The impacts of the micro built environment on pedestrian route choice: a stated preference experiment

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Abstract: This paper reports the results of a stated preference experiment that was administered to estimate the impact of the micro built environment on pedestrian route choice from/to metro station and their final destination. The micro built environment was varied in terms of 8 attributes, which are street length, average number of building floors on sides of the street, shops in the front line of streets, street crossing facilities, width of sidewalks, greenery, the density of street lamps and crowdedness of pedestrians. In total, 803 respondents were recruited in Tianjin, China to complete face to face interviews. A multinomial logit model was applied to estimate preference functions. Results indicate that pedestrians are more likely to choose street segment with either trees or green hedge. In addition, preferences significantly vary with age and motivation to walk as a transport mode. People who are 10 to 22 years old have a lower probabilities to choose street segment with 50% shops than people in other age. People who are 23 to 45 years old are more likely not choose the street segment with sidewalk wider than 3.5 meters, and also likely not choose street segment with either trees or hedge than people in other age. People who are more motivated to walk are more likely to choose street segments with both trees and hedge, and with sidewalk wider than 3.5 meters, than people who are less motivated.

Keyword: micro built environment, stated preference, discrete choice model, pedestrians.

1. Introduction

Safe, efficient and accessible public transportation is regarded as one of the important interventions to reduce urban problems, such as air pollution, congestion, noise, and suboptimal-health of people (Cheshire, 2017; Becky, 2017). Efficiency in this context refers to the seamless integration of different transportation modes, including walking. However, in many countries, including China, there is often a lack of integration of the planning of public transport terminals/stations and the design of the surrounding micro built environment for pedestrians. A pedestrian unfriendly environment may lead to fewer people choosing walking for access-egress trips (Saelens, 2008). Eventually, it results in fewer people shifting from private cars to public transportation due to the inconvenient or unattractive last mile.

As walking for exercising and pleasure differs walking as a mode of transportation, the influence of features of the built environment may depend on trip purpose (Saelens, 2008). To understand how to design a friendly built environment around public transportation stations for pedestrians, it is necessary to explore pedestrians' preference for the micro built environment in the context of route choice for utilitarian trips which take the public transportation station as an origin or destination. The results can help urban planning and design improve the accessibility of public stations and enhance community vitality (Kitamura, 1997; Kwan, 2003; Handy, 2002). However, the number of such studies is very limited, especially in Asian countries (Meghan, 2010).

The paper investigates the impact of the micro (street-scale) built environment on pedestrians' preferences of street segments, using a stated choice experiment. The micro street-scale built environment includes street length, average number of building floors on sides of the street, shops in the front line of streets, street crossing facilities, width of sidewalks, greenery, the density of street lamps and crowdedness of pedestrians in this study. Using a multinomial logit model, the influence of built environment attributes and interaction with socio-demographic variables on pedestrian utility is estimated.

2. Stated choice design and data collection

A stated choice experiment design is used to systematically vary urban street attributes. In total, 8 attributes with 4 levels were selected to measure the micro (street-scale) built environment. These attributes were selected, based on related research (e.g., Saelens, 2008; Cui, 2013). Detailed information is shown in **Table 1**.

Table 1 Selected attributes and levels

Attributes	Explanation	Levels
Street length	The length of one street segment, from one crossing to the next crossing.	(SL1) Less than 100 meters (SL2) 100 to 200 meters (SL3) 200 to 300 meters (SL4) More than 300 meters
Average number of building floors on sides of streets	The average number of building floors on the street segment.	(ABF1) 1 to 3 floors (ABF2) 4 to 6 floors (ABF3) 7 to 12 floors (ABF4) 13 and more floors
Shops in the front line of streets	The percentage of the street front occupied by shops.	(SFS1) 100% (SFS2) 50% (SFS3) 25% (SFS4) None
Crossing facilities	The facilities at a street crossing, including zebras and traffic lights.	(CF1) Lights and zebras (CF2) Only zebras (CF3) Only lights (CF4) Nothing
Width of the sidewalk	The width of the pedestrian sidewalk which can be used.	(WW1) Wider than 3.5 meters (more than four persons in parallel) (WW2) 3.5 to 1.5 meters (three to four persons in parallel) (WW3) Below 1.5 meters (two persons in parallel at most) (WW4) No sidewalk
Street greenery	The plants along the street, including trees and green hedge.	(SG1) Both trees and green hedges (SG2) Either trees or green hedges (SG3) Lower than the average density of trees (SG4) No greenery
Crowdedness	The pedestrian flow on the sidewalks.	(CD1) Almost no one in the streets (CD2) Not crowded (CD3) Somewhat crowded (CD4) Very crowded
Density of street lamps	The (average) distance between two lamps in a street segment.	(SP1) Less than 15 meters (SP2) Between 15 and 30 meters (SP3) More than 30 meters (SP4) No lamps

Stated choice experiments are used to simultaneously estimate a utility function and choice model. Choice experiments require researchers to combine a set of attribute levels into a set of attribute profiles and put these profiles into choice sets according to a particular design. A full factorial factor design, which includes all possible combinations of the 8 attributes with 4 levels each would thus result in 4^8 different profiles. To reduce the number of profiles, an orthogonal fractional factor design was used to select a subset of 64 attribute profiles that show zero correlation. This was done in the SAS software. The selected profiles were systematically varied in 64 choice sets consisting of two unlabeled street profiles and the "none of these" option. To reduce respondent burden, the 64 choice sets were blocked into 16 blocks of 4 sets of choice sets each. For each respondent, the 4 choice sets from one randomly selected block were presented. And finally each block should be collected with the same number of samples for the estimation reason. Respondents were requested to choose the street alternative they like best or to choose the "none of these" option based on the question "which street do you prefer to walk on the way from/to the metro station?" **Table 2** provides an example of a choice set.

In addition to these preference measurements, socio-demographic information was collected including age and gender. In addition, respondents were invited to express their motivation in walking on 5 points Likert scale, from "strongly motivated" to "strongly not motivated".

The survey was administered in the city center of Tianjin, a big city in China. 23 trained university students were recruited to conduct the face to face interviews on the streets in September, 2018. Respondents were first asked whether they were willing and had enough time (about 15 minutes) to complete the paper questionnaire on the streets. 806 started with completing the questionnaires and only three quitted halfway because they were interrupted. Thus, 803 completed questionnaires were collected.

Table 2 An example of a stated choice set

	Street A	**Street B**	**None of these**
Street length	100 to 200 meters	100 to 200 meters	
Average number of building floors on sides of streets	4 to 6 floors	1 to 3 floors	
Shops in the front line of streets	25%	100%	
Crossing facilities	Only lights	Only lights	
Width of the sidewalk	1.5 to 3.5 meters (three to four persons in parallel)	No sidewalk	
Street greenery	Either trees or hedge	No greenery	
Crowdedness of pedestrians	Somehow crowded	Not crowded	
Density of street lamps	Nothing	One by 15 to 30 meters	
Your Choice	**[ ]**	**[ ]**	**[ ]**

3. Results

3.1 Descriptive statistics

The distributions of respondents' socio-demographic characteristics and motivation to walk are shown in **Table 3**. There are slightly more females than males. Most respondents are between 23 and 45 years old. As for the motivation question, most respondents indicated to "somehow motivated" or feel neutral about walking.

Table 3 Distribution of Social demographic information and motivation to walk

	Category	Number	Percentage
Gender	Female	447	55.7%
	Male	356	44.3%
Age	10 to 22 years	267	33.2%
	23 to 45 years	422	52.6%
	46 to 65 years	114	14.2%
Motivation to walk as a transport mode	Strongly motivated	92	11.5%
	Somehow motivated	342	42.6%
	Normal	264	32.9%
	Somehow not motivated	83	10.3%
	Strongly not motivated	22	2.7%

3.2 Estimation Multinomial Logit Model

To estimate pedestrians' preferences for micro built environment attributes, it was assumed that the choices are driven by a multinomial logit model and that preferences can be described in terms of the linear additive utility function. The alternative-specific constants, attributes of the built environment, socio-demographic variables and motivation to walk are included for analysis. Both socio-demographic variables and motivation to walk are entered into the indirect utility functions in two ways. Firstly, they are entered as main effects, which allows for estimation of the marginal utility that a covariate produces. Secondly, they are entered as interaction terms with the eight designed attributes. This indicates whether the utility of a particular attribute differs between categories of the socio-demographic variable. The dependent variable is the probability of choosing an alternative. Effect coding is used for the 32 levels of the micro built environment and also used for "age" and "gender". For age, the 46 to 65 years old category is used as the reference. For gender, males constitute the reference. "Motivation to walk as a transport mode" is used as a continuous variable.

The estimation results are listed in **Table 4**. McFadden's pseudo-rho-squared is 0.205, and the adjusted rho-squared is 0.168. The constants for the two alternative streets are 1.905 (left side in **Table 2**) and 1.915 (right side in **Table 2**), respectively. The small difference between the two intercepts suggests that the bias in preference estimates is small. The estimated main effects show respondents' part-worth utilities/preferences for the 32 attribute levels of the micro built environment. Results indicate that the effect of these selected socio-demographic variables and the motivation to walk do not have a significant effect on the utility for the micro built environment when walking to/from a metro station to the activity location at the conventional 5% confidence level.

First, most of the micro built environment main effects shown in **Table 4** are not significant, except the street segment with either trees or hedge. The significant positive impacts of street segment with either trees or hedge on the utility are observed. It indicates that people have a higher probability to choose the street segment with either trees or hedge than other street segments with both trees and hedge or only a few trees or no greenery.

Next, the significant results of the interaction terms between micro built environment and socio-demographic variables and the motivation to walk are interpreted below. As to the impacts of shops in the front of the street, significant negative effects on people who are 10 to 22 years old are observed for street segment with 50% shops. It suggests that if a person is 10 to 22 years old, the probabilities to choose this street segment is reduced, than people of other age.

For the width of the sidewalk, the significances show that if the street segment with sidewalk wider than 3.5 meters, people who are 23 to 45 years old are more likely not choose this street segment than people who are 10 to 22 years old and 46 to 65 years old. However, the probability to take the street segment with sidewalks wider than 3.5 meters is higher for people who are more motivated to walk than people who are less motivated.

The estimated results for interaction between street greenery and age indicate that for people who are 23 to 45 years old, the probability to choose this street segment with either trees or hedge is reduced than people in age 10 to 22 and 46 to 65 years old. And the people who are 23 to 45 years old have a greater utility for choosing the street segment with only a few trees than people of age 10 to 22 and 46 to 65 years old. For interaction term between street greenery and motivation to walk, the results indicate that people who are more motivated to walk are more likely to choose street segment with both trees and hedge than people who are less motivated.

From the analysis above, it can be concluded that there is significant heterogeneity in people's preference for the attributes. Other different preferences of people in different gender, age and motivated to walk are also shown in **Table 4**, but not significant.

Table 4 Multinomial Logit Model Estimation Results

Levels	Parameter	Female	Male	10-22 years old	23-45 years old	46-65 years old	Motivation to walk
SL1	-0.307	0.014	-0.014	-0.016	0.062	-0.046	0.079
	(-1.540)	(0.300)		(-0.220)	(0.940)		(1.47)
SL2	0.050	0.023	-0.023	-0.079	-0.009	0.088	0.032
	(0.240)	(0.460)		(-1.070)	(-0.130)		(0.580)
SL3	0.098	-0.074	0.074	0.086	-0.018	-0.068	-0.058
	(0.480)	(-1.540)		(1.130)	(-0.260)		(-1.070)
SL4	0.159						
ABF1	0.332	0.017	-0.017	-0.032	-0.014	0.046	-0.056
	(1.650)	(0.350)		(-0.420)	(-0.200)		(-1.050)
ABF2	0.096	0.031	-0.031	-0.068	-0.115	0.183	0.041
	(0.490)	(0.670)		(-0.930)	(-1.730)		(0.780)
ABF3	-0.074	-0.022	0.022	0.070	-0.033	-0.037	-0.010
	(-0.370)	(-0.460)		(0.920)	(-0.480)		(-0.190)
ABF4	-0.354						
SFS1	0.234	-0.051	0.051	0.103	0.087	-0.190	-0.079
	(1.180)	(-1.080)		(1.350)	(1.270)		(-1.490)
SFS2	-0.064	0.003	-0.003	-0.149*	-0.106	0.255	0.046
	(-0.320)	(0.060)		(-1.970)	(-1.570)		(0.850)
SFS3	0.140	0.050	-0.050	-0.039	0.051	-0.012	-0.001
	(0.710)	(1.060)		(-0.530)	(0.750)		(-0.02)

SFS4	-0.310						
CF1	0.333	0.023	-0.023	0.023	0.026	-0.049	-0.003
	(1.670)	(0.500)		(0.300)	(0.380)		(-0.070)
CF2	0.010	-0.028	0.028	-0.002	-0.048	0.050	-0.002
	(0.050)	(-0.590)		(-0.030)	(-0.690)		(-0.040)
CF3	0.136	-0.046	0.046	-0.105	-0.028	0.133	-0.060
	(0.660)	(-0.940)		(-1.420)	(-0.410)		(-1.090)
CF4	-0.479						
WW1	-0.109	0.089	-0.089	-0.018	-0.140*	0.158	0.105*
	(-0.550)	(1.870)		(-0.230)	(-2.080)		(1.980)
WW2	0.336	-0.017	0.017	0.092	-0.015	-0.077	-0.061
	(1.700)	(-0.370)		(1.240)	(-0.220)		(-1.150)
WW3	-0.169	-0.044	0.044	-0.105	0.198	-0.093	0.026
	(-0.840)	(-0.930)		(-1.370)	(2.850)		(0.480)
WW4	-0.058						
SG1	-0.193	0.047	-0.047	-0.106	0.062	0.044	0.140**
	(-0.960)	(0.970)		(-1.360)	(0.880)		(2.610)
SG2	0.454*	0.008	-0.008	0.069	-0.140*	0.071	-0.059
	(2.300)	(0.170)		(0.940)	(-2.090)		(-1.120)
SG3	0.104	-0.090	0.090	-0.052	0.167*	-0.115	-0.041
	(0.520)	(-1.890)		(-0.680)	(2.480)		(-0.77)
SG4	-0.365						
CD1	0.019	-0.034	0.034	0.106	-0.070	-0.036	0.005
	(0.100)	(-0.720)		(1.490)	(-1.080)		(0.090)
CD2	0.240	0.038	-0.038	0.084	0.084	-0.168	-0.006
	(1.220)	(0.790)		(1.100)	(1.220)		(-0.110)
CD3	-0.095	-0.016	0.016	-0.109	0.103	0.006	0.048
	(-0.490)	(-0.340)		(-1.440)	(1.510)		(0.930)
CD4	-0.164						
SP1	-0.254	0.010	-0.010	0.100	-0.094	-0.006	0.057
	(-1.280)	(0.210)		(1.310)	(-1.350)		(1.080)
SP2	0.002	0.106	-0.106	-0.115	-0.025	0.140	0.039
	(0.010)	(2.240)		(-1.530)	(-0.360)		(0.730)
SP3	-0.211	-0.041	0.041	0.070	0.076	-0.146	0.084
	(-1.060)	(-0.860)		(0.940)	(1.130)		(1.570)
SP4	0.463						
Intercept (alternative1)	1.905**						
	(7.480)						
Intercept (alternative1)	1.915**						
	(23.760)						
Female	-0.081						

	(-1.350)
Male	0.081
10 to 22 years old	-0.033
	(-0.360)
23 to 45 years old	-0.033
	(-0.400)
46 to 65 years old	0.066
Motivation to walk	-0.115
	(-1.720)

Note: T-value in parentheses. ** indicates significant values at the 1% level. * indicates significant values at the 5% level.

4. Conclusion and discussion

This study provides insights into pedestrians' preferences for the micro built environment of street-segments in route choice from/to metro stations. Specifically, the results indicate that pedestrians prefer street segment with either trees or hedge, not too much or too less greenery. Results also indicate that preference vary as a function of age and general motivation to walk. These results can be used by urban planners and designers in creating environments close to metro stations that stimulate walking.

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Reference

Becky, P.Y. Loo, Amy H.T. Cheng, Samantha L. Nichols. (2017). "Transit-oriented development on greenfield versus infill sites: some lessons from Hong Kong". Landscape and urban planning, 167: 37-48.

Cheshire, P.C., DG Hay. (2017). "Urban problems in western Europe: an economic analysis". Annual of Internal Medicine, 134: 96-105.

Cui, J. Q., et al. (2013). "Underground pedestrian systems development in cities: Influencing factors and implications". Tunneling and Underground Space Technology 35: 152-160.

Handy SL, Boarnet MG, Ewing R, Killingsworth RE. (2002). "How the built environment affects physical activity: views from urban planning". Am J Prev Med, 23: 64-73.

Kitamura, R., et al. (1997). "A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area". Transportation, 24(2): 125-158.

Meghan, W., et al. (2010). "How far out of the way will we travel? Built environment influences on route selection for bicycle and car travel". Transportation Research Record, 2190: 1-10.

Mei-Po Kwan, Alan T. Murray, Morton E. O'Kelly, Michael Tiefelsdorf. (2003). "Recent advances in accessibility research: Representation, methodology and applications." Journal of Geographical Systems, 5: 129-138.

Owen, N., Humpel, N., et al. (2004). "Understanding Environmental Influences on Walking: Review and Research Agenda". American Journal of Preventive Medicine, 27: 67-76.

Saelens B.E., & Handy, S.L. (2008). "Built environment correlates of walking: a review". Medicine & Science in Sports & Exercise, 40(7): S550-S566.