and built environment attributes on the elderly's public transport use in Zhongshan yield some interesting findings. The social environment attributes relating to the degree of ageing and the affluence of the neighborhood were significantly associated with the public transport use among the elderly. With regard to the proportions of elderly population in the neighborhood, the elderly would have more public transport trips if they live in a neighborhood with a smaller older population. The neighborhood-level aggregate data also provided some support. For the elderly living in a younger or an older neighborhood, i.e., the proportion of the elderly population was below or above average in Zhongshan, the frequency of everyday public transport trips was 0.29 and 0.24 respectively. In terms of the average income of the neighborhood, the elderly in neighborhoods with high or medium income would use public transport more frequently than their counterparts in low-income ones. The research data indicates that the elderly residing in a high-income neighborhood would make nearly twice public transport trips (0.35 trips/day) than the elderly in a low-income neighborhood (0.18 trips/day). Thus, for neighborhoods with a low average income these data demonstrates a weaker social norm to ride a bus for everyday trips. The reasons to the above finding remain unclear due to the limitation of available data at the current stage. Previous studies showed that it may be connected to social norms with active travel behaviors (Ball, Jeffery, Abbott, McNaughton, & Crawford, 2010). One assumption is that in a social environment with younger population or medium-to-high average income, residents may more willingly engage in pro-environmental behavior and choose eco-friendly travel modes (Doran & Larsen, 2015). Then, those social norms may regulate behavior of the elderly and influence their travel mode choice. Although the underlying reasons need to be explored in future research, the results showed the potentiality to promote public transport use among the elderly by balancing neighborhood age structure and enhancing neighborhood income level. It is worth mentioning that the current policy of providing free bus card to the elderly is partly in consistency with the possible effects of the social environment factor, the average income in a neighborhood. The main purpose of the policy was to encourage low-income elderly to choose public transport without a financial barrier. Since the policy was initiated in 2010, the same year in which the research data was collected, it was hard to conclude if it is effective to promote public transport use among the elderly in low-income neighborhoods. Therefore, the real effectiveness of the "free bus car" policy remains to be examined in future studies. According to the research findings, it may be more effective if coupling the current free bus card policy with the policy of enhancing neighborhood income level.

The built environment attributes featuring public transport service, land-use diversity, and aesthetics showed significant correlation to the elderly's public transport trips, albeit to varied degrees.

- Living close to a bus-stop is strongly related to more public transport trips by the elderly. This is in consistency with previous literature that shorter walking distance between home and bus-stops will enhance the attractiveness of public transport and increase public transport use by the elderly (Chen, 2010; Hess, 2012).
- In the environment with more bus-stops, the elderly tend to increase the public transport use. This is in accordance with our expectation that denser bus-stops may provide more bus lines and available destinations which facilitate public transport service for the elderly (Burkhardt, 2003). The local policy of extending bus lines to rural areas, which was implemented in 2010, was in compliance with the effects of bus-stop density and distance from home to the nearest bus-stop. Generally, the level of public transport service in the rural areas of Zhongshan is lower than in the urban areas. The bus-stops in rural areas are scarce and the distance between home and the nearest bus-stop is sometimes twice of that in urban areas. Therefore, extending and increase bus lines will not only increase the bus-stop density, but also shorten the distance from home to the nearest bus-stop in rural areas. Consequently, the rural elderly may be attracted to public transport from other travel modes and their everyday public transport trips are expected to rise.
- In neighborhoods with mixed land-use patterns, the propensity of elderly to use public transport is lower. That may be because that mixed development increases the possibility of having short-to-medium distance trips instead of long distance ones. In that case, walking and cycling may serve as better mode choices than public transport.
- With more green space from home to bus-stops, the elderly tend to have more public transport trips. In Zhongshan, the average walking distance from home to the nearest bus-stop is 500

meters, equaling to eight to ten minutes' walking. Abundant greenery along the walking route not only brings aesthetic enjoyment but also provides shelters and resting places during walking, which facilitate the walking environment for the elderly (Aceves-González, et al., 2015). In the first quartile of neighborhoods in terms of the percentage of green space, the elderly make 0.34 public trips per day. While in the counterparts of the last quartile, the elderly make only 0.25 public trips per day.

Based on the discussions above, we could find out that policies involving attitudes, social and built environment may be potentially effective to increase the public transport use among the elderly. The findings in this study provide insights for transportation and public health agencies, practitioners, and researchers into four possible interventions as below.

- Disseminating an active life style involving positive attitudes towards public transport is of essential importance. We recommend diversified initiatives, e.g., public transport campaigns, and specialized websites, given that it is hard to change attitudes among the elderly instantly.
- Develop neighborhoods with relatively well-balanced structures of age and income which help to avoid the over aggregation of the elderly or low-income population.
- Optimize the location of bus-stops. This policy includes enhancing bus-stop densities in adjacent areas of elderly's home, and shortening the distance between home and the nearest bus-stop.
- Provide abundant greenery, especially along major walking routes connecting the residential areas and the bus-stops.

6 Strengths and limitations

This study has several strengths and limitations. In terms of the strengths, firstly, the study focused on the elderly population, and provided informative policy implications for the ageing society. Secondly, the study revealed the personal, attitudinal, household, social environment, and built environment correlates of the elderly's public transport use in a developing country under the context of rapid urbanization and motorization. It helps to further promote the comparative studies between different contexts. In terms of the limitations, firstly, the dependent outcome, public transport trips, is based on self-reports which therefore may not capture all domains of this activity due to the bias of subjectivity in self-report. However, self-report in transport is one of the most commonly used methods in the research field, and it remains as the primary source for assessing public transport use in large-scale studies like this. Secondly, cross-sectional data were used in this study. For this reason, the full evaluation of causal inferences about the effects of different factors on public transport use requires further longitudinal and multilevel analyses over time.

7 Conclusion

This study makes an important contribution to the existing literature by investigating the correlates of the public transport use of the elderly in Zhongshan, a medium-sized Chinese city. The research findings suggest that a strong preference to public transport is substantially related to more public transport trips of the elderly in Zhongshan. In terms of the social environment, the elderly tend to use public transport more frequently if residing in a neighborhood with less elderly population and medium-to-high average income. With respect to the built environment, all else being equal, living in a neighborhood with easy access to public transport, high level of public transport service, and sufficient green space is associated with more public transport trips of the elderly.

The findings facilitate the notion of developing public transport-friendly communities and are informative to create public health interventions which help to promote the public transport use together with physical activities among the elderly in Zhongshan. Possible interventions include: (1) disseminate an active life style involving positive attitudes towards public transport; (2) develop neighborhoods with relatively balanced structure of age and income; (3) optimize bus-stop locations with higher stop densities and shorter distance between home and the nearest bus-stop; and (4) provide abundant green space, especially along major walking routes connecting home and the bus-stops.

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