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Analysis of the impact of street-scale built environment design near metro stations on pedestrian and cyclist road segment choice: A stated choice experiment

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ABSTRACT

The mismatch between the design of the micro-scale built environment around metro stations and pedestrian/cyclist preferences causes inconvenience and dissatisfaction. How to design streets near metro stations to provide a walking/biking friendly built environment is still a key question in promoting the use of metro systems. To identify which general attributes of the street-scale built environment are relevant for pedestrians/cyclists and increase walkability/cycle-ability, this paper reports the results of a stated choice experiment in which eight built environment attributes were systematically varied: street segment length, average number of building floors on both sides of the street, retail shops in frontage of streets, street crossing facilities for pedestrians/cyclists, width of sidewalks/bicycle paths, greenery, density of street lamps and crowdedness of pedestrian/cyclists to understand their influence on a road segment choice and preferences. A total of 803 respondents were recruited from Tianjin, China to complete the stated choice experiment through on-street face-to-face interviews. A multinomial logit model was estimated to unravel pedestrian/cyclist preferences using the stated choice data. The results indicate that pedestrians and cyclists have similar preferences for road segments with building lower than 6 floors, 50% retail shops in frontage, more greenery, lamps between 15 m and 30 m, more crossing facilities, wider sidewalk/bike lane and not crowded. These significant built environment attributes can be used in urban design projects with a walking/biking friendly built environment around a metro station.

1. Introduction

As an efficient means of public transportation, the number of metro lines in China has increased rapidly. In that process, the integrated design of the micro-scale built environment has not received much attention. In suburban areas, the wide roads and big city blocks tend to make metro stations hard to reach. In central areas, there tends to be a lack of biking lanes for the increasing number of cyclists. Moreover, pedestrians and cyclists often need to share the same space in high-density areas (Yang and Gakenheimer, 2007; Lin et al., 2015), creating conflicts and unsafe situations. Furthermore, infrastructure such as crossing facilities, greenery, and street lamps are either absent or not well designed on some streets around metro stations.

To create user-friendly walking and biking environments, an understanding of pedestrian and cyclist preferences is critically relevant. Although there have been many studies about the relationship between the built environment and user preferences at different spatial scales, as reviewed in Saelens and Handy (2008), Ewing and Cervero (2010), McCormack and Shiell (2011) and Day (2016), there still is a paucity of studies quantifying the nature and strength of the relationships at the micro-scale. There are many walkability studies, but these do not address user preferences. Rather, these studies can be better viewed as audits of the built environment to identify elements that are supposed, based on expert judgment, to negatively impact the propensity to walk/bike (Day et al., 2006; Clifton et al., 2007; Winters et al., 2013; Sun et al., 2017). Thus, the focus is more concerned with bad and good practices (Sun et al., 2017) rather than with eliciting user preferences. It is a hands-on approach that has led to long checklists of elements in the built environment that refrain people from walking/biking. The second stream consists of studies that attempt to explain or predict walking/biking preferences/choice behavior as a function of attributes of the built environment (and a set of covariates) (Broach et al., 2012; Guo and Loo, 2013; Borgers and Timmermans, 2015; Wang and Akar, 2018; Lue and Miller, 2019; Rossetti et al., 2019). Relative to the first stream of research, it allows designers and planners to predict and assess the impact of design features on different aspects of pedestrian and cycling behavior. Although these studies are relevant in principle, very

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few have examined the impact of micro-level attributes. Further research on the contribution of street-level built environment variables to the formation of a user route preferences should thus be welcomed.

This study contributes to reducing this gap in the literature by investigating user preferences about street-level infrastructure design. Pedestrians/cyclists' preferences for the micro built environment at the street-level will be studied quantitatively. A stated choice experiment is developed to elicit pedestrians/cyclists' preferences, while a discrete choice model is used to estimate the quantitative relationship between attributes of the micro-scale built environment and pedestrians/cyclists' overall preferences. Moreover, as most studies originate from developed countries, and different culture and built environment may not generalize the results of these studies to developing countries such as China, our project complements this earlier work. To the extent that Chinese studies do address the issue, they are mostly concerned with high-density first-tier cities such as Hong Kong, Beijing and Shanghai, while few concerning second/third-tier cities (Wang and Zhou, 2017).

The remainder of this paper is organized as follows. In section 2, the stated choice experiment design and the data collection are discussed. Section 3 presents the model estimation and results, followed by the discussion in section 4. Finally, conclusions and policy recommendations are given in section 5.

2. Stated choice design and data collection

2.1. Attribute selection

The literature shows that a wider range than attributes have been included in studies of route choice of walkers and related to cyclists. Not only road-related attributes (e.g., sidewalk presence, sidewalk width, presence of traffic lights, presence of zebras), but also buildings height, presence of public lighting, have been studied, but also functional aspects such as presence of retail frontage and greenery (Kemperman and Timmermans, 2009; Guo and Loo, 2013; Alfonzo et al., 2014; Borgers and Timmermans, 2015; Gonzalez et al., 2016; Moniruzzaman and Paez, 2016; Sun et al., 2017). Sidewalk width/bike lane width, public lighting, crossing facilities and vehicle traffic volume have been proved to be important factors that have a significant influence on walking/biking (Sener et al., 2009; Ferster et al., 2019). These four attributes are included in this study.

Based on the literature and conceptual considerations, some attributes (road segment length, retail frontage, greenery and building height) which were not studied widely are also included in this study to get some insights. The related literature is listed in the second column of Table 1 and Table 2. Finally, eight attributes each with four levels were selected to represent the micro street-scale built environment for walking and biking respectively. Five attributes are common for walking and biking, which are road segment length, retail frontage, greenery, lamps and building height. The other three attributes: pedestrian crossing facilities, pedestrian traffic volume and width of the sidewalk are specific for walking. Cyclist crossing facilities, cyclist/vehicle traffic volume and width of bike lanes are specific for biking. Note that although some attributes are the same, they have different definitions or different levels for walking and biking in the experimental design.

All attributes are described in terms of 4 attribute levels as shown in

Table 1
Selected attributes and levels for pedestrians.

Attributes	Related literature	Explanation	Levels
Street segment length	Dijkstra and Timmermans, 2002; Zhu and Timmermans, 2011	The length of one road segment, from one crossing to the next crossing.	Shorter than 100 m 100 m to 200 m 200 m to 300 m More than 300 m
The average number of building floors on sides of streets	Alfonzo et al., 2014; Sun et al., 2017;	The average number of building floors on the road segment.	1 to 3 floors 4 to 6 floors 7 to 12 floors 13 and more floors
Retail shops in frontage of streets	Dijkstra and Timmermans, 2002; Kurose et al., 2009; Zhu and Timmermans, 2011; Guo and Loo, 2013; Borgers and Timmermans, 2015	The percentage of the street front occupied by retail shops.	100% of retail shops 50% of retail shops 25% of retail shops No retail shops
Crossing facilities	Dijkstra and Timmermans, 2002; Zhu and Timmermans, 2011; Guo and Loo, 2013; Kim et al., 2014; Sun et al., 2017; Mehdizadeh et al., 2018	The facilities at a street crossing, including zebras and traffic lights.	Lights and zebras Only zebras Only lights No pedestrian crossing facilities
Width of the sidewalk	Clifton et al., 2007; Guo and Loo, 2013; Kim et al., 2014; Sun et al., 2017	The real width of the pedestrian sidewalk can be used.	Wider than 3.5 m (more than four persons in parallel) 3.5 to 1.5 m (three to four persons in parallel) Below 1.5 m (two persons in parallel at most) No sidewalk
Street greenery	Clifton et al., 2007; Kim et al., 2014; Rodriguez et al., 2015; Sun et al., 2017	The plants along the street, including trees and green hedges.	Higher than average density with trees and green hedges Higher than average density with either trees or green hedges Lower than the average density of trees No greenery
Crowdedness	Koh and Wong, 2013; Cerin et al., 2014	The pedestrian flow on the sidewalks.	Almost no one in the streets Not crowded Somewhat crowded Very crowded
The density of street lamps	Kelly et al., 2011; Gase et al., 2015; Moniruzzaman and Paze, 2016; Sun et al., 2017	The (average) distance between two lamps in a road segment.	Less than 15 m Between 15 and 30 m More than 30 m No lamps

Table 2
Selected attributes and levels for cyclists.

Attributes	Related literature	Explanation	Levels
Street segment length	–	The length of one road segment, from one crossing to the next crossing.	Shorter than 100 m 100 m to 200 m 200 m to 300 m More than 300 m
The average number of building floors on sides of streets	–	The average number of building floors on the road segment.	1 to 3 floors 4 to 6 floors 7 to 12 floors 13 and more floors
Retail shops in frontage of streets	Kemperman and Timmermans, 2009;	The percentage of the street front occupied by retail shops.	100% of retail shops 50% of retail shops 25% of retail shops No retail shops
Crossing facilities	Dill and Gliebe, 2008; Winters et al., 2013; Broach et al., 2012	The facilities at a street crossing, including traffic lights and separation fences.	Traffic lights and separation fences Only traffic lights Only separation fences No bicycle crossing facilities
Width of the bicycle paths	Clifton et al., 2007; Sener et al., 2009; Gonzalez et al., 2016	The real width of the bicycle paths which can be used, except occupied by parking or other facilities.	Wider than 2.5 m (more than three cyclists in parallel) 2.5 to 1.5 m (two to three cyclists in parallel) Below 1.5 m (one to two cyclists in parallel at most) No cyclist path
Street greenery	Sener et al., 2009; Gonzalez et al., 2016	The plants along the street, including trees and green hedges.	Higher than average density with trees and green hedges Higher than average density with either trees or green hedges Lower than the average density of trees No greenery
Crowdedness	Sener et al., 2009; Dill and Gliebe, 2008; Broach et al., 2012; Koh and Wong, 2013; Gonzalez et al., 2016;	The vehicles and cyclists flow on the bicycle path.	Almost no car or bike in the streets Not crowded Somewhat crowded Very crowded
The density of street lamps	Gase et al., 2015	The (average) distance between two lamps in a road segment.	Less than 15 m Between 15 and 30 m More than 30 m No lamps

Table 1 (for pedestrians) and Table 2 (for cyclists). The average number of building floors were based on China's national standard "Code for Design of Civil Buildings" (GB50352–2005). Retail shops' presence in the street front was set as 0%, 25%, 50%, and 100%. The density of street lamps was based on the Chinese national standard "Standard for Lighting Design of Urban Road" (CJJ 45–2015).

For pedestrians, crossing facilities involve traffic lights and zebras. Zebras usually give pedestrians more rights than traffic lights. For cyclists, the crossing facilities are traffic lights and separation facilities. The separation facilities are usually a fence to separate vehicles and cyclists. For pedestrians, traffic volume means pedestrian flow size on the sidewalk. The influence of vehicles was not considered as almost all sidewalks have a clear boundary or are separated from vehicle lanes. However, there is no clear boundary or separation for cyclists and vehicles in most streets in China. The vehicle and cyclist volumes may have a joint influence on cyclists. Width of the sidewalk was based on the Chinese national standard "Code for transport planning on urban road" (GB50220–95). Width of bicycle paths is based on the Chinese national standard "Code for transport planning on urban road" (GB50220–95).

2.2. Experimental design

The application of stated choice experiments involves the creation of a design that combines the attribute levels in a particular manner. In this study, the eight attributes with four levels would result in 4^8 different profiles in a full factorial experimental design that involves all possible combinations of attribute levels. To reduce this number, an orthogonal fractional factorial involving a subset of 64 attribute profiles was selected. Choice sets were created by randomly combining these 64 attribute profiles, thereby creating choice sets of 2 unlabeled alternatives. The "none of these" option was added to each choice set to allow for the possibility that both alternatives fall below some choice threshold. The 64 choice sets were organized into sixteen blocks of four sets of choice sets. Each respondent received a randomly selected block to reduce respondent burden. Respondents were requested to choose from each choice set the street profile they like best for walking respectively cycling, or to indicate they do not like either one by choosing the "none of these" option. An example of a choice set for pedestrians is shown in Table 3, while Table 4 provides an example of a choice set for cyclists.

2.3. Data collection

2.3.1. Questionnaire design and survey administration

The questionnaire started with a short introduction to the research project and the motivation behind the study. The questionnaire consisted of two parts. The first part included the socio-demographic variables and the motivation to walk/bike. The socio-demographic information concerned age, gender, car ownership (accessible with family or mutual ownership with others), education level, and family composition. Respondents were invited to express their motivation to walk/bike on a 5 point Likert scale, from "strongly motivated" to "not motivated at all". The second part of the questionnaire included the eight stated choice questions (the first four are for walking, the second four are for biking). Respondents were asked about their preferences when

Table 3
An example of a stated choice set for pedestrians.

	Street profile A	Street profile B
Street segment length	100 m to 200 m	100 m to 200 m
The average number of building floors on sides of streets	4 to 6 floors	1 to 3 floors
Retail shops in frontage of streets	25% of retail shops	100% of retail shops
Crossingfacilities	Only traffic lights	Only traffic lights
Width of the sidewalk	1.5 to 3.5 m(three to four persons parallel)	No sidewalk
Street greenery	Higher than average density with either trees or green hedges	No greenery
Crowdedness	Somewhat crowded	Not crowded
The density of street lamps	No lamps	Between 15 m to 30 m
Your Choice	[]	[]

Table 4
An example of a stated choice set for cyclists.

	Street profile A	Street profile B
Street segment length	More than 300 m	Less than 100 m
The average number of building floors on sides of streets	13 and more floors	13 and more floors
Retail shops in frontage of streets	25% of retail shops	No retail shops
Crossing facilities for cyclists	Traffic lights and separation fences	Only separation fences
Width of the bicycle path	Below 1.5 m (one to two cyclists in parallel at most)	No bicycle path
Street greenery	No greenery	Higher than average density with either trees or green hedges
Crowdedness (car and bike)	Almost no car or bike in the streets	Almost no car or bike in the streets
The density of street lamps	More than 30 m	Less than 15 m
Your Choice	[]	[]

traveling to/from a metro station. Before asking respondents to complete these 8 tasks, an example choice set and an explanation of all attributes and their levels were shown to respondents.

The survey was administered in the area around a “typical” metro station in the city center of Tianjin, China. The reason for interviewing respondents in an area close to a metro station is that preferences are shaped according to experiences. We therefore assume that the stated preferences of respondents interviewed in the vicinity of a metro station are most reliable. Fig. 1 shows some images of the typical built environment around metro stations in the center of Tianjin. Interviews took place within a radius of 800 m around the metro station. Twenty-three university students were recruited and trained to conduct the face to face street interviews that took place in September 2018. Respondents were selected randomly on the selected streets and introduced to the project. The respondents who completed the questionnaire were given a small gift. The completed questionnaires were checked by the person who was in charge of the survey on a daily basis. Eight hundred six respondents started the questionnaires and only three quitted halfway because of private matters. 803 completed questionnaires were collected over a period of 25 days. The response rate is about 10%.

2.3.2. Sample characteristics

The distributions of respondents' socio-demographic characteristics are shown in Table 5. Compared to data from the Tianjin Statistical Bureau, which shows that 9.6% of the population is over 65 years old, our sample underrepresents the elderly (Tianjin Statistic Bureau, 2019). The sample has slightly more females than males, which is consistent with our expectation since the study area has major shopping stores. The education level of the sample is much higher compared to the general population of Tianjin. This may be explained by the fact that several universities are close to the study area. Half of the respondents have at least one car in their family. Considering the study area is located in the city center, the sample over-represents higher-income households which are associated with car ownership. Most respondents belong to families with less than three members. As for the motivation questions, most respondents indicated to be “somewhat motivated” or feel neutral about walking/private biking/shared biking.

3. Analysis and results

The design of the experiment was based on the assumption that the stated choices and underlying user preferences can be captured in terms of a linear-additive utility function and a multinomial logit model. The multinomial choice model can be derived from random utility theory assuming that the error terms of the utility function are independently and identically Gumbel distributed (Hausman and McFadden, 1984). Maximum Likelihood was used for model estimation (Hensher et al., 2005). Because the choice alternatives are unlabeled, often researchers decide not to estimate an alternative specific constant (Hensher et al., 2005). In contrast to this practice, we decide to estimate the constants because it allows testing the existence of experimental artifacts, such as the tendency to prefer the alternative listed on the left. Thus, alternative-specific constants and effects for the attribute levels of the built environment, socio-demographics and motivation to walk/use private/shared bikes were estimated.

The socio-demographic variables were entered into the indirect utility functions in two ways. Firstly, they were entered as main effects, which allows the estimation of the general effects of these covariates on choice probabilities. Secondly, they were entered as interaction terms with the eight designed attributes. It indicates whether the utility of a particular attribute differs between categories of the socio-demographic variable. The model estimation started with all socio-demographic variables and their interactions with the built environment attribute levels. Only the interactions of age and gender with built environment attribute levels turned out to be significant. After removing insignificant variables, only age and gender were kept in the final model. The motivation variables were estimated in terms of main effects only.

Effect coding was used for the micro-scale built environment attributes and the socio-demographic variables. This means that for each attribute with four levels, three indicator variables are constructed. Each indicator variable corresponds with one of the categories is coded as 1. The remaining category is coded as -1 on all three indicator variables. Consequently, the effects of the attribute levels of a single attribute sum to one, and the estimated effects can be interpreted as differences from the mean. The significance test implies testing whether an estimated effect differs from the mean utility for that attribute more

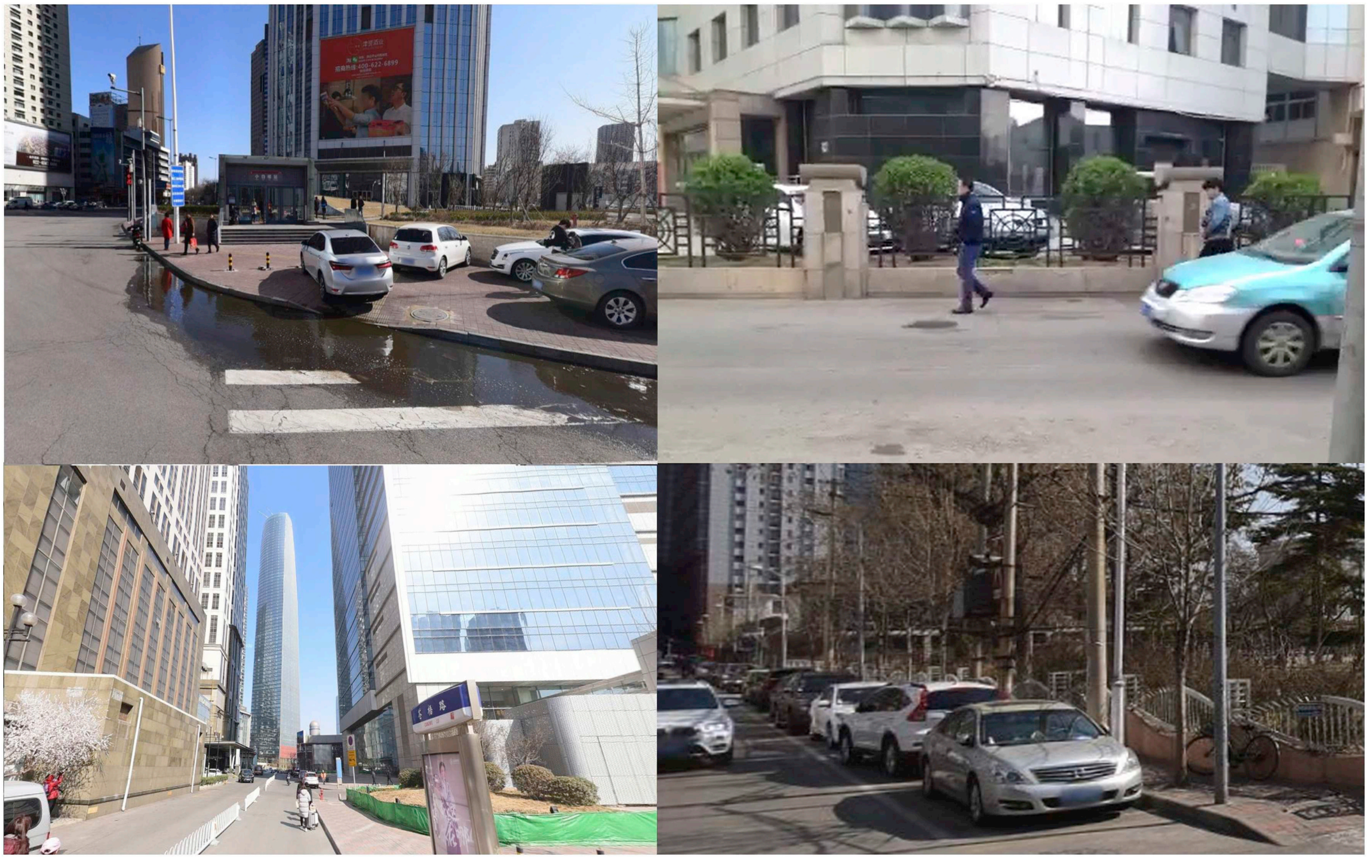

Fig. 1. Images of the built environment in the study area (Source: Photos by author, March 20, 2016).

Table 5
Distribution of socio-demographic information and motivation to walk and bike.

	Category	Number	Percentage
Age	10 to 22 years	267	33.2%
	23 to 45 years	422	52.6%
	46 to 65 years	114	14.2%
Gender	Female	447	55.7%
	Male	356	44.3%
Education	High school/ technical school and below	186	23.2%
	University/college	526	65.5%
	Master and more	91	11.3%
Car ownership	Owns car	403	50.2%
	Does not own a car	400	49.8%
Number of family member	1	185	23.0%
	2	120	14.9%
	3	309	38.5%
	4	137	17.1%
	More than 5	52	6.5%
Motivated to walk as a transport mode	Strongly motivated	92	11.5%
	Somewhat motivated	342	42.6%
	Normal	264	32.9%
	Not really motivated	83	10.3%
	Not motivated at all	22	2.7%
Motivated to use a private bike as a transport mode	Strongly motivated	64	8.0%
	Somewhat motivated	223	27.8%
	Normal	274	34.1%
Motivated to use a shared bike as a transport mode	Not really motivated	171	21.3%
	Not motivated at all	71	8.8%
	Strongly motivated	103	12.8%
	Somewhat motivated	365	45.5%
	Normal	239	29.8%
	Not really motivated	60	7.5%
	Not motivated at all	36	4.5%

than random. The motivation variables were treated as continuous variables. Because a single respondent completed more than one task, it cannot be assumed that all measurements are fully independent. Estimation should take these so-called panel effects into account.

The results of the model estimation with panel effects are listed in Tables 6 and 7. The estimation results of the attributes common for pedestrians and cyclists are listed in Table 6. The results of the attributes that differ between pedestrians and cyclists (crossing facilities, the width of paths and crowdedness) are listed in Table 7. For pedestrians, McFadden's pseudo-rho-squared is 0.200, and the adjusted rho-squared is 0.179. For cyclists, McFadden's pseudo-rho-squared is 0.205, and the adjusted rho-squared is 0.183. These measures suggest a good model fit. The constants for the two alternative street profiles for pedestrians are both significant, 1.918 (left side in Table 6) and 1.926 (right side in Table 6) respectively. The constants for the two alternative street profiles for cyclists are also both significant, 0.858 (left side in Table 6) and 0.897 (right side in Table 6) respectively. The small difference between the left and right constants suggests that the bias in preference estimates due to experimental artifacts is small. The estimated main effects represent respondents' part-worth utilities for the 32 attribute levels of the micro-scale built environment. Results indicate that the selected socio-demographic and motivation variables do not have a significant effect on the utility of the micro built environment when walking/biking at the conventional 5% confidence level.

3.1. Interpretation of the common attributes

As demonstrated in Table 6, the part-worth utilities for the street segment length attribute level for pedestrians show a zig-zag pattern. The part-worth utility first increases until it reaches its highest utility for a street segment length of 100 to 200 m. Then, the part-worth utility

Table 6
Estimation results for the common attributes of pedestrians and cyclists.

	Pedestrians						Cyclists					
	Main effects	Interaction effects					Main effects	Interaction effects				
	Parameter (t-value)	Female	Male	10 to 22 years old	23 to 45 years old	46 to 65 years old	Parameter (t-value)	Female	Male	10 to 22 years old	23 to 45 years old	46 to 65 years old
Constant1	1.918** (7.540)						0.902** (3.710)					
Constant2	1.926** (7.580)						0.919** (3.780)					
Street segment length: less than 100 m	−0.025 (−0.470)	0.001 (−0.010)	−0.001	−0.029 (−0.410)	0.058 (0.890)	−0.029	0.099 (1.800)	−0.079 (−1.640)	0.079	−0.058 (−0.800)	−0.017 (−0.260)	0.075
Street segment length: 100 m to 200 m	0.158** (2.880)	0.026 (0.530)	−0.026	−0.091 (−1.260)	−0.010 (−0.150)	0.101	0.072 (1.310)	0.065 (1.340)	−0.065	−0.066 (−0.900)	−0.029 (−0.440)	0.095
Street segment length: 200 m to 300 m	−0.110 (−1.920)	−0.071 (−1.510)	0.071	0.101 (1.380)	−0.018 (−0.260)	−0.084	−0.147* (−2.500)	−0.016 (−0.330)	0.016	0.107 (1.430)	0.048 (0.690)	−0.155
Street segment length: More than 300 m	−0.023						−0.024					
Buildings: 1 to 3 floors	0.120* (2.030)	0.021 (0.440)	−0.021	−0.007 (−0.090)	−0.005 (−0.070)	0.011	0.074 (1.220)	−0.073 (−1.510)	0.073	0.105 (1.370)	0.062 (0.870)	−0.166
Buildings: 4 to 6 floors	0.238** (4.380)	0.028 (0.610)	−0.028	−0.077 (−1.070)	−0.117 (−1.770)	0.193	0.127* (2.320)	0.073 (1.560)	−0.073	−0.199** (−2.750)	0.016 (0.250)	0.182
Buildings: 7 to 12 floors	−0.103 (−1.760)	−0.014 (−0.300)	0.014	0.056 (0.750)	−0.033 (−0.480)	−0.023	−0.092 (−1.550)	−0.119* (−2.500)	0.119	0.029 (0.390)	−0.08 (−1.160)	0.051
Buildings: 13 and more floors	−0.256						−0.11					
100% of retail shops	−0.058 (−1.010)	−0.048 (−1.020)	0.048	0.133 (1.790)	0.099 (1.450)	−0.232	−0.04 (−0.710)	0.088 (1.850)	−0.088	0.123 (1.670)	−0.105 (−1.540)	−0.019
50% of retail shops	0.112* (2.010)	0.002 (0.040)	−0.002	−0.166* (−2.260)	−0.119 (−1.780)	0.285	0.174** (3.120)	−0.059 (−1.240)	0.059	−0.12 (−1.640)	−0.116 (−1.730)	0.236
25% of retail shops	0.136* (2.400)	0.054 (1.170)	−0.054	−0.038 (−0.530)	0.056 (0.830)	−0.018	0.092 (1.610)	−0.035 (−0.740)	0.035	−0.008 (−0.100)	0.184** (2.700)	−0.176
No retail shops	−0.190						−0.226					
Higher than average density with trees and green hedges	0.323** (5.390)	0.038 (0.810)	−0.038	−0.154* (−2.040)	0.042 (0.600)	0.112	0.246** (3.990)	0.008 (0.170)	−0.008	−0.087 (−1.120)	−0.023 (−0.320)	0.110
Higher than average density with either trees or green hedges	0.238** (4.280)	0.006 (0.130)	−0.006	0.083 (1.150)	−0.136 (−2.050)	0.053	0.218** (3.870)	−0.017 (−0.360)	0.017	−0.053 (−0.730)	−0.022 (−0.330)	0.075
Lower than average density of trees	−0.043 (−0.770)	−0.079 (−1.670)	0.079	−0.03 (−0.400)	0.169* (2.520)	−0.139	−0.149** (−2.590)	−0.040 (−0.840)	0.040	0.041 (0.540)	0.081 (1.190)	−0.122
No greenery	−0.518						−0.315					
Lamps: less than 15 m	−0.036 (−0.620)	0.004 (0.080)	−0.004	0.078 (1.060)	−0.103 (−1.490)	0.025	−0.079 (−1.330)	0.069 (1.480)	−0.069	−0.067 (−0.900)	0.120 (1.730)	−0.053
Lamps: between 15 and 30 m	0.135* (2.370)	0.103* (2.180)	−0.103	−0.123 (−1.680)	−0.027 (−0.400)	0.150	0.197** (3.370)	−0.093* (−1.970)	0.093	−0.136 (−1.820)	−0.119 (−1.720)	0.254
Lamps: more than 30 m	0.087 (1.560)	−0.046 (−0.980)	0.046	0.048 (0.670)	0.069 (1.030)	−0.117	0.091 (1.620)	−0.033 (−0.710)	0.033	0.099 (1.36)	0.064 (0.950)	−0.163
No lamps	−0.186						−0.210					
Motivation to walk	−0.118 (−1.770)						–					
Motivation to use a private bicycle	–						0.101 (1.80)					
Motivation to use a shared bicycle	–						0.087 (1.390)					

Main effects of socio-demographics		Main effects of socio-demographics
Female	−0.081 (−1.350)	−0.116 (−1.920)
Male	0.081	0.116
10 to 22 years old	−0.036 (−0.390)	0.119 (1.270)
23 to 45 years old		

(continued on next page)

Table 6 (*continued*)

Main effects of socio-demographics		Main effects of socio-demographics
	−0.034 (−0.410)	−0.159 (−1.920)
46 to 65 years old	0.070	0.040

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

rapidly decreases until it increases again but stays negative. Only the effect for the second level is significant at the conventional confidence level, indicating that the utility for this level is significantly higher than the average utility across all street segment length values. The estimated part-worth utilities for the number of building floors show that pedestrians prefer moderately high buildings (4 to 6 floors) to low rise buildings (1 to 3 floors). The estimated part-worth utilities for the lowest two attribute levels are both significantly higher than the average utility across all four levels of building height. The utilities for the two highest levels of building heights are both negative and decreasing, suggesting that respondents have a lower level for high-rise buildings. The estimated part-worth utilities for the percentage retail shops show that pedestrians prefer the situation that retail shops occupy 25% to 50% of the street front. The estimated part-worth utilities for the second and third attribute levels are both significantly higher than the average utility across all four levels of retail frontage. The estimated part-worth utilities for two attribute levels of street greenery (higher than average density with trees and green hedges and higher than average density with either tree or green hedge) are both significantly higher than the average utility across all street greenery levels. It indicates that pedestrians prefer more greenery in the street segments. The estimated part-worth utilities for the density of amps show that pedestrians prefer the spatial intervals between 15 and 30 m and more than 30 m. The estimated part-worth utility for the attribute level "lamps between 15 and 30 meters" is significantly higher than the average utility across all four levels.

As indicated, to examine whether these estimated part-worth utilities differ between categories of the selected socio-demographic variables, we estimated the interaction effects between each of the socio-demographic variables and each attribute level. The main effects of the socio-demographic variables are not significant, implying that the average utility does not differ between men and women and

Table 7
Estimation results for the attributes that differ between pedestrians and cyclists.

	Main effects	Interaction effects				
Pedestrians	Parameter (t-value)	Female	Male	10 to 22 years old	23 to 45 years old	46 to 65 years old
Lights and zebras	0.321** (5.470)	0.024 (0.510)	−0.024	0.018 (0.240)	0.026 (0.370)	−0.044
Only zebras	0.013 (0.210)	−0.031 (−0.660)	0.031	−0.002 (−0.030)	−0.053 (−0.770)	0.055
Only lights	−0.085 (−1.560)	−0.042 (−0.880)	0.042	−0.087 (−1.200)	−0.022 (−0.330)	0.109
No pedestrian crossing facilities	−0.248					
Wider than 3.5 m	0.252** (4.520)	0.090 (1.910)	−0.090	−0.043 (−0.590)	−0.136* (−2.030)	0.178
3.5 to 1.5 m	0.117* (2.110)	−0.016 (−0.350)	0.016	0.101 (1.390)	−0.011 (−0.160)	−0.090
Below 1.5 m	−0.065 (−1.110)	−0.051 (−1.090)	0.051	−0.109 (−1.460)	0.188** (2.720)	−0.079
No sidewalk	−0.304					
Almost no one in the streets	0.021 (0.400)	−0.029 (−0.620)	0.029	0.110 (1.570)	−0.064 (−1.000)	−0.045
Not crowded	0.231** (4.03)	0.036 (0.770)	−0.036	0.084 (1.130)	0.075 (1.110)	−0.159
Somewhat crowded	0.073 (1.280)	−0.014 (−0.310)	0.014	−0.129 (−1.750)	0.106 (1.580)	0.023
Very crowded	−0.324					
Cyclists						
Traffic lights and separation fences	0.42** (7.000)	−0.006 (−0.120)	0.006	−0.071 (−0.94)	−0.063 (−0.90)	0.134
Only traffic lights	−0.028 (−0.470)	0.008 (0.170)	−0.008	0.113 (1.53)	0.012 (0.18)	−0.126
Only separation fences	−0.104 (−1.890)	−0.007 (−0.150)	0.007	−0.054 (−0.74)	0.892	−0.838
No bicycle crossing facilities	−0.288					
Wider than 2.5 m	0.349** (6.220)	0.016 (0.340)	−0.016	0.062 (0.85)	−0.061 (−0.93)	−0.001
2.5 to 1.5 m	0.105 (1.870)	−0.061 (−1.280)	0.061	−0.003 (−0.04)	0.048 (0.71)	−0.045
Below 1.5 m	−0.076 (−1.280)	−0.011 (−0.220)	0.011	−0.03 (−0.41)	0.007 (0.10)	0.024
No cyclist path	−0.378					
Almost no car or bike in the streets	0.316** (5.890)	−0.059 (−1.270)	0.059	0.03 (0.42)	−0.099 (−1.53)	0.069
Not crowded	0.219** (3.830)	0.001 (0.010)	−0.001	0.104 (1.39)	0.078 (1.15)	−0.182
Somewhat crowded	−0.025 (−0.430)	0.031 (0.670)	−0.031	−0.052 (−0.7)	0.007 (0.10)	0.045
Very crowded	−0.510					

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

between age groups beyond sampling error. Only a few interactions are significant. One is the interaction between 50% of retail shops and 10 to 22 years old. The negative sign of the estimated interaction effect suggests that the utility for this combination of variables is significantly lower. The estimated interaction between trees and green hedges for the 10 to 22 years old is also significant. Finally, the estimated interaction between attribute level "lower than the average density of trees" and the 23 to 45 years old is significant and positive.

For cyclists, Table 6 shows that only the effect of the third level of the street segment length attribute is significant and negative at the conventional level, which indicates that cyclists do not prefer street segment lengths from 200 m to 300 m. The estimated part-worth utilities for the number of building floors show that cyclists prefer moderately high buildings (4 to 6 floors) to low rise buildings (1 to 3 floors). Especially, the estimated part-worth utility for the second attribute level is significantly higher than the average utility across all four levels of building height. The part-worth utilities for the shop frontage show that cyclists prefer 25% to 50% of retail shops in frontage. The estimated part-worth utility for 50% of retail shops is significantly higher than the average utility across all four levels of retail frontages. The part-worth utilities for street greenery show that cyclists prefer more greenery in streets. The estimated part-worth utilities for the first two attribute levels are significantly higher than the average utility across all four levels of street greenery. The part-worth utility for the third attribute level is significantly lower than the average utility. The estimated part-worth utilities for the density of lamps show that cyclists do not prefer streets without lamps, probably for safety reasons. And they have a significant preference for "lamps between 15 and 30 meters".

As in the analysis of pedestrian preferences, we also estimated the main effects of the socio-demographic variables and the interaction effects between each of the socio-demographic variables and each attribute level for cyclists. Table 6 shows that the main effects of the socio-demographic variables are not significant, implying that the average utility of street profiles does not differ between the categories of the selected socio-demographic variables. Only four interaction effects are significant at conventional confidence levels. The estimated interaction between 4 and 6 floors and 10 to 22 years old is significant and negative. The same holds for the interaction between buildings with 7 to 12 floors and females, which indicates that female cyclists derive a lower utility for road segments with buildings from 7 to 12 floors than men. The estimated interaction between 25% of retail shops and 23 to 45 years old is significant and positive. The estimated interaction between a lamp interval of between 15 and 30 m and females is also significant and positive.

3.2. Interpretation of the specific attributes

Table 7 displays the model estimation results for the attributes that differ between pedestrians and cyclists. For pedestrians, the estimated part-worth utilities for crossing facilities show that pedestrians prefer more crossing facilities. Only the effect for the first level is significant at the conventional level, indicating that the utility for the first attribute level is significantly higher than the average utility across all crossing facilities levels. The estimated part-worth utilities for sidewalk width show that pedestrians prefer wider sidewalks. The estimated part-worth utilities for the first two attribute levels are both significant, which suggests that utilities for these two attribute levels are significantly higher than the average utility across all sidewalk width values. The estimated part-worth utilities for crowdedness show that pedestrians prefer road segments that are not crowded. The estimated part-worth utilities for the second level is significantly higher than the average utility.

As for the estimated interaction effects, only a few are significant as shown in Table 7. The interaction between sidewalks wider than 3.5 m and 23 to 45 years old is significant. The negative sign of the estimated interaction effect suggests that the utility of sidewalks wider than 3.5 m for this age group is significantly lower. The estimated interaction between sidewalks below 1.5 m and 23 to 45 years old is significant and positive.

For cyclists, only the effect for the first level of crossing facilities is significant at the conventional level, indicating that the utility for the first attribute level is significantly higher than the average utility across all crossing facilities levels. It indicates that cyclists prefer more crossing facilities. The estimated part-worth utilities for bicycle paths show that cyclists prefer wider paths. The estimated part-worth utility for the first attribute level is significant at the conventional level. For crowdedness, the estimated part-worth utilities for the first two levels are significant at the conventional level. Table 7 shows that none of the estimated interaction effects for cyclists are significant at conventional confidence levels.

4. Discussion

The results show that not only the general road-related variables (sidewalk width/bike lane width, crossing facilities, public lighting and traffic volume) have significant influence on pedestrians/cyclists, but also building height, greenery, retail shop frontage and street segment length have significant influence on pedestrians/cyclists with specific road segment choice behavior. For the road-related variables, the results show that both pedestrians and cyclists prefer wider sidewalks/bike lanes, more crossing facilities, less pedestrian/cyclist/vehicle traffic volume and proper street lamp density.

Comparing the preference differences between pedestrians and cyclists in this study, they have similar preferences but different significance for most built environment attributes and levels. Pedestrians' preference for street segment length from 100 m to 200 m suggests that pedestrians tend to avoid too many street crossings. Cyclists also prefer shorter road segments but without significance performance. But cyclists have a significant negative preference for longer street segment length from 200 m to 300 m. Especially, pedestrians are more sensitive to building height and retail shops in frontage. Cyclists are more sensitive to greenery. Lower buildings are preferred by both pedestrians/cyclists. It might because that lower buildings can provide a broad vision for them. Pedestrians have a significant preference for buildings lower than 6 floors. Cyclists have a significant preference for buildings with 4 to 6 floors. The results of retail shops in frontage show that pedestrians prefer proper retail shops 25% to 50% occupation in frontage of the streets. Too many shops may bring too many pedestrians and make it crowded. And the shops often occupy the space of sidewalks illegally. Cyclists prefer retail shops 50% occupation in frontage of the streets. It might because that shops bring vitality for the streets and this attracts cyclists significantly, though shops are not connected with cyclists directly in space. Cyclists have significant positive preferences for higher than average density with either tree and/or green hedge and significant negative preferences for lower than the average density of trees. Pedestrians only have significant positive preferences for higher than average density with either tree and/or green hedge. Cyclists are more sensitive to greenery. It might because cyclists get the shadows mostly from trees. While pedestrians may get shadows not only from greenery but also from buildings. This might be the reason why pedestrians do not have a significant negative preference for lower than the average density of trees.

Some of the results are consistent with the literature. Pedestrians and cyclists prefer more greenery, more crossing facilities, and wider sidewalks/wider bike lanes. Greenery and sidewalks/bike lanes were studied about the presence in most of the past studies (Dill and Gliebe, 2008; Rodriguez et al., 2015; Lue and Miller, 2019; Rossetti et al., 2019). In this study, they were studied at four levels to show more detailed influences on pedestrians/cyclists. Pedestrians/cyclists' preferences for the levels were quantitative measured exactly. Traffic light as one of crossing facilities was studied in past studies (Dill and Gliebe, 2008; Sener et al., 2009; Gonzalez et al., 2016). However, zebra as also one of the important crossing facilities were less studied together with traffic lights. This study included these two crossing facilities together and provided both preferences for them.

This study also found a few inconsistent results. For example, the literature showed that more shop (retail) frontage had a positive influence on pedestrians in both New York and Hong Kong (Guo and Loo, 2013). In this study, we found that too many retail shops are not the most preferred attribute level by pedestrians. 25% to 50% of retail shops in frontage are the best levels for pedestrians. And their preference for proper street lamp density (15 m to 30 m) is different from past researches that more public lighting is better (Gase et al., 2015). Their preferences for street lamps between 15 m to 30 m show that they prefer to avoid streets without lamps for safety reasons. On the other hand, they also prefer not to have too many lamps which act as barriers for them. Pedestrians' preference for too lengthy streets is lower, which may indicate they like breaks in the building blocks. This is inconsistent with the general results in the pedestrian route choice model, less crossing number is preferred in route choice (Guo and Loo, 2013). It may because it is studied in different contexts (whole route choice or road segment preference). And in the context of this study, shorter street segments and smaller blocks make higher road density and higher connectivity of road networks in a fixed area (Rodrigue et al., 2006).

5. Conclusions and policy recommendations

The aim of this study was to provide more insights into the relationships between the micro-scale built environment and pedestrians/cyclists' preferences. To that end, a stated choice experiment was designed and administered in a downtown area in Tianjin, China. This experiment systematically varied the levels of a set of micro-scale attributes of the built environment. Pedestrians and cyclists were invited to judge the resulting street profiles and indicate which one they would choose assuming they were to walk/bike to/from a metro station to their destination. The advantage of using a stated choice experiment relative to judgments of specific road segments is that we had control over the covariance of the attribute levels and thus ceteris paribus the results reflect a more fundamental measurement of consumer preferences.

Results indicate that on average both pedestrians and cyclists prefer functional environments and facilities around the metro station. A road segment length from 100 m to 200 m is suggested for street design around the metro stations. Buildings lower than six floors are strongly recommended. In normal streets (except for shopping streets), 25% to 50% of retail shops frontages could be planned for pedestrians/cyclists passing by. The greenery enhances the functionality of the environment. Trees and green hedges are highly recommended in all streets. Street lamps for pedestrians and cyclists are recommended as intervals from 15 m to 30 m. These findings can be used in practical urban design projects of new districts under construction to describe a walking/biking friendly built environment around a metro station. For urban renewal design projects, these findings can be inspirations for the built-up areas. Street segment length and building height are not easy to restructure. Retail shop frontage, greenery and lamp density are may be constructed based on these findings. Interestingly, the main effects of the selected socio-demographic variables and most interactions (few exceptions) of built environment attribute levels and socio-demographics are not significant for the sample size. It indicates that the overall preferences and the preferences for specific attribute levels do not significantly differ between pedestrians and cyclists of different gender and age.

One potential limitation of a stated choice experiment is the restricted range of identified attributes. Based on the literature, we have covered all important factors. However there is still a potential risk that other factors should be included as well. As for the MNL model, the assumed linear utility is representative of a compensatory decision-making process. There is nothing in the current analysis to falsify this assumption. Thus, future research may examine the relative performance of models that can capture non-compensatory or semi-compensatory choice models, such as for example non-compensatory decisions rules (Foerster, 1979; Swait, 2001) and regret-rejoice models (Chorus et al., 2008; Chorus, 2012; Jang et al., 2018; Rasouli and Timmermans, 2018). What's more, the stated choice experiment assumed that the observed choice can reflect the joint influence of preferences based on the individual's expressed preference. However it might be difficult for respondents to express their preference with such a setting.

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