

The Built Environment and the Frequency of Cycling Trips by Urban Elderly: Insights from Zhongshan, China

Yi Zhang¹, Chaoyang Li², Chuan Ding³, Chunli Zhao⁴ and Jianzhong Huang*⁵

¹ Assistant Professor, State Key Laboratory of Ocean Engineering, Shanghai Jiao Tong University;
Research Fellow, Key Laboratory of Special Environment Road Engineering of Hunan Province, Changsha University of Science & Technology, China

² Professor, Department of Architecture, Shanghai Jiao Tong University, China

³ Assistant Professor, School of Transportation Science and Engineering, Beijing Key Laboratory for Cooperative Vehicle
Infrastructure System and Safety Control, Beihang University, China;

Post-Doctoral Research Fellow, Department of Geography, Hong Kong Baptist University, Hong Kong

⁴ Ph.D. Fellow, Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark

⁵ Associate Professor, College of Architecture and Urban Planning, Key Laboratory of Ecology and Energy-saving Study of Dense
Habitat (Ministry of Education of China), Tongji University, China

Abstract

As a form of active transport, cycling provides significant health benefits to the elderly. Among voluminous active transport-related literature, few studies have investigated the correlates of the cycling activity of urban elderly. This study explored the effects of individual, household, and built environment attributes on the frequency of cycling trips by urban elderly, with data collected from 33 urban neighborhoods of Zhongshan, China. The negative binomial regression models detect that, all else being equal, living in a neighborhood with a compact urban form and safe cycling environment is strongly connected to more cycling trips by the urban elderly. The models also suggest that attitudes towards cycling or driving and household ownership of bicycles or cars are significantly related to urban elderly's cycling trips. The findings facilitate our understanding of the effects of built environment on cycling activity and provide insights into an effective design of interventions on health promotion of the urban elderly in China.

Keywords: urban elderly; frequency of cycling trips; built environment; negative binomial regression

1. Introduction

There is strong evidence that regular active transport, including walking and cycling, provides substantial health benefits to the elderly (Nelson *et al.*, 2007). Active transport, as a part of physical activity, is positively associated with prevention of chronic diseases, disability, and bone fractures among the elderly (Keysor, 2003). As an important form of active transport, cycling is accessible and easy to incorporate into daily life. Promoting cycling among the elderly is a crucial component of efforts to improve their overall physical activity levels (Zhang *et al.*, 2014c). Up to year 2014, the population of the elderly (aged 65 and

over) in China was 137 million, accounting for 10% of the Chinese population. At the same time, the figures for Korea and Japan are even as high as 12% and 25%, respectively. With the growing elderly population, it is a challenge to promote active transport among the elderly as a health promotion (Wanner *et al.*, 2012).

Taking China as an example, the National Health and Family Planning Commission of China (NHFPC) has launched an initiative of "Ten Thousand Steps a Day" for the Chinese elderly since 2007, aiming to promote all kinds of walking activities. However, few interventions with regard to the promotion of cycling activity have been implemented in China. In the past three decades, the level of motorization in urban environments in China has been growing and the mode split of active transport continues to shrink (Zhang *et al.*, 2015). As a popular travel mode in China's urban areas, evidence concerning the correlates that may impact on elders' cycling activity is scarce, leading to a lack of practical implications for the design of health interventions.

This study makes an important contribution to the literature. With data collected in Zhongshan, China, the

*Contact Author: Jianzhong Huang, Associate Professor,
College of Architecture and Urban Planning,
Key Laboratory of Ecology and Energy-saving Study of Dense
Habitat (Ministry of Education of China), Tongji University,
Shanghai 200092, China
Tel: 86-21- 65982345 Fax: 86-21- 65982345
E-mail: hjz03213@126.com

(Received October 3, 2015 ; accepted July 11, 2016)

DOI <http://doi.org/10.3130/jaabe.15.511>

correlates of the cycling activity of urban elderly are investigated in an effort to better understand the impact of individual, household, and neighborhood-level built environment attributes on such active transport. Firstly, the study generated three categories of attributes: individual, household, and built environment. Then, negative binomial regression models were used to examine specifically how the frequency of urban elderly's cycling trips are related to the built environment, together with individual and household attributes. The cycling trips in the present study include both transportation and recreational cycling. This study focuses 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 for the urban elderly.

2. Literature Review

The planning and design fields (Handy *et al.*, 2002; Saelens *et al.*, 2003) and the public health field (McCormack and Shiell, 2011) have mutually contributed to the proliferation of research on the environmental correlates of active transport by the elderly in the western context (Saelens and Handy, 2008). The findings have facilitated our understanding of the environmental correlates concerning active transport by the elderly and provided important policy implications for interventions. To be specific, the environmental correlates in previous literature are defined as two categories, the social and the built environment. The social environment "includes the culture that the individual was educated or lives in, and the people and institutions with whom they interact" (Barnett and Casper, 2001). The built environment is defined as "the human-made space in which people live, work, and recreate on a day-to-day basis" (Roof and Oleru, 2008) and "encompasses places and spaces created or modified by people including buildings, parks, and transportation systems" (Srinivasan *et al.*, 2003).

In a recent review mainly focusing on the Western context, Van Cauwenberg *et al.* (2011) concluded that the following built environment features would impact active transport of the elderly, albeit to varied degrees: (1) walkability, *e.g.*, residential density, land use mix diversity, and street connectivity (Kemperman and Timmerman, 2009); (2) access to services, *e.g.*, access to public transportation and recreational facilities (Nagel *et al.*, 2008); (3) walking facilities, *e.g.*, sidewalks and walking trails (Nagel *et al.*, 2008); (4) safety, *e.g.*, presence of heavy traffic and neighborhood crime-related safety (Li *et al.*, 2005; Nagel *et al.*, 2008; Sugiyama *et al.*, 2009; de Leon *et al.*, 2009); (5) aesthetics, *e.g.*, greenery and scenery (Sugiyama

et al., 2009); and (6) urbanization, *e.g.*, the difference between urban and rural residents (Kemperman and Timmerman, 2009). Similarly, Saelens *et al.* (2003) found that neighborhoods with higher density, greater connectivity, and more land use mix report higher rates of walking/cycling for utilitarian purposes than low-density, poorly connected, and single land use neighborhoods. In terms of the effects of social environment, the role models and neighborhood social cohesion were found to be related to walking time, and peer support would influence older adults' physical activity (Clark and Scott, 2013; Chaudhury *et al.*, 2012).

The environmental attributes employed in active transport-related studies were typically derived (Siu *et al.*, 2012) by: (1) surveying individuals' perceptions of the social or built environment (Rodríguez *et al.*, 2009; Shigematsu *et al.*, 2009); (2) aggregating neighborhood measures from secondary data, such as Census or Traffic Analysis Zone (Zhang *et al.*, 2013; Riva *et al.*, 2009; Zhang *et al.*, 2014a; Ding *et al.*, 2015b); (3) measuring these characteristics within a certain distance of the individuals' residences (Frank *et al.*, 2007; 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 (Ewing and Cervero, 2010). In Ewing and Cervero's research (2010), the built environment variables that influenced travel behavior were named with words beginning with D as "five Ds" from five aspects: density, design, distance to transit, destination accessibility, and diversity.

Worth mentioning is that the majority of active transport studies were predominantly conducted in the Western contexts and their findings are not necessarily translatable to the Asian contexts (Van Cauwenberg *et al.*, 2011). In recent years, Asian scholars began to examine the effects of built environment on travel behavior and health outcomes of different age groups (Zhang *et al.*, 2011; Lee *et al.*, 2015; An *et al.*, 2014; Zhang *et al.*, 2014b; Ding *et al.*, 2014). However, few studies have examined the environmental representations in the Chinese context, let alone the association between the environment attributes and cycling activity among Chinese urban elderly, as the present paper does. Since the cycling activity of the urban elderly is an indispensable starting point to facilitate the understanding and design effective interventions on health promotion, the present paper will serve as an extended body of literature.

3. Data and Methods

3.1 Study Area

As stated in previous studies (Zhang *et al.*, 2013; Zhang *et al.*, 2014a), the Zhongshan Metropolitan Area was chosen to examine the cycling behaviors of the urban elderly in the Chinese context. Zhongshan

is a medium-sized prefecture-level city in Guangdong Province of southern China (Fig. 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 levels, as well as urban transport characteristics to Zhongshan. Thus, the research findings in Zhongshan might be typical and informative concerning the type of cities. In Zhongshan, the urban elderly make 2.96 trips per day on average, among which 10% (0.29 times per day) were by cycling.

3.2 Data Collection

The frequency of urban elderly's cycling trips was derived from the Zhongshan Household Travel Survey (ZHTS) in 2010. Selected by stratified random sampling covering the whole of Zhongshan City, the sample size of the urban elderly over 60 was 1264 (648 male and 616 female) from 33 urban neighborhoods, with a sample rate of 2.0%. The ZHTS provided the self-reported data of one-day cycling trips, together with individual and household data.

The following data for the characterization of built environment attributes come from the Zhongshan Municipal Bureau of Urban Planning (Zhang *et al.*, 2013; Zhang *et al.*, 2014a): (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 Built Environment Attributes

Ewing and Cervero suggested (2010) that each D variable of the "five Ds" built environment contains a number of attributes that are commonly used in travel behavior-built environment research (Table 1.). In this study, considering the best available data, the authors identified five neighborhood-level built environment attributes in response to the five Ds: population density (density), intersection density (design), land-use mixture (diversity), bus-stop density (distance to transit), and commercial accessibility (destination accessibility). In terms of the built environment features that would also impact the active transport of the elderly (Van Cauwenberg *et al.*, 2011), *e.g.*, safety, aesthetics, or urbanization, the authors did not employ them due to the limited available data.

Table 1. The Meaning and Commonly Used Attributes of the Five Ds Built Environment Variables

Five Ds	Meaning	Commonly used attributes
Density	The variable of interest per unit of area	Population density, dwelling units density, employment density
Design	Street network characteristics within an area	Average block size, number of intersections per square mile, bike lane density, average building setbacks, average street widths, numbers of pedestrian crossings, street trees
Diversity	The number of different land uses in a given area and the degree to which they are represented	Entropy measures of diversity, jobs-to-housing ratios, jobs-to-population ratios
Distance to transit	The level of transit service at the residences or workplaces	Distance from residences or workplaces to the nearest rail station or bus stop, transit route density, number of stations per unit area, bus service coverage rate
Destination accessibility	Ease of access to trip attractions	Distance to the central business district, number of jobs or other attractions reachable within a given travel time, distance from home to the closest store

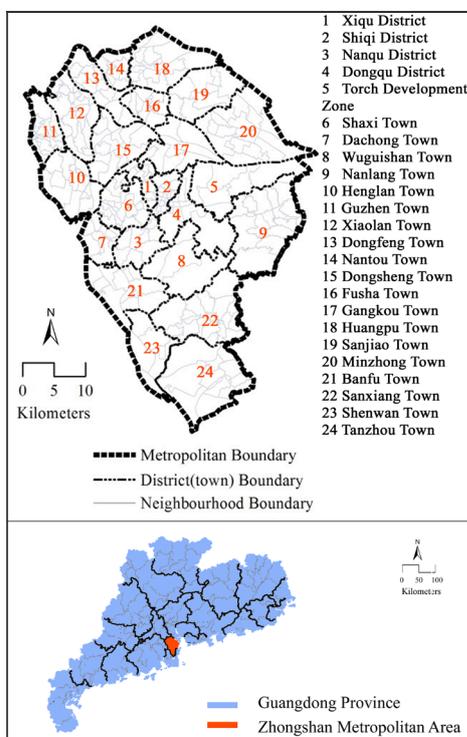


Fig.1. Study Area

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

The population density, intersection density, and bus-stop density are self-explanatory. The land-use diversity and commercial accessibility were 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. The authors 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:

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

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 *et al.*, 2013; Ding *et al.*, 2014). 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 diary of ZHTS shows that travel distance of one-kilometer covers 70% of urban elderly's home-based shopping trips and is acceptable by urban elderly. For each neighborhood, the authors obtained the commercial accessibility by the following 2 steps. For step 1, the authors defined the centroid of each neighborhood as the origin, distributed the acceptable travel distance of one kilometer to the main roads from the origin, and formed an enclosed area with the endpoints of the acceptable travel distances in ArcGIS. For step 2, the authors collected the data of area coverage of commercial facilities in the enclosed area in ArcGIS, divided the data by the population of the neighborhood, and finally obtained the commercial accessibility.

3.4 Model Specification

In built environment-travel behavior research, poisson regression and negative binomial regression are extensively used for non-negative count dependent variables (Lewsey and Thomson, 2004; Jang, 2005). In this study, the dependent variable, urban elderly's cycling trips, is a non-negative count variable. Therefore, the authors 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 urban elderly's cycling trips is equal to the expected value (Long, 1997; Long and Freese, 2006). As this assumption could not be met by the dependent variable in this study, the authors preferred negative binomial regression to poisson regression. The percentage of urban elderly making 0, 1-2 or 3+ cycling trips is 84.6%, 12.6% and 2.8%, respectively. Thus the count of urban elderly's cycling trips has more zero observations than non-zero ones, indicating the necessity to test if a zero-inflated negative binomial regression is more suitable than a standard one. The authors 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,

household, and built environment attributes on the frequency of urban elderly's cycling trips. The authors have checked for 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 follows:

$$Nr_{\text{frequency}} = \beta_0' + \beta_1' * HHSIZE_1 + \beta_2' * HHSIZE_2 + \beta_3' * HIGHINC + \beta_4' * MEDINC + \beta_5' * BIKES + \beta_6' * EBIKES + \beta_7' * MOTORS + \beta_8' * CARS + \beta_9' * GENDER + \beta_{10}' * AGE + \beta_{11}' * PROBIKE + \beta_{12}' * PROWALK + \beta_{13}' * PROEBIKE + \beta_{14}' * PROEBIKE \quad (2)$$

where $Nr_{\text{frequency}}$ is the frequency (times/day) of cycling trips; 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, 6.4 Renminbi = 1 US Dollar) and 20,000–60,000 RMB (with a reference category of 0–20000 RMB); BIKES, EBIKES, MOTORS, and CARS represent the number of bicycles, electric bikes, motorcycles and private cars in a household, respectively; GENDER denotes whether the respondents are male or female; AGE means the respondent's age in years; PROBIKE, PROWALK, PROEBIKE, or PROBUS demonstrates whether the respondents favor bicycle, walking, e-bike, or bus over other travel modes in daily travel.

Along with the basic model presented above, regression of the dependent variables proceeded in an expanded model. The expanded model adds five built environment attributes as independent variables, where POPULATION, INTERSECTION, MIXTURE, BUSSTOP, and COMMERCIAL demonstrate the population density, intersection density, land-use mixture, bus-stop density, and commercial accessibility of 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 2.). Nearly 20% of the respondents live alone and over 40% live with a partner. Three-quarters of the respondents live in medium-to-high-income households. The household ownership of bicycles averaged 0.53, a little lower than that of motorcycles. Nearly one-eighth of respondents favored bicycles over other travel modes. The average age of the respondents was 67.46 years. The standard deviation values of intersection density and bus-stop density were close to their mean values, implying substantial variations of road network design and transit service among urban neighborhoods.

4.2 Negative Binomial Regression Analysis

The results of negative binomial regressions indicated how different socio-demographic, attitudinal and built environment attributes were related to the frequency of urban elderly's cycling trips (Table 3.).

At the individual level, two demographic and two attitudinal variables showed significance at 95% confidence. Being female or older in age was related to less cycle trips. The urban elderly's attitudes towards cycling or driving may play a remarkable role in their

Table 2. Descriptive Statistics of Dependent and Independent Variables (Sample Size = 1264 Urban Elderly)

Variable	Description	Mean	S. D.	Min.	Max.
Dependent Variables					
Frequency	Frequency of urban elderly's cycling trips, times per day, count	0.29	0.81	0	8
Individual Attributes (Independent Variables)					
GENDER	1 = Male, 0 = Female, binary	0.51	0.50	0	1
AGE	Age of the respondent in years, count	67.46	6.61	60	95
PROWALK	The respondent favors walking over other modes, binary, 1 = yes	0.32	0.47	0	1
PROBIKE	The respondent favors bicycle over other modes, binary, 1 = yes	0.13	0.34	0	1
PROEBIKE	The respondent favors e-bike over other modes, binary, 1 = yes	0.05	0.23	0	1
PROBUS	The respondent favors bus over other modes, binary, 1 = yes	0.24	0.43	0	1
Household Attributes (Independent Variables)					
HHSIZE_1	Household size is one person, binary, 1 = yes	0.20	0.40	0	1
HHSIZE_2	Household size is two persons, binary, 1 = yes	0.41	0.49	0	1
HHSIZE > 2	Household size is three or more persons, binary, 1 = yes	0.39	0.49	0	1
HIGHINC	High household income (>60000 RMB/yr), binary, 1 = yes	0.20	0.40	0	1
MEDINC	Medium household income (20000-60000 RMB/yr), binary, 1 = yes	0.55	0.50	0	1
LOWINC	Low household income (<20000 RMB/yr), binary, 1 = yes	0.25	0.44	0	1
BIKES	Number of bikes in a household, count	0.53	0.67	0	4
E-BIKES	Number of electric bikes in a household, count	0.15	0.42	0	3
MOTORS	Number of motorcycles in a household, count	0.65	0.78	0	3
CARS	Number of private cars in a household, count	0.19	0.44	0	4
Built Environment Attributes (Independent Variables)					
POPULATION	Population density, 1000 persons/km ² , continuous	20.22	10.62	2	44
INTERSECTION	Intersection density, number of 5 intersections per km ² , continuous	5.90	3.40	0.4	12.36
MIXTURE	Land-use mixture, Entropy Index, continuous	0.67	0.18	0.33	1
BUSSTOP	Bus-stop density, number of bus stops per km ² , continuous	4.01	3.41	0	10.38
COMMERCIAL	Area coverage of commercial establishments within 1 km from the center of a neighborhood, in ha, continuous	5.96	2.91	0.25	13.39

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

Table 3. Negative Binomial Regressions of the Frequency of Urban Elderly's Cycling Trips

Category	Variable	Basic Model		Expanded Model	
		Coef.	z	Coef.	z
Personal attributes	MALE	0.320**	1.96	0.294*	1.83
	AGE	-0.035**	-2.52	-0.035**	-2.53
	PROBIKE	1.836***	9.08	1.841***	8.99
	PROWALK	-0.132	-0.58	-0.119	-0.52
	PROEBIKE	0.340	0.91	0.271	0.72
	PROBUS	-1.621***	-4.55	-1.647***	-4.61
Household attributes (HHSIZE > 2 and LOWINC are reference categories)	HHSIZE_1	-0.138	-0.57	-0.087	-0.35
	HHSIZE_2	-0.169	-0.82	-0.084	-0.41
	HIGHINC	0.421	1.57	0.389	1.43
	MEDINC	0.028	0.14	0.045	0.22
	BIKES	0.944***	7.32	1.042***	8.01
	EBIKES	-0.177	-0.96	-0.187	-0.99
	MOTORS	-0.082	-0.68	-0.018	-0.15
	CARS	-0.470**	-2.57	-0.458**	-2.51
Built environment	POPULATION			0.025*	1.43
	INTERSECTION			-0.091**	-2.39
	MIXTURE			-0.580	-0.84
	BUSSTOP			0.061	2.33
	COMMERCIAL			-0.112***	-3.71
Summary statistics	cons	-0.362	-0.36	0.311	0.27
	Number of obs	1264		1264	
	LR chi2	365.98		390.84	
	Prob > chi2	0.0000		0.0000	
	Pseudo-R2	0.2065		0.2205	
	Log likelihood	-703.1682		-690.7385	

Note: *denotes significance at $p < 0.1$, **denotes significance at $p < 0.05$, and ***denotes significance at $p < 0.01$. Blank cells mean variable was not included in that model. Obs = observations; LR = likelihood ratio; chi2 = chi-square; prob = probability.

cycling trips. Those who preferred cycling to other modes would make 5.27 times more cycling trips than their counterparts. Likewise the urban elderly who favored the car over other modes would cycle significantly less.

At the household level, only vehicle ownership showed significant associations. As expected, having an additional bike in a household was related to a 156.95% ($= \exp(0.944) - 1$) increase in the frequency of cycling trips, while on the contrary, having an additional car was associated with a 37.47% decrease in the frequency of cycling trips.

At the built environment level, three variables representing density, design, and destination accessibility were statistically significant at 90% confidence. The urban elderly who live in the most-populated environment would make 104.27% more cycling trips than in the least-populated environment. Denser intersections and greater accessibility to commercial establishments were related to less cycling activity among the urban elderly in Zhongshan. Compared to the average value of road intersections density, a 20% increase in intersection density is related to 10.25% decrease in the frequency of urban elderly's cycling trips. Similarly, with an increase of one-hectare commercial establishments, the urban elderly's cycling trips would decrease by 10.56%.

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 Log likelihood of each model represents the overall goodness of fit. The changes of Pseudo-R², LR chi2 and Log likelihood in expanded models implied that the built environment contributed to strengthening the explanatory power and enhanced the predictability of the models.

5. Discussion and Policy Implications

Individual and household attributes related to gender, age, attitudes towards travel modes, and the availability of vehicles, are highly associated with urban elderly's cycling frequency. To be specific, being male or younger, favoring cycling than other modes in daily travel, owning more bikes or fewer cars, is related to an increase in the frequency of urban elderly's cycling trips. Male or younger urban elderly are more physically active to ride a bicycle than their female or older counterparts, which is an important reason for their higher frequency of cycling trips. The findings on the correlation of positive attitude towards cycling is consistent with previous literature (Ding *et al.*, 2014), including the Theory of Planned Behavior (Godin and Kok, 1996). This implies the potential effects of the dissemination of a healthy life style involving cycling activity among the urban elderly. The negative association of motorized vehicles on cycling demonstrates the potential effects of policies that discourage vehicle ownership in promoting cycling.

The correlations of the built environment attributes on the cycling activity of the urban elderly in Zhongshan yield some interesting findings. The built environment attributes featuring land-use density, road network design, and destination accessibility showed significant correlation to the frequency of urban elderly's cycling trips, albeit to varied degrees.

In populated neighborhoods, the urban elderly tend to cycle more in terms of frequency. That may be because the compact urban form, closely related to high population density, increases the possibility of having short-to-medium distance trips instead of long distance ones.

In the environment with more intersections, the propensity of urban elderly to cycle is lower. This may be due to safety concerns as the urban elderly sometimes decide whether or not to cycle by comparing cycling with other transport options in terms of safety (Heinen *et al.*, 2010; Ding *et al.*, 2015a). Previous study suggested that the risk of traffic accidents for cyclists in China is high when they cross road intersections (Cherry, 2007). Therefore, the urban elderly tend to cycle less if the surrounding environment has more intersections.

With more commercial establishments within accessible distance, the urban elderly are very likely to cycle less. The average distance of a single shopping trip by urban elderly in Zhongshan is around 1 km, while the distance for a single walking or cycling trip is 0.8 km and 2.5 km, respectively. Therefore, compared to cycling, walking is a more suitable mode choice for shopping trips to nearby commercial establishments.

To promote cycling activity among urban elderly, it would be a great challenge to incorporate health interventions into the policy-making and practice of land-use and transportation planning and other public policies. From the discussions above, the authors found that interventions involving attitudes, vehicle ownership, and built environment may be potentially effective to increase the frequency of cycling trips among the urban elderly. The findings in the paper provide insights for transportation and public health agencies, practitioners, and researchers into three possible interventions as follows.

- Disseminating a healthy life style involving cycling activity. As it is hard to change attitudes among the elderly instantly, the authors recommended diversified initiatives, *e.g.*, cycling campaigns, specialized websites, which have been proven to be successful in the Ten Thousand Steps a Day program. The authors even recommend incorporating the promotion of cycling activity into the Ten Thousand Steps a Day program.

- Discouraging vehicle ownership. The findings indicated that more car ownership is related to less cycling, consistent with a previous study in the Chinese context (Zhao, 2014). It is recommended to encourage cycling through policies to discourage vehicle ownership.

- Maintaining a compact urban form related to high-density development and providing a safer environment for cyclists, especially at intersections.

6. Strengths and Limitations

This study has a number of strengths and limitations. In terms of the strengths, firstly, the study focused on the urban elderly population and provided informative policy implications for the aging society. Secondly, the study revealed the individual, household, and built environment correlates of urban elderly's cycling activity in a developing country with rapid urbanization and motorization, which might further promote comparative research between different contexts. In terms of the limitations, firstly, the dependent outcome, frequency of cycling trips, is based on self-reports, and therefore, may be subject to self-report bias that does not cover all domains of this activity. However, self-reports in active transport are common in the field and remain the primary source for assessing cycling activity in large-scale studies like this. Secondly, cross sectional data were used in this study. The full evaluation of causal inferences concerning the effects of individual, household, and built environment on cycling activity will require longitudinal and multilevel analyses over time.

7. Conclusions

This study makes an important contribution to the literature. The correlates of the cycling activity of the urban elderly in Zhongshan, China, are investigated in an effort to better understand the possible impact of individual, household, and built environment attributes on such active transport. Firstly, the study generated three categories of attributes as independent variables: individual, household, and neighborhood –level built environment. Then, negative binomial regression models were used to examine specifically how the frequency of urban elderly's cycling trips are related to the built environment attributes, together with individual and household attributes.

The research findings suggest that a positive attitude towards cycling and the availability of household bicycles are strongly related to more cycling trips by the urban elderly in Zhongshan. The findings on the correlation of attitude imply the potential effects of the dissemination of a healthy life style involving cycling activity among the urban elderly. With respect to the built environment, all else being equal, living in a neighborhood with a compact urban form and a safe cycling environment is associated with more cycling trips by the urban elderly.

The findings provide insights for transportation and public health agencies, practitioners, and researchers into the effective design of interventions from the prospective of attitudes, vehicle ownership and built environment on health promotion of the urban elderly in China. Among the possible interventions, the

authors suggested to (1) disseminate a healthy life style involving cycling activity; (2) discourage car ownership; (3) maintain a compact urban form related to high density development; and (4) provide a safer environment for cyclists, especially at intersections.

Acknowledgment

The authors acknowledge the financial support of Project 12&ZD203 and 14BSH032 by the National Social Science Foundation of China, and Project 51308336, 51408065 and 71503018 by the National Natural Science Foundation of China, and Project 15JCZZ05 by the Social and Natural Sciences Interdisciplinary Research Foundation of Shanghai Jiao Tong University, and Project KFJ150503 by the Open Fund of the Key Laboratory of Special Environment Road Engineering of Hunan Province (Changsha University of Science & Technology).

References

- 1) An, S., Lee, J. and Sohn, D. (2014) Relationship between the Built Environment in the Community and Individual Health in Incheon, Korea. *Journal of Asian Architecture and Building Engineering* 13(1): 171-178.
- 2) Barnett, E. and Casper, M. (2001) A definition of "social environment". *American Journal of Public Health* 91(3): 465.
- 3) Cerin, E., Lee, K.-y., Barnett, A., *et al.* (2013) Walking for transportation in Hong Kong Chinese urban elders: a cross-sectional study on what destinations matter and when. *International Journal of Behavioral Nutrition and Physical Activity* 10(1): 78.
- 4) Chaudhury, H., Mahmood, A., Michael, Y.L., *et al.* (2012) The influence of neighborhood residential density, physical and social environments on older adults' physical activity: An exploratory study in two metropolitan areas. *Journal of Aging Studies* 26(1): 35-43.
- 5) Cherry, C. (2007) Electric Bike Use in China and Their Impacts on the Environment, Safety, Mobility and Accessibility. UC Berkeley Center for Future Urban Transport: A Volvo Center of Excellence.
- 6) Clark, A.F. and Scott, D.M. (2013) Does the social environment influence active travel? An investigation of walking in Hamilton, Canada. *Journal of Transport Geography* 31: 278-285.
- 7) de Leon, C.F.M., Cagney, K.A., Bienias, J.L., *et al.* (2009) Neighborhood Social Cohesion and Disorder in Relation to Walking in Community-Dwelling Older Adults A Multilevel Analysis. *Journal of aging and health* 21(1): 155-171.
- 8) Ding, C., Lin, Y. and Liu, C. (2014) Exploring the influence of built environment on tour-based commuter mode choice: A cross-classified multilevel modeling approach. *Transportation Research Part D: Transport and Environment* 32: 230-238.
- 9) Ding, C., Ma, X., Wang, Y., *et al.* (2015a) Exploring the influential factors in incident clearance time: Disentangling causation from self-selection bias. *Accident Analysis & Prevention* 85: 58-65.
- 10) Ding, C., Wang, Y., Yang, J., *et al.* (2015b) Spatial heterogeneous impact of built environment on household auto ownership levels: evidence from analysis at traffic analysis zone scales. *Transportation Letters: The International Journal of Transportation Research*: 1942787515Y.0000000004.
- 11) Ewing, R. and Cervero, R. (2010) Travel and the Built Environment. *Journal of the American Planning Association* 76(3): 265-294.
- 12) Frank, L., Kerr, J., Chapman, J., *et al.* (2007) Urban form relationships with walk trip frequency and distance among youth. *American Journal of Health Promotion* 21(4): 305-311.
- 13) Godin, G. and Kok, G. (1996) The theory of planned behavior: a review of its applications to health-related behaviors. *American Journal of Health Promotion* 11(2): 87-98.

- 14) Handy, S.L., Boarnet, M.G., Ewing, R., *et al.* (2002) How the built environment affects physical activity: views from urban planning. *American journal of preventive medicine* 23(2): 64-73.
- 15) Heinen, E., van Wee, B. and Maat, K. (2010) Commuting by Bicycle: An Overview of the Literature. *Transport Reviews* 30(1): 59-96.
- 16) Jang, T.Y. (2005) Count data models for trip generation. *Journal of Transportation Engineering* 131(6): 444-450.
- 17) Kemperman, A. and Timmerman, H. (2009) Influences of built environment on walking and cycling by latent segments of aging population. *Transportation Research Record: Journal of the Transportation Research Board* 2134(-1): 1-9.
- 18) Keysor, J.J. (2003) Does late-life physical activity or exercise prevent or minimize disablement?: A critical review of the scientific evidence. *American journal of preventive medicine* 25(3): 129-136.
- 19) Kockelman, K.M. (1997) Travel behavior as function of accessibility, land use mixing, and land use balance: evidence from San Francisco Bay Area. *Transportation Research Record: Journal of the Transportation Research Board* 1607(1): 116-125.
- 20) Lee, G., Jeong, Y. and Kim, S. (2015) The Effect of the Built Environment on Pedestrian Volume in Microscopic Space-Focusing on the Comparison Between OLS (Ordinary Least Square) and Poisson Regression. *Journal of Asian Architecture and Building Engineering* 14(2): 395-402.
- 21) Lewsey, J.D. and Thomson, W.M. (2004) The utility of the zero-inflated Poisson and zero-inflated negative binomial models: a case study of cross-sectional and longitudinal DMF data examining the effect of socio-economic status. *Community Dentistry and Oral Epidemiology* 32(3): 183-189.
- 22) Li, F., Fisher, K.J., Brownson, R.C., *et al.* (2005) Multilevel modelling of built environment characteristics related to neighbourhood walking activity in older adults. *Journal of epidemiology and community health* 59(7): 558-564.
- 23) Long, J.S. (1997) *Regression models for categorical and limited dependent variables*: Sage Publications, Incorporated.
- 24) Long, J.S. and Freese, J. (2006) *Regression models for categorical dependent variables using Stata*: StataCorp LP.
- 25) McCormack, G.R. and Shiell, A. (2011) In search of causality: a systematic review of the relationship between the built environment and physical activity among adults. *International Journal of Behavioral Nutrition and Physical Activity* 8(1): 125.
- 26) Nagel, C.L., Carlson, N.E., Bosworth, M., *et al.* (2008) The relation between neighborhood built environment and walking activity among older adults. *American Journal of Epidemiology* 168(4): 461-468.
- 27) Nelson, M.E., Rejeski, W.J., Blair, S.N., *et al.* (2007) Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Medicine and science in sports and exercise* 39(8): 1435.
- 28) Riva, M., Gauvin, L., Apparicio, P., *et al.* (2009) Disentangling the relative influence of built and socioeconomic environments on walking: the contribution of areas homogenous along exposures of interest. *Social Science & Medicine* 69(9): 1296-1305.
- 29) Rodríguez, D.A., Evenson, K.R., Diez Roux, A.V., *et al.* (2009) Land use, residential density, and walking: the multi-ethnic study of atherosclerosis. *American journal of preventive medicine* 37(5): 397-404.
- 30) Roof, K. and Oleru, N. (2008) Public health: Seattle and King County's push for the built environment. *Journal of environmental health* 71(1): 24-27.
- 31) Saelens, B.E. and Handy, S.L. (2008) Built environment correlates of walking: a review. *Medicine and science in sports and exercise* 40(7 Suppl): S550.
- 32) Saelens, B.E., Sallis, J.F., Black, J.B., *et al.* (2003) Neighborhood-based differences in physical activity: an environment scale evaluation. *American Journal of Public Health* 93(9): 1552-1558.
- 33) Shigematsu, R., Sallis, J., Conway, T., *et al.* (2009) Age differences in the relation of perceived neighborhood environment to walking. *Medicine & Science in Sports & Exercise* 41(2): 314.
- 34) Siu, V.W., Lambert, W.E., Fu, R., *et al.* (2012) Built Environment and Its Influences on Walking among Older Women: Use of Standardized Geographic Units to Define Urban Forms. *Journal of environmental and public health* 2012: 203141.
- 35) Srinivasan, S., O'Fallon, L.R. and Dearry, A. (2003) Creating healthy communities, healthy homes, healthy people: initiating a research agenda on the built environment and public health. *American Journal of Public Health* 93(9): 1446-1450.
- 36) Sugiyama, T., Thompson, C.W. and Alves, S. (2009) Associations between neighborhood open space attributes and quality of life for older people in Britain. *Environment and Behavior* 41(1): 3-21.
- 37) Van Cauwenberg, J., De Bourdeaudhuij, I., De Meester, F., *et al.* (2011) Relationship between the physical environment and physical activity in older adults: A systematic review. *Health & Place* 17(2): 458-469.
- 38) Wanner, M., Götschi, T., Martin-Diener, E., *et al.* (2012) Active transport, physical activity, and body weight in adults: a systematic review. *American journal of preventive medicine* 42(5): 493-502.
- 39) Zhang, Y., Chen, L., Zhu, W., *et al.* (2011) Relationship between physical activity and environment in Shanghai, China: analysis and evaluation in adults aged 45-80. *Medicina Dello Sport* 64(3): 269-284.
- 40) Zhang, Y., Li, Y., Liu, Q., *et al.* (2014a) The Built Environment and Walking Activity of the Elderly: An Empirical Analysis in the Zhongshan Metropolitan Area, China. *Sustainability* 6(2): 1076-1092.
- 41) Zhang, Y., Li, Y., Yang, X., *et al.* (2013) Built Environment and Household Electric Bike Ownership. *Transportation Research Record: Journal of the Transportation Research Board* 2387(1): 102-111.
- 42) Zhang, Y., Wu, W., Li, Y., *et al.* (2014b) Does the Built Environment Make a Difference? An Investigation of Household Vehicle Use in Zhongshan Metropolitan Area, China. *Sustainability* 6(8): 4910-4930.
- 43) Zhang, Y., Yang, X., Li, Y., *et al.* (2014c) Household, Personal and Environmental Correlates of Rural Elderly's Cycling Activity: Evidence from Zhongshan Metropolitan Area, China. *Sustainability* 6(6): 3599-3614.
- 44) Zhang, Y., Yang, X., Liu, Q., *et al.* (2015) Who Will Use Pre-Trip Traveler Information and How Will They Respond? Insights from Zhongshan Metropolitan Area, China. *Sustainability* 7(5): 5857-5874.
- 45) Zhao, P. (2014) The Impact of the Built Environment on Bicycle Commuting: Evidence from Beijing. *Urban Studies* 51(5): 1019-1037.