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Urban Built Environment Perceptions and Female Cycling Behavior: A Gender-Comparative Study of E-bike and Bicycle Riders in Nanjing, China

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Abstract: As cities globally prioritize sustainable transportation, understanding gender-differentiated responses to the urban built environment is critical for equitable mobility planning. This study combined the Social Ecological Model (SEM) with the theoretical perspective of Gendered Spatial Experience to explore the differentiated impacts of the Perceived Street Built Environment (PSBE) on the cycling behavior of men and women. Questionnaire data from 285 e-bike and traditional bicycle riders (236 e-bike riders and 49 traditional cyclists, 138 males and 147 females) from Gulou District, Nanjing, between May and October 2023, were used to investigate gender differences in cycling behavior and PSBE using the Mann–Whitney U-test and crossover analysis. Linear regression and logistic regression analyses examined the PSBE impact on gender differences in cycling probability and route choice. The cycling frequency of women was significantly higher than that of men, and their cycling behavior was obviously driven by family responsibilities. Greater gender differences were observed in the PSBE among e-bike riders. Women rated facility accessibility, road accessibility, sense of safety, and spatial comfort significantly lower than men. Clear traffic signals and zebra crossings positively influenced women's cycling probability. Women were more sensitive to the width of bicycle lanes and street noise, while men's detours were mainly driven by the convenience of bus connections. We recommend constructing a gender-inclusive cycling environment through intersection optimization, family-friendly routes, lane widening, and noise reduction. This study advances urban science by identifying gendered barriers in cycling infrastructure, providing actionable strategies for equitable transport planning and urban design.

Keywords: urban cycling; built environment perception; gender mobility equity; e-bike; urban design

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1. Introduction

Bicycles are a flexible, efficient, and sustainable mode of transportation [1] and contribute to expanding personal spatial mobility, reducing the demand for motor vehicles, alleviating traffic congestion, and accelerating social sustainability. However, the full release of cycling potential depends on the systematic support of urban Street Built Environment (SBE). This support acts on cyclists through four interrelated but hierarchical dimensions of the Perceived Street Building Environment (PSBE).

The safety dimension constitutes the bottom-line guarantee for cycling decisions. It focuses on cyclists' perceptions of physical protection and risk control [2], with core elements including the completeness of motor-vehicle/non-motor-vehicle separation facilities,

the adequacy of nighttime lighting, the clarity of intersection signs [3], and the sense of security against crime [4]. Studies have shown that women are significantly more sensitive to safety than men [5,6]. Women not only worry about traffic accident risks [7–10] but also remain vigilant against personal safety threats (such as harassment or robbery) [11], thus relying more on separation facilities [8,12,13] and lighting conditions [11]. Safety perception is an important factor promoting the likelihood of female cycling [7,12,14–17]. In terms of cycling routes, women are more inclined to ride on lanes with traffic separation and off-road paths [8,18].

The comfort dimension focuses on the physical and mental pleasure of the cycling experience, covering the dual attributes of natural and artificial environments. Its connotations include the aesthetic quality of street greening, road surface flatness, noise control levels, and environmental hygiene conditions [19–22]. Different from safety, comfort reflects higher-order needs for the cycling environment [23]. Women often attach more importance to the aesthetic experience of space [24], but existing studies rarely explore the differences in comfort perception between male and female cyclists, which is also the most frequently overlooked dimension in research on how PSBE affects gendered cycling behavior.

The facility accessibility dimension focuses on the convenience of destination connectivity, that is, the degree to which the cycling network covers daily activity nodes (residences, schools, supermarkets, parks, bus stops) [25]. This dimension may generate differentiated needs due to gendered family divisions of labor. Women usually assume more family responsibilities, such as childcare and shopping, leading to more complex travel chains compared to men [15,26–31]. Female cyclists are more inclined to use bicycles for non-commuting trips such as traveling with children and shopping [32], so they may have higher demands for the accessibility of various facilities linking multiple destinations such as home, schools, or supermarkets. However, existing studies rarely explore the impact of this dimension on cycling behavior in the context of gender differences and family obligations.

The road accessibility dimension, as a fundamental support [25], emphasizes the continuity and capacity of the road network structure. Its core indicators include the width of bicycle lanes and the density of intersections, etc. This dimension directly affects the directness and smoothness of cycling. In the study of gendered cycling, this dimension is usually simplified or overlooked.

Overall, existing studies have the following limitations. First, although the safety dimension has received much attention, the comfort, facility accessibility, and road accessibility dimensions of PSBE and their gender differences in cycling research have been systematically ignored. Second, key social factors explaining gender differences in cycling (such as family responsibilities and travel purposes) have not been fully integrated into the analytical framework of PSBE impacts, leading to possible biases in the interpretation of PSBE effects. More importantly, with the explosive growth of e-bikes globally, especially in China (with an ownership of 350 million, MIIT, China, 2024 [33]), their significant differences in speed, cycling experience, and physical exertion requirements may reshape the PSBE perceptions and behavioral patterns of cyclists (especially women). However, existing studies on gender differences have almost completely ignored the group of e-bike users.

This study aims to fill the above gaps. Based on the survey data of cyclists in Gulou District, Nanjing, it systematically explores: (1) What are the differences in the four-dimensional PSBE perceptions between male and female cyclists (by transportation type)? (2) How do family responsibilities moderate the impact of PSBE on cycling probability and route choice? (3) How does the e-bike amplify gendered environmental responses?

2. Research Framework and Hypotheses

2.1. Research Framework

This study employs the Social Ecological Model (SEM) [34] as the core theoretical framework while integrating the theoretical perspective of Gendered Spatial Experience [35] to analyze the complex multi-level interaction mechanisms in cycling behavior. The core proposition of SEM is that cycling behavior decisions are the result of dynamic mutual construction of individual, social, and environmental factors.

At the individual level, it includes the biological gender attributes of cyclists and their derived gendered perceptions. Existing studies have shown that socially constructed gender roles make women more sensitive to risks in the built environment [11]. Compared with bicycles, the higher speed and volume of e-bikes may amplify environmental pressures, further reinforcing perceptual differences in safety, comfort, and road accessibility.

At the social level, it focuses on the gendered division of labor. Women assume more family care responsibilities (such as childcare and shopping), leading to their trips showing characteristics of multi-purpose chains [15,22,26–30]. This may not only enhance their likelihood of cycling but also strengthen the demand for specific environmental elements (such as accessibility to schools/supermarkets), affecting their cycling routes.

At the built environment level, it pays attention to the Gender-Responsive Design of physical space. The four dimensions of PSBE (safety, comfort, facility accessibility, and road accessibility) act on cyclists through the perception process, and their effects vary due to gender roles.

The above three levels of factors continue to interact through Spatialized Gender Practice: family responsibilities (social level) drive women to rely more on high-facility accessibility road networks (environmental level), superimposed with safety perception, thereby affecting cycling probability. E-bikes (individual level) may increase women's sensitivity to road accessibility (such as lane width) and comfort (road surface, noise, etc.), further influencing route choices (Figure 1). This integrated framework provides a new perspective for revealing the deep mechanisms of gender differences in cycling.

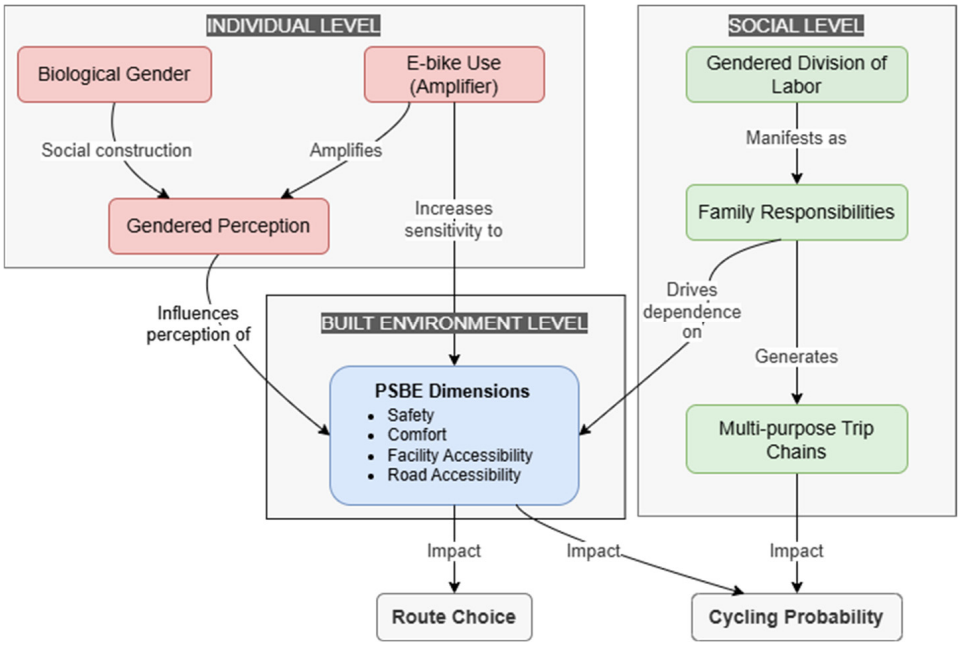


Figure 1. Research framework.

2.2. Research Hypotheses

Hypothesis 1. *Gendered Environmental Perception*

Female cyclists have significantly stronger negative evaluations of PSBE safety (H1a: insufficient lighting, lack of motor vehicle separation facilities) and comfort (H1b: noise, lack of greening) than male cyclists, and this difference is particularly prominent among e-bike users. This hypothesis is derived from gender construction theory that women are socialized as risk-averse, and the speed characteristics of e-bikes amplify environmental pressure perception.

Hypothesis 2. *Multilevel Influence on Cycling Probability*

The influence of PSBE elements on cycling probability shows gendered differentiation.

H2a. *Safety improvements (such as intersection sign optimization) have a stronger promoting effect on female cycling probability than on male cycling probability.*

H2b. *Family responsibilities (such as the age of children and housework hours) positively moderate women's demand for facility accessibility (convenience of schools/supermarkets/bus stops), thereby increasing their cycling frequency.*

Hypothesis 3. *Gendered Spatial Logic of Route Choice*

Cycling route choice presents distinct gender-environment interaction characteristics:

H3a. *Female e-bike riders have a stronger detour response to the perception of road accessibility (such as insufficient lane width).*

H3b. *Women are significantly more likely to choose detours for comfort (such as smooth roads and low noise) than men.*

3. Data and Methods

3.1. Research Area

The research area was the Gulou District of Nanjing City, China, with a total area of 54.18 square kilometers and a permanent population of 942,700 [36], including 11 expressways, 12 main roads, 34 secondary roads, and other branch roads within the district (see Figure 2). The participants in this study were private bicycle and e-bike riders in the research area.

3.2. Questionnaire Design

The questionnaire consisted of four modules: basic personal information, daily travelling information, cycling behavior information, and the PSBE evaluation scales. Basic personal information included gender, age, marital status, family obligations, personal driver's license, and household car ownership. Daily travelling information included the frequency of walking, cycling, private car, and bus trips within a week and the cycling frequency for commuting, housework, and leisure trips during the week. Cycling behavior information included the cycling purpose, tool, route, and duration.

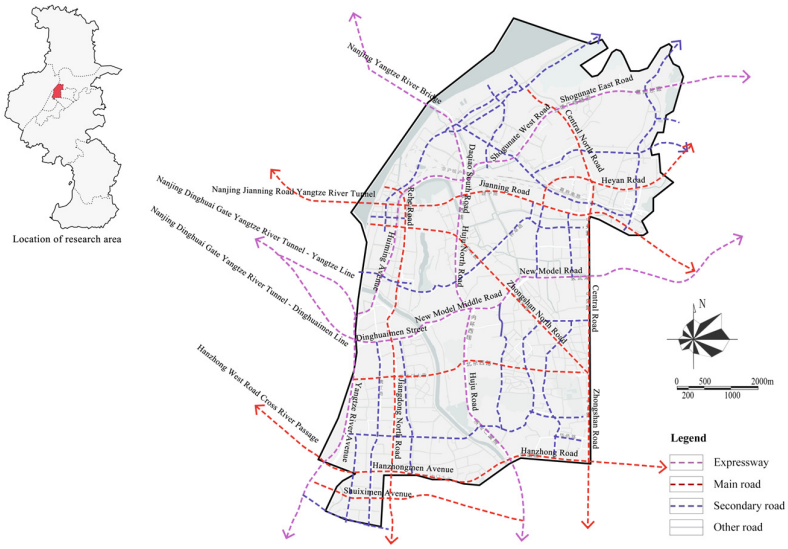


Figure 2. Research area and traffic map of Gulou District.

The PSBE questionnaire was divided into four dimensions: facility accessibility, road accessibility, safety perception, and comfort perception; it included 14 perception indicators (see Table 1). The indicator-setting principle was based on studies by Alfonzo et al. [23,37–39], assuming that cyclists have specific perceived demands for objective SBE. When the cyclists' subjective perceptions of objective SBE have already met their demands, they are more willing to choose cycling along the shortest route. When other routes meet their demands, cyclists will choose a non-shortest route for a more comfortable SBE experience. Each item was scored on a five-point Likert scale, with 0 indicating strongly disagree and 5 indicating strongly agree. Additionally, items with a negative PSBE influence, such as road intersections, parking, and noise, were scored inversely.

Table 1. PSBE variables.

Dimensions	Objective SBE Indicators	PSBE Evaluation
Facility accessibility	Density of public service facilities and distribution of surrounding parking spots	Convenient cycling to nearby parks, shopping malls, and schools
	Density of public transport stations and distribution of surrounding parking spots	Convenient cycling to nearby bus or subway stations
Road accessibility	Width of bicycle lane	Non-motor lanes sufficiently spacious
	Density of road intersections	Too many road intersections (reverse scoring)
	Traffic overlap with motor vehicles and pedestrians	Conflict between motor vehicles and pedestrians due to occupied roads
Safety perception	Density of crossing facilities	Sufficient traffic lights and zebra crossings
	Brightness and density of lighting facilities	Adequate nighttime lighting on streets
	Clarity and density of traffic signs	Clear road signs for cycling
	Density of separate facilities for motor and non-motor vehicles	Adequate separate facilities for bicycle lanes
Comfort perception	Beauty of plants	Beautiful road greening
	Richness of plants	Abundant street planting species
	Street cleanliness	Clean and tidy streets
	Road slope and flatness	Flat road surface
	Noise level	Loud noise from motor vehicles or street engineering operations

3.3. Data Acquisition

We surveyed e-bike and bicycle riders in the research area from May to October 2023. Through spatial-gender stratified random sampling, respondents were selected as representative SBE and gender samples from 12 main roads, 34 secondary roads, and other branches. Questionnaires were distributed at bicycle parking spots on the streets mentioned above, together with face-to-face surveys of cyclists after they completed one ride. We obtained 285 valid questionnaires from 300 questionnaires, including 138 from men and 147 from women and 236 e-bike and 49 bicycle riders. All respondents were users of private bicycles and e-bikes, excluding shared-bicycle users. Respondents were informed of the survey's purpose in advance. This study was approved by the Ethics Committee of the authors' university. Sample attributes are illustrated in Table 2.

Table 2. Sample Attributes.

Attribute-Divided Layers	Variables	Categories	Proportion of Categorical Variables	
			Male (138)	Female (147)
Personal attributes	Age	Average age	44.69	37.66
		Under 24	19 (13.8%)	27 (18.4%)
		25–34	31 (22.5%)	25 (17.0%)
		35–44	24 (17.4%)	60 (40.8%)
		45–54	20 (14.5%)	18 (12.2%)
		55 years or older	44 (31.8%)	17 (11.6%)
	Level of education	Below junior high school	32 (23.2%)	28 (19.0%)
		Senior high school	33 (23.9%)	27 (18.4%)
		Bachelor's degree or above	73 (52.9%)	92 (62.6%)
	Occupational status	Retired people students, and homemakers	49 (35.5%)	42 (28.6%)
		Individual jobholders	27 (19.6%)	47 (32.0%)
		Enterprise staff	52 (37.7%)	32 (21.8%)
		Public institutions, government agencies, and organizations	10 (7.2%)	26 (17.6%)
	Personal monthly income	Below 4000 yuan	32 (23.2%)	47 (32.0%)
		4000–8000 yuan	50 (36.2%)	55 (37.4%)
		8000–12,000 yuan	32 (23.2%)	37 (25.2%)
		12,000–16,000 yuan	16 (11.6%)	6 (4.1%)
		Above 16,000 yuan	8 (5.8%)	2 (1.3%)
	Duration of stay in Nanjing		21 years	27 years
	Youngest child's age	No children under 16.	92 (66.7%)	68 (46.3%)
		14–16	3 (2.2%)	6 (4.1%)
		7–13	30 (21.7%)	56 (38.1%)
		3–6	11 (8.0%)	13 (8.8%)
		Less than 3	2 (1.4%)	4 (2.7%)
	Any older people to be cared for?	No	122 (88.4%)	126 (85.7%)
		Yes	16 (11.6%)	21 (14.3%)
	Marital status	Unmarried, divorced, or widowed	41 (29.7%)	41 (27.9%)
		Married	97 (70.3%)	106 (72.1%)
	Average working hours per day (h)		6.18	6.92
	Average length of housework per day (h)		1.11	1.40
	Average length of childcare per day (h)		0.58	1.31
	Average leisure time per day (h)		3.30	2.85

Table 2. *Cont.*

Attribute-Divided Layers	Variables	Categories	Proportion of Categorical Variables	
			Male (138)	Female (147)
Allocation of traffic resources	Possession of a driver's license or not	No Yes	51 (37.0%) 87 (63.0%)	56 (38.1%) 91 (61.9%)
	Average number of household bicycles		0.31	0.33
	Average number of household e-bikes		1.51	1.61
	Average number of household cars		0.60	0.62
Cycling attributes	Average frequency of cycling per week		0.57	1.32
	Average frequency of riding an e-bike per week		8.51	9.98

3.4. Variables

Cycling behavior and PSBE were the key variables. Indicators of cycling behavior were divided into daily cycling and single-cycle behaviors. Daily cycling behaviors included cycling frequency per week, proportion of cycling frequency per week, proportion of cycling frequency for commuting per week, proportion of cycling frequency for housework per week, and proportion of cycling frequency for leisure per week. The variables of single cycling behavior included the cycling purpose, cycling tool, cycling duration, and cycling route. These variables are presented in Table 3.

Table 3. Cycling behavior variables.

Cycling Behavior	Specific Elements	Quantification Methods
Daily cycling behavior (within a week)	Cycling frequency per week	
	Proportion of cycling frequency per week	Proportion of cycling frequency to total travel frequency within a week
	Proportion of cycling frequency for commuting per week	Proportion of cycling frequency for commuting to total cycling frequency within a week
	Proportion of cycling frequency for housework per week	Proportion of cycling frequency for housework to total cycling frequency within a week
	Proportion of cycling frequency for leisure per week	Proportion of cycling frequency for leisure to total cycling frequency within a week
Single cycling behavior	Cycling purpose	Commuting = 0, housework = 1, leisure = 2
	Cycling tool	Bicycle = 0, e-bike = 1
	Cycling duration	Duration of this cycling (minutes)
	Cycling route	Selecting the shortest route = 0, not selecting the shortest route = 1

3.5. Models

Mann–Whitney U-tests and crossover analyses were used to detect gender differences in daily cycling behavior, single cycling behavior, and PSBE. A linear regression model

was adopted to investigate the influence of the PSBE on the cycling probability. In the model, the dependent variable was the cycling possibility index, which was constructed by min-max normalization of two values, namely the frequency of cycling within a week and the proportion of cycling trips to the total number of trips within a week, followed by summation based on equal weights. With PSBE as the independent variable, the control variables were age, gender, level of education, family obligations (youngest child age less than 13 years old, average household working hours per day), driver's license, and average number of household bicycles and e-bikes.

Binary logistic regression was applied to investigate the influence of the PSBE on male and female cycling routes. In the model, the dependent variable was the choice of cycling route, choosing the shortest route for cycling as a value of 0 while taking a detour or choosing a non-shortest route as a value of 1. The independent variable was PSBE. We controlled for variables of travel purpose (commuting cycling, leisure cycling, and housework cycling) and road redundancy (proxied by the network density within a 500-m range of the origin-destination) to control the possible influences of different travel purposes and road selectivity on cycling routes and to more accurately evaluate the role of PSBE.

4. Results

4.1. Gender Differences in Cycling Behavior

The Mann–Whitney U-test for gender differences in cycling frequency and the proportion of cycling for different purposes are illustrated in Table 4. The cycling frequency and proportion of housework cycling of women were significantly higher than that among men, but the proportion of leisure cycling was significantly higher in men. There was no significant gender difference in the proportion of cycling trips, the proportion of commuting cycling, or single cycling duration.

Table 4. Gender differences in cycling behavior based on the Mann–Whitney U-test.

Indicators	Gender	Median (IQR)	Average ± S.D.	Z	*p*
Cycling frequency per week	Male	8.00 (7.00~12.25)	9.090 ± 4.435	0.111	<0.001 ***
	Female	11.00 (7.00~15.00)	11.300 ± 5.078		
Proportion of cycling per week	Male	1.00 (0.69~1.00)	0.816 ± 0.274	−1.892	0.059
	Female	1.00 (0.89~1.00)	0.900 ± 0.190		
Proportion of cycling frequency for commuting per week	Male	0.10 (0.00~0.64)	0.331 ± 0.370	−1.853	0.064
	Female	0.38 (0.00~0.60)	0.400 ± 0.317		
Proportion of cycling frequency for housework per week	Male	0.24 (0.00~0.51)	0.300 ± 0.310	−2.000	0.046 *
	Female	0.36 (0.14~0.55)	0.354 ± 0.255		
Proportion of cycling frequency for leisure per week	Male	0.32 (0.10~0.50)	0.372 ± 0.326	−3.086	0.002 **
	Female	0.14 (0.00~0.40)	0.250 ± 0.266		
Duration of this cycling trip (min)	Male	15.00 (10.00~20.00)	15.790 ± 10.506	−0.510	0.610
	Female	15.00 (10.00~20.00)	16.540 ± 11.269		

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The purpose, tools, and shortest route of this cycling trip are listed in Table 5. There was no significant gender difference in the choice of cycling tool, with approximately the same number of men and women choosing to ride bicycles and e-bikes. Regarding the cycling route, there was a significant gender difference in that men were more likely to choose the shortest route (61.2%).

Table 5. Gender differences in cycling behavior based on crossover analysis.

Indicators	Variables	Gender		χ^2	*p*
		Male (138)	Female (147)		
Purpose of this cycling trip	Commuting	19 (13.8%)	38 (25.9%)	6.903	0.032 *
	Leisure	64 (46.4%)	54 (36.7%)		
	Housework	55 (39.8%)	55 (37.4%)		
Mode of this cycling trip	Bicycle	23 (16.7%)	26 (17.7%)	0.052	0.820
	E-bike	115 (83.3%)	121 (82.3%)		
Is this cycling route the shortest?	Yes	74 (61.2%)	49 (41.5%)	9.218	0.002 **
	No	47 (38.8%)	69 (58.5%)		

Note: * $p < 0.05$, ** $p < 0.01$.

There was a significant gender difference in the purpose of the cycling trip. A higher proportion of men cycling for leisure is consistent with the results illustrated in Table 4. During this cycling trip, the lower proportion of male and female commuting cycles was partly related to the sample selection of the distributed questionnaires. Commuting cyclists had a lower time budget than cyclists for housework and leisure, leading to a lower response rate.

4.2. Gender Differences in PSBE

The PSBE scores are illustrated in Table 6. There were significant gender differences in facility accessibility (convenient cycling to nearby parks, shopping malls, and schools, and convenient cycling to nearby bus or subway stations), road accessibility (bike lanes sufficiently spacious, conflict between motor vehicles and pedestrians due to occupied roads), safety perception (adequate nighttime lighting, clear road signs, and adequate separate facilities for bicycle lanes), and comfort perception (beautiful road greenery, clean and tidy streets, and low noise), with men scoring higher in all aspects.

The PSBE scores of the e-bike and bicycle riders are presented in Table 7. There are significant differences between e-bike and bicycle riders' perceptions of convenient cycling to nearby parks, shopping malls, and schools, bicycle lane spaciousness, and street cleanliness. Bicycle riders perceived the designated bicycle lanes to be wider and cleaner.

Table 6. Gender differences in PSBE.

Indicators	Variables	Gender	Median (IQR)	Average ± S.D.	Z	*p*
Facility accessibility	Convenient cycling to nearby parks, shopping malls, and schools	Male	4 (4~5)	4.12 ± 0.811	−2.230	0.026 *
		Female	4 (3~5)	3.83 ± 1.036		
	Convenient cycling to nearby bus or subway stations	Male	4 (4~5)	4.24 ± 0.731	−4.445	<0.001 ***
		Female	4 (3~5)	3.69 ± 1.052		
Road accessibility	Non-motor lanes sufficiently spacious	Male	4 (3~4)	3.38 ± 0.946	−2.073	0.038 *
		Female	3 (3~4)	3.24 ± 0.863		
	Too many road intersections (reverse)	Male	2 (2~3)	2.46 ± 0.997	−0.489	0.625
		Female	2 (2~3)	2.39 ± 1.037		
	Conflict between motor vehicles and pedestrians due to occupied roads (reverse)	Male	2 (1~3)	2.17 ± 1.003	−2.195	0.028 *
		Female	2 (1~2)	1.97 ± 1.056		
Safety perception	Sufficient traffic lights and zebra crossings	Male	4 (3.75~5)	4.07 ± 0.961	−1.760	0.078
		Female	4 (3~5)	3.90 ± 0.920		
	Adequate nighttime lighting on streets	Male	4 (4~5)	4.15 ± 0.801	−4.963	<0.001 ***
		Female	4 (3~4)	3.53 ± 1.100		
	Clear road signs for cycling	Male	4 (4~5)	4.30 ± 0.698	−4.074	<0.001 ***
		Female	4 (3~5)	3.87 ± 0.916		
	Adequate separate facilities for bicycle lanes	Male	4 (3~4)	3.51 ± 0.946	−2.450	0.014 *
		Female	3 (3~4)	3.24 ± 0.976		

Table 6. *Cont.*

Indicators	Variables	Gender	Median (IQR)	Average ± S.D.	Z	*p*
Comfort perception	Beautiful road greening	Male	4 (4~5)	4.25 ± 0.772	−2.991	0.003 **
		Female	4 (3~5)	3.92 ± 0.918		
	Abundant street planting species	Male	4 (4~5)	4.12 ± 0.829	−1.271	0.204
		Female	4 (3~5)	3.95 ± 0.953		
	Clean and tidy streets	Male	4 (3~4)	3.78 ± 0.886	−3.137	0.002 **
		Female	4 (3~4)	3.44 ± 0.973		
	Flat road surface	Male	4 (3~4)	3.64 ± 0.894	−1.369	0.171
		Female	4 (3~4)	3.50 ± 0.975		
	Loud noise from motor vehicles or street engineering operations (reverse)	Male	3 (2~3)	2.76 ± 1.098	−3.813	<0.001 ***
		Female	2 (1~3)	2.31 ± 1.292		

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 7. PSBE differences between bicycle and e-bike riders.

Indicators	Variables	Cycling Mode	Median (IQR)	Average ± S.D.	Z	*p*
Facility accessibility	Convenient cycling to nearby parks, shopping malls, and schools	Bicycle	4(4~5)	4.20 ± 0.957	−2.318	0.020 *
		E-bike	4(3~5)	3.92 ± 0.935		
	Convenient cycling to nearby bus or subway stations	Bicycle	4(3~5)	3.88 ± 1.053	−0.406	0.685
		E-bike	4(3~5)	3.97 ± 0.929		
Road accessibility	Non-motor lanes sufficiently spacious	Bicycle	4(3~4)	3.57 ± 0.842	−2.436	0.015 *
		E-bike	3(3~4)	3.25 ± 0.910		
	Too many road intersections (reverse)	Bicycle	2(2~3.5)	2.61 ± 1.151	−1.113	0.266
		E-bike	2(2~3)	2.39 ± 0.985		
	Conflict between motor vehicles and pedestrians due to occupied roads (reverse)	Bicycle	2(1~3)	2.31 ± 1.084	−0.952	0.341
		E-bike	2(1~2)	2.02 ± 1.019		
Safety perception	Sufficient traffic lights and zebra crossings	Bicycle	4(3~5)	3.84 ± 1.048	−0.1	0.921
		E-bike	4(3~5)	4.01 ± 0.918		
	Adequate nighttime lighting on streets	Bicycle	4(3~5)	3.84 ± 1.048	−0.11	0.913
		E-bike	4(3~5)	3.83 ± 1.009		
	Clear road signs for cycling	Bicycle	4(4~5)	4.04 ± 0.912	−0.246	0.806
		E-bike	4(4~5)	4.08 ± 0.831		
	Adequate separate facilities for bicycle lanes	Bicycle	3(3~4)	3.39 ± 0.862	−1.921	0.055
		E-bike	3(3~4)	3.37 ± 0.991		
Comfort perception	Beautiful road greening	Bicycle	4(4~5)	4.22 ± 0.771	−1.154	0.248
		E-bike	4(3~5)	4.05 ± 0.881		
	Abundant street planting species	Bicycle	4(4~5)	4.22 ± 0.743	−1.416	0.157
		E-bike	4(3~5)	3.99 ± 0.922		
	Clean and tidy streets	Bicycle	4(3~5)	3.88 ± 0.971	−2.458	0.014 *
		E-bike	4(3~4)	3.55 ± 0.933		
	Flat road surface	Bicycle	4(3~4)	3.51 ± 0.938	−0.303	0.762
		E-bike	4(3~4)	3.58 ± 0.939		
	Loud noise from motor vehicles or street engineering operations (reverse)	Bicycle	3(1.5~4)	2.63 ± 1.286	−0.634	0.526
		E-bike	2(2~3)	2.51 ± 1.208		

Note: * $p < 0.05$.

Gender differences between e-bike and bicycle riders in the PSBE are illustrated in Table 8. In the bicycle samples, there were significant differences between male and female cyclists in terms of the convenience of reaching bus or subway stations and the adequacy of nighttime lighting. Male cyclists gave higher ratings. In the e-bike samples, there were significant differences between male and female riders in facility accessibility (convenient cycling to nearby parks, shopping malls, and schools, and convenient cycling to nearby bus or subway stations), road accessibility (bike lanes sufficiently spacious, conflict between motor vehicles and pedestrians due to occupied roads), safety perception (adequate nighttime lighting on streets, clear road signs for cycling, and sufficient separate facilities for bicycle lanes), and comfort perception (beautiful road greening, clean and tidy streets, and low noise), with male riders scoring higher in all aspects.

Table 8. Gender differences between e-bike and bicycle riders in PSBE.

Indicators	Variables	Gender	Bicycle (N = 49)				E-bike (N = 236)			
			Median (IQR)	Average ± S.D.	Z	*p*	Median (IQR)	Average ± S.D.	Z	*p*
Facility accessibility	Convenient cycling to nearby parks, shopping malls, and schools	Male	4 (4~5)	4.35 ± 0.775	−0.813	0.416	4 (4~5)	4.07 ± 0.814	−2.185	0.029 *
		Female	4 (4~5)	4.08 ± 1.093			4 (3~5)	3.78 ± 1.021		
	Convenient cycling to nearby bus or subway stations	Male	5 (4~5)	4.35 ± 0.775	−2.942	0.003 **	4 (4~5)	4.22 ± 0.723	−3.497	<0.001 ***
		Female	4 (3~4)	3.46 ± 1.104			4 (3~5)	3.74 ± 1.039		
Road accessibility	Non-motor lanes sufficiently spacious	Male	4 (3~4)	3.52 ± 0.994	−0.088	0.93	4 (3~4)	3.36 ± 0.938	−2.321	0.020 *
		Female	4 (3~4)	3.62 ± 0.697			3 (3~4)	3.16 ± 0.876		
	Too many road intersections (reverse)	Male	2 (2~4)	2.57 ± 1.121	−0.312	0.755	2 (2~3)	2.43 ± 0.975	−0.722	0.47
		Female	3 (2~3.25)	2.65 ± 1.198			2 (2~3)	2.34 ± 0.996		
	Conflict between motor vehicles and pedestrians due to occupied roads (reverse)	Male	2 (1~3)	2.30 ± 1.185	−0.031	0.975	2 (2~3)	3.54 ± 0.939	−2.653	0.008 **
		Female	2 (2~3)	2.31 ± 1.011			2 (1~2)	3.21 ± 1.016		
Safety perception	Sufficient traffic lights and zebra crossings	Male	4 (3~5)	4.00 ± 1.044	−1.055	0.291	4 (4~5)	2.15 ± 0.966	−1.446	0.148
		Female	4 (3~4.25)	3.69 ± 1.050			4 (3~5)	1.89 ± 1.055		
	Adequate nighttime lighting on streets	Male	4 (4~5)	4.22 ± 0.850	−2.428	0.015 *	4 (4~5)	4.08 ± 0.947	−4.337	<0.001 ***
		Female	4 (3~4)	3.50 ± 1.105			4 (3~4)	3.94 ± 0.888		
	Clear road signs for cycling	Male	4 (4~5)	4.22 ± 0.671	−0.942	0.346	4 (4~5)	4.14 ± 0.793	−4.017	<0.001 ***
		Female	4 (3.75~5)	3.88 ± 1.071			4 (3~4.5)	3.54 ± 1.103		
	Adequate separate facilities for bicycle lanes	Male	3 (3~4)	3.35 ± 0.982	−0.773	0.44	4 (3~4)	4.31 ± 0.705	−2.946	0.003 **
		Female	4 (3~4)	3.42 ± 0.758			3 (3~4)	3.87 ± 0.885		
Comfort perception	Beautiful road greening	Male	4 (4~5)	4.30 ± 0.703	−0.571	0.568	4 (4~5)	4.23 ± 0.787	−3.024	0.002 **
		Female	4 (3~5)	4.15 ± 0.834			4 (3~5)	3.87 ± 0.930		
	Abundant street planting species	Male	4 (4~5)	4.22 ± 0.736	−0.097	0.922	4 (4~5)	4.10 ± 0.848	−1.452	0.147
		Female	4 (4~5)	4.23 ± 0.765			4 (3~5)	3.89 ± 0.982		
	Clean and tidy streets	Male	4 (4~5)	4.13 ± 0.757	−1.426	0.154	4 (3~4)	3.71 ± 0.896	−2.863	0.004 **
		Female	4 (3~4)	3.65 ± 1.093			3 (3~4)	3.39 ± 0.943		
	Flat road surface	Male	4 (3~4)	3.78 ± 0.736	−1.682	0.093	4 (3~4)	3.62 ± 0.923	−0.72	0.471
		Female	4 (2~4)	3.27 ± 1.041			3 (3~4)	3.55 ± 0.957		
	Loud noise from motor vehicles or street engineering operations (reverse)	Male	3 (1~4)	2.57 ± 1.161	−0.185	0.853	3 (2~3)	2.80 ± 1.086	−4.341	<0.001 ***
		Female	2 (1.75~4)	2.69 ± 1.408			2 (1~3)	2.23 ± 1.257		

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4.3. The Influence of PSBE on Cycling Probability

A regression model was established with the cycling possibility index as the dependent variable. Given that the cycling possibility index did not conform to a normal distribution, a Box-Cox transformation was carried out, resulting in a λ value of −0.391. As this value is greater than −0.5, it satisfies the assumptions of linear regression.

Table 9 presents the regression model of PSBE on cycling probability (after Box-Cox transformation), covering all cycling samples and distinguishing between male and female groups. Notably, the variance inflation factors (VIFs) for all variables are below 2.5, effectively eliminating the interference of multicollinearity.

Table 9. Linear regression model of PSBE for cycling probability index (Box-Cox).

Grouped Regression Model							
Variables		**All (N = 285)**		**Male (N = 138)**		**Female (N = 147)**	
		β	*p*	β	*p*	β	*p*
	(constant)		<0.001		0.090		0.001
	Female	0.163	0.011 *				
Facility accessibility	Convenient cycling to nearby parks, shopping malls, and schools	−0.010	0.887	0.142	0.142	−0.110	0.326
	Convenient cycling to nearby bus or subway stations	−0.019	0.772	0.074	0.412	−0.056	0.585
Road accessibility	Non-motor lanes sufficiently spacious	−0.038	0.512	0.057	0.533	−0.063	0.462
	Too many road intersections (reverse)	−0.004	0.948	−0.012	0.893	−0.015	0.852
	Conflict between motor vehicles and pedestrians due to occupied roads (reverse)	0.048	0.405	−0.037	0.690	0.139	0.086
Safety perception	Sufficient traffic lights and zebra crossings	0.144	0.011 *	0.078	0.376	0.171	0.047 *
	Adequate nighttime lighting on streets	0.045	0.491	−0.015	0.873	0.130	0.153
	Clear road signs for cycling	−0.162	0.009 **	−0.105	0.250	−0.239	0.011 *
	Adequate separate facilities for bicycle lanes	0.051	0.378	0.030	0.746	0.075	0.378
Comfort perception	Beautiful road greening	−0.066	0.286	−0.083	0.353	−0.005	0.960
	Abundant street planting species	−0.067	0.276	−0.032	0.744	−0.175	0.068
	Clean and tidy streets	−0.027	0.648	0.049	0.583	−0.087	0.294
	Flat road surface	−0.008	0.889	−0.163	0.073	0.125	0.122
	Loud noise from motor vehicles or street engineering operations (reverse)	−0.007	0.909	0.097	0.298	0.003	0.966
Age		0.014	0.847	−0.043	0.722	0.005	0.963
Level of education		−0.151	0.032 *	−0.392	<0.001 ***	−0.038	0.704
Youngest child age less than 13 years old		0.213	<0.001 ***	0.257	0.005 **	0.196	0.019 *
Average household working hours per day		0.211	<0.001 ***	0.213	0.031 *	0.234	0.009 **
The possession of a driver's license		0.139	0.029 *	0.078	0.443	0.162	0.081
Average number of household bicycles and e-bikes		−0.003	0.959	−0.050	0.611	0.025	0.771
Purpose of this cycling trip: housework		0.091	0.127	0.013	0.888	0.218	0.010*
Sample capacity		285		137		148	
R2		0.278		0.264		0.264	
Adjusted R2		0.217		0.131		0.131	
F		F = 4.586, $p < 0.001$ ***		F = 1.983, $p < 0.012$ *		F = 3.573, $p < 0.001$ ***	

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Among all samples, gender (0.163) positively influenced the cycling probability, indicating that women were more likely to cycle. Among the SBE factors, only sufficient traffic lights and zebra crossings (0.156) had positive influences. Notably, the perception of adequate signal facilities had a significantly negative influence on the cycling probability (−0.162), partly because road signs are usually concentrated in complex and conflict-prone road sections. Among the other control variables, the level of education (−0.151) showed a significantly negative effect. Living with a young child less than 13 years old (0.213),

average household working hours per day (0.211), and possession of a driver's license (0.139) significantly positively influenced cycling probability.

Among the male samples, none of the SBE factors significantly influenced cycling probability. Among the control variables, the level of education (−0.392) showed a significantly negative effect. Living with a young child less than 13 years old (0.257) and average household working hours per day (0.213) significantly positively influenced cycling probability.

Among the female samples, sufficient traffic lights and zebra crossings (0.171) significantly positively influenced women's cycling probability. The perception of adequate signal facilities had a significantly negative influence on the cycling probability (−0.239). Among the other control variables, living with a young child less than 13 years old (0.196) and average household working hours per day (0.234) significantly positively influenced women's cycling probability.

In general, PSBE only exerted an influence on the cycling probability of women and had no significant influence on men. Women's cycling probability was significantly promoted by perceptions of safety at intersections, such as traffic lights and zebra crossings, but inhibited by complex road signs. Childcare needs generally promoted cycling, but household trips only significantly drive female cycling.

4.4. The Influence of PSBE on Cycling Route

The logistic regression model of the PSBE for the cycling route, that is, whether a detour is chosen for cycling, is illustrated in Table 10, including all samples and those from e-bike users. Some questionnaires lacked sufficient clarity regarding specific cycling routes; only responses from cyclists with clearly defined routes were included in the analysis. We collected 239 samples, comprising 202 e-bike riders and 37 traditional bicycle riders. Owing to the small sample size of bicycle riders, this study focused solely on all samples and those from e-bike users.

Among all cycling samples, women were more inclined to choose a detour than men (OR = 4.21). Cycling for leisure (OR = 14.72) and housework (OR = 11.53) was more likely to lead to detours than commuting trips. The width of bicycle lanes (OR = 0.69) significantly negatively influenced detour cycling: the wider the bicycle lane, the more conducive it is for cyclists to choose the shortest route. The choice of the shortest route was not significantly influenced by whether an e-bike or bicycle was used as the cycling tool.

Among all samples of male cycling, those cycling for leisure (OR = 12.84) and housework (OR = 8.56) were more likely to take detours than were those who were commuting. The probability of detours for leisure trips was greater than that for housework trips. The impact of PSBE was weak, with only the convenience of reaching bus or subway stations (OR = 2.11) showing a significant effect on males, indicating that male detours were driven by the convenience of bus connections.

Among all the samples of female cycling, compared with commuting trips, female cycling for leisure (OR = 26.93) and housework (OR = 28.55) were more likely to take detours, with the detour-taking probability of women higher than that of men. In addition, unlike men, women were more likely to take detours for household chores than leisure activities. The spaciousness of bicycle lanes (OR = 0.5) reduced the likelihood of detour cycling among females. Road surface flatness (OR = 2.08) and loud noise from motor vehicles or street engineering (reverse scoring, OR = 1.55) had a significant impact on female detours, suggesting that females tended to detour to avoid noise and bumpy or steep roads.

Table 10. Regression model of PSBE for non-shortest cycling path selection.

Variables	All Riders (N = 239)									E-bike Riders (N = 202)								
	All			Male			Female			All			Male			Female		
	B (SE)	OR (95% CI)	*p*	B (SE)	OR (95% CI)	*p*	B (SE)	OR (95% CI)	*p*	B (SE)	OR (95% CI)	*p*	B (SE)	OR (95% CI)	*p*	B (SE)	OR (95% CI)	*p*
(constant)	−2.85 (1.72)	0.058	0.097	−10.01 (3.82)	0	0.009	−0.94 (2.27)	0.389	0.678	−1.71 (1.91)	0.181	0.372	−7.23 (4.7)	0.001	0.123	−0.88 (2.52)	0.416	0.727
Women	1.44 (4.21)	4.21 (2.19–8.09)	<0.001 ***							1.59 (0.37)	4.88 (2.34–10.16)	<0.001 ***						
Convenient cycling to nearby parks, shopping malls, and schools	−0.18 (0.83)	0.83 (0.55–1.26)	0.387	0.2 (0.3)	1.22 (0.68–2.2)	0.503	−0.55 (0.4)	0.58 (0.26–1.26)	0.168	−0.13 (0.23)	0.88 (0.56–1.39)	0.588	0.34 (0.34)	1.4 (0.72–2.71)	0.32	−0.64 (0.46)	0.53 (0.22–1.3)	0.166
Convenient cycling to nearby bus or subway stations	0.19 (1.21)	1.21 (0.81–1.81)	0.36	0.75 (0.34)	2.11 (1.09–4.06)	0.026 *	0.11 (0.35)	1.11 (0.56–2.22)	0.764	0.28 (0.23)	1.33 (0.84–2.08)	0.222	0.87 (0.4)	2.39 (1.1–5.2)	0.028 *	0.28 (0.4)	1.32 (0.61–2.88)	0.48
Non-motor lanes sufficiently spacious	−0.37 (0.69)	0.69 (0.48–0.99)	0.041 *	−0.16 (0.26)	0.85 (0.51–1.42)	0.531	−0.7 (0.35)	0.5 (0.25–0.99)	0.047*	−0.38 (0.21)	0.69 (0.46–1.03)	0.072	−0.02 (0.32)	0.98 (0.53–1.83)	0.95	−0.8 (0.4)	0.45 (0.21–0.98)	0.045 *
Too many road intersections (reverse)	0.09 (1.1)	1.1 (0.82–1.48)	0.537	−0.05 (0.22)	0.95 (0.61–1.47)	0.811	−0.07 (0.27)	0.93 (0.55–1.6)	0.799	0.06 (0.18)	1.06 (0.75–1.51)	0.73	0.15 (0.28)	1.16 (0.67–2.02)	0.602	−0.18 (0.3)	0.83 (0.46–1.5)	0.542
Conflict between motor vehicles and pedestrians due to occupied roads (reverse)	0.2 (1.23)	1.23 (0.89–1.68)	0.208	0.2 (0.25)	1.22 (0.75–2)	0.427	0.51 (0.28)	1.67 (0.96–2.92)	0.07	0.06 (0.19)	1.06 (0.74–1.53)	0.74	−0.29 (0.33)	0.75 (0.39–1.44)	0.384	0.49 (0.32)	1.64 (0.88–3.05)	0.121
Sufficient traffic lights and zebra crossings	−0.22 (0.8)	0.8 (0.57–1.11)	0.187	−0.09 (0.24)	0.92 (0.57–1.47)	0.725	−0.42 (0.32)	0.66 (0.35–1.22)	0.181	−0.4 (0.21)	0.67 (0.45–1.01)	0.053	−0.4 (0.31)	0.67 (0.37–1.23)	0.193	−0.29 (0.38)	0.75 (0.36–1.58)	0.451
Adequate nighttime lighting on streets	0.21 (1.24)	1.24 (0.87–1.76)	0.237	0.18 (0.3)	1.2 (0.67–2.15)	0.541	0.41 (0.27)	1.5 (0.89–2.55)	0.129	0.06 (0.2)	1.06 (0.72–1.58)	0.761	−0.39 (0.4)	0.68 (0.31–1.5)	0.337	0.5 (0.29)	1.64 (0.94–2.87)	0.082
Clear road signs for cycling	0.06 (1.06)	1.06 (0.69–1.63)	0.786	0.44 (0.33)	1.56 (0.82–2.95)	0.176	0.01 (0.39)	1.01 (0.47–2.17)	0.98	−0.07 (0.24)	0.93 (0.58–1.5)	0.770	0.38 (0.38)	1.47 (0.7–3.07)	0.309	−0.4 (0.45)	0.67 (0.28–1.63)	0.379
Adequate separate facilities for bicycle lanes	−0.23 (0.79)	0.79 (0.56–1.12)	0.188	−0.35 (0.24)	0.71 (0.44–1.13)	0.146	−0.01 (0.34)	0.99 (0.51–1.9)	0.971	−0.17 (0.2)	0.84 (0.57–1.24)	0.382	−0.41 (0.29)	0.67 (0.38–1.18)	0.163	0.1 (0.36)	1.11 (0.55–2.24)	0.78
Beautiful road greening	0 (1)	1 (0.67–1.48)	0.986	0.4 (0.31)	1.49 (0.81–2.75)	0.204	−0.13 (0.34)	0.88 (0.45–1.73)	0.712	0.05 (0.22)	1.05 (0.68–1.63)	0.814	0.2 (0.36)	1.23 (0.61–2.48)	0.574	0.1 (0.4)	1.1 (0.51–2.41)	0.807
Abundant street planting species	0.05 (1.05)	1.05 (0.73–1.52)	0.78	0.33 (0.29)	1.39 (0.78–2.47)	0.262	−0.07 (0.31)	0.94 (0.51–1.7)	0.827	0.13 (0.21)	1.14 (0.76–1.72)	0.519	0.34 (0.35)	1.41 (0.72–2.77)	0.321	−0.03 (0.33)	0.97 (0.51–1.87)	0.931
Clean and tidy streets	−0.06 (0.95)	0.95 (0.67–1.34)	0.758	0.24 (0.26)	1.27 (0.77–2.1)	0.352	−0.36 (0.31)	0.7 (0.38–1.3)	0.258	−0.1 (0.2)	0.91 (0.61–1.35)	0.639	0.31 (0.3)	1.36 (0.76–2.46)	0.304	−0.47 (0.36)	0.63 (0.31–1.28)	0.199
Flat road surface	0.19 (1.21)	1.21 (0.86–1.7)	0.27	−0.3 (0.27)	0.74 (0.44–1.26)	0.265	0.73 (0.31)	2.08 (1.13–3.82)	0.019 *	0.05 (0.2)	1.05 (0.71–1.53)	0.816	−0.25 (0.3)	0.78 (0.43–1.42)	0.417	0.6 (0.36)	1.82 (0.91–3.66)	0.09
Loud noise from motor vehicles or street engineering operations (reverse)	0.2 (1.22)	1.22 (0.94–1.57)	0.133	0.15 (0.2)	1.17 (0.79–1.71)	0.433	0.44 (0.21)	1.55 (1.03–2.33)	0.035 *	0.27 (0.15)	1.31 (0.97–1.76)	0.080*	0.23 (0.24)	1.26 (0.78–2.02)	0.345	0.57 (0.24)	1.76 (1.1–2.81)	0.018 *
Purpose of cycling: leisure	2.69 (14.72)	14.72 (5.03–43.09)	<0.001 ***	2.55 (0.9)	12.84 (2.21–74.49)	0.004 **	3.29 (0.82)	26.93 (5.37–134.96)	<0.001 ***	2.96 (0.63)	19.21 (5.63–65.58)	<0.001 ***	3.19 (1.2)	24.28 (2.32–254.47)	0.008 **	2.89 (0.88)	17.9 (3.2–100.1)	0.001 **
Purpose of cycling: housework	2.45 (11.53)	11.53 (4.06–32.76)	<0.001 ***	2.15 (0.89)	8.56 (1.51–48.64)	0.015 *	3.36 (0.8)	28.66 (6.03–136.1)	<0.001 ***	2.63 (0.59)	13.93 (4.36–44.53)	<0.001 ***	2.76 (1.18)	15.84 (1.57–160.15)	0.019 *	3.29 (0.85)	26.81 (5.03–142.79)	<0.001 ***
Average network density within a 500 m range of OD	−0.01 (0.99)	0.99 (0.9–1.1)	0.902	−0.06 (0.07)	0.95 (0.82–1.09)	0.432	0.05 (0.1)	1.05 (0.86–1.29)	0.605	−0.01 (0.06)	0.99 (0.89–1.11)	0.900	−0.07 (0.08)	0.93 (0.79–1.09)	0.371	0.08 (0.11)	1.09 (0.87–1.35)	0.465
Sample capacity		N = 239			N = 121			N = 118			N = 202			N = 100			N = 102	
Nagelkerke R^2		0.285			0.231			0.435			0.328			0.333			0.483	
Hosmer test for significance		6.449, $p = 0.597$			3.960, $p = 0.861$			3.771, $p = 0.877$			4.867, $p = 0.772$			6.465, $p = 0.595$			8.285, $p = 0.406$	
Prediction accuracy		71.5%			68.6%			80.5%			73.8%			75.0%			78.4%	

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Among the samples of e-bike riders, women were more likely to take a detour for cycling than men (OR = 4.88). Cycling for leisure (OR = 19.21) and housework (OR = 13.93) were more likely to be chosen as detours than commuting trips.

Among the samples of male e-bike riders, compared with commuting trips, those cycling for leisure (OR = 24.28) and household (OR = 15.84) purposes were more prone to take detours, with the probability of taking detours for leisure travel greater than that for housework. The impact of PSBE was weak, with only the convenience of reaching bus or subway stations (OR = 2.39).

Among the samples of female e-bike riders, compared with commuting trips, those cycling for leisure (OR = 17.9) and housework (OR = 26.81) purposes were more inclined to take detours, with the probability of women taking detours higher than that of men. Women were more likely to take a detour for housework than for leisure travel. The spaciousness of bicycle lanes (OR = 0.45) reduced the likelihood of detour cycling among females. Loud noise from motor vehicles or street engineering (reverse scoring, OR = 1.76) had a significantly positive influence on female e-bike riders taking detours. In contrast, the flatness of the road surface showed no significant influence, demonstrating that female e-bike riders paid less attention to the flatness of the road surface.

Overall, the probability of detour cycling was significantly higher among females than males (overall OR = 4.21, e-bike OR = 4.88), and females were more sensitive to the spaciousness of bicycle lanes (overall females OR = 0.5, e-bike females OR = 0.45) and street noise (overall females OR = 1.55, e-bike females OR = 1.76). Male detours were driven by the convenience of bus connections (overall males OR = 2.11, e-bike males OR = 2.39). In terms of travel purposes, leisure (overall OR = 14.72) and housework (overall OR = 11.53) significantly promoted detours. E-bikes further amplified these effects.

5. Discussion

5.1. Data Interpretation

The cycling frequency of women was higher than that of men, which is consistent with the findings of relevant studies in other countries characterized by high rates of bicycle ownership [40]. Notably, there were specific differences between male and female cyclists regarding their cycling purposes, with men engaging more frequently in cycling activities for leisure. In contrast, no significant differences were observed between cycling tools (i.e., e-bikes and bicycles).

Compared with bicycle riders, gender differences in PSBE perception are more pronounced among e-bike riders, manifested in multiple aspects such as facility accessibility (convenience of cycling to nearby parks, shopping malls, schools, bus stops, or subway stations), road accessibility (lane width), safety (sufficient street lighting at night, clear road cycling signs, and adequate bicycle lane separation facilities), and comfort (beautiful road greening, clean streets, and low noise). Males scored higher than females in all these aspects. This confirms Hypotheses H1a and H1b: female cyclists show significantly stronger negative evaluations of PSBE safety and comfort than males, and this difference is particularly prominent among e-bike users.

The cycling probability of females is significantly higher than that of males, and it is more obviously driven by family care responsibilities, confirming the gender division of labor theory.

Perceptions of the built environment show gender differentiation. Females are more sensitive to the adequacy of traffic lights/zebra crossings and the clarity of road signs, partially supporting Hypothesis H2a that safety improvements (such as intersection sign optimization) have a stronger promoting effect on female cycling probability than on males.

Notably, the safety perception of night lighting (β = 0.130, p = 0.153) only shows a weak correlation with females, failing to reach statistical significance. This indicates that lighting-related crime safety issues, which receive extensive international attention, are not the core factors affecting female cycling probability in China. Motor vehicle-bike lane separation facilities (β = 0.075, p = 0.378), identified as an important factor affecting cycling feasibility in other literature, were not identified in this study. This may be related to the fact that major roads in the selected study area are all equipped with special bicycle lanes.

In addition, park/shopping mall accessibility has no effect in the overall sample (β = −0.010, p = 0.887) and is negatively correlated with female cycling probability (β = −0.110, p = 0.326), challenging the conventional Hypothesis H2b that "convenient facilities motivate cycling". This may be attributed to the high facility accessibility in the selected study area.

For every 1-unit increase in perceived lane width, the detour probability of females decreases by 55% (OR = 0.45), and the e-bike group is more sensitive, supporting Hypothesis H3a that female e-bike riders have a stronger detour response to perceived insufficient lane width (road accessibility).

Females' detour sensitivity to noise (OR = 1.55, p = 0.035) is significantly higher than that of males, and e-bikes amplify this effect (OR = 1.76, p = 0.018), supporting Hypothesis H3b that females are more likely to choose detours for comfort (smooth roads, low noise, etc.) than males. Comfort perceptions related to aesthetics did not significantly affect female cycling route choices, suggesting that basic comfort needs (noise reduction, flatness) take precedence over aesthetics.

5.2. Theoretical Analysis

Based on the SEM framework, the study reveals the interaction mechanism of individual, social, and built environment factors on gendered cycling behavior.

As a transportation tool, e-bikes amplify females' sensitivity to comfort (noise) and accessibility (width) (supporting H1b and H3b), making them a technical variable that cannot be ignored in gender studies.

Cycling behavior shows significant gender differences. Females exhibit high cycling probability and high detour characteristics. While their cycling likelihood is higher than males', their route choices are more risk-averse. Due to family responsibilities, females need to expand their mobility through cycling but are constrained by negative perceptions of convenience and comfort, incurring additional time-space costs.

The study breaks through the traditional research paradigm of single-dimensional safety dominance. Empirical results establish the core status of road accessibility (width) and comfort (noise) in cycling route choices, especially in the context of e-bikes, where these two dimensions constitute the priority for gender-inclusive design.

5.3. Policy Recommendations

The findings of this study can provide references for promoting gender equality and designing street environments suitable for e-bike travel, following the principles of valuing individual-level perceptual differences, highlighting the importance of family responsibilities at the social level, and adjusting through the four dimensions of PSBE. Specific policy recommendations are as follows:

5.3.1. Intersection Renovation

The perception of intersection chaos affects female cyclists' cycling probability. Setting up bicycle-specific traffic lights (height-adapted to cycling sightlines), bicycle-specific intersection marking guidance, and luminous zebra crossings in female cycling hotspots can help motivate female cycling.

5.3.2. Family-Friendly Cycling Road Renovation

Family responsibilities are highly correlated with cycling probability. Construct childcare cycling paths connecting schools, community centers, and supermarkets with continuous separated lanes. Optimize parking facilities at conflict points such as schools and supermarkets to reduce curb step interference.

5.3.3. Lane Width Renovation

Female e-bike riders are more sensitive to bicycle lane width. It is recommended to encourage bicycle lane width design suitable for e-bike scales, increasing the minimum width of e-bike lanes from 1.5 m to 2.2 m in female cycling hotspots and childcare path areas.

5.3.4. Noise Reduction Treatment

Noise control is central to female detour decisions. Consider dedicated noise-reducing lanes for e-bikes, such as laying rubber-modified asphalt on main roads for noise reduction, installing interval sound barriers along roads, and implementing appropriate engineering operation controls.

6. Conclusions

6.1. Main Conclusions

Through empirical analysis, this study reveals the complex interaction between PSBE, gender, and cycling behavior. The main conclusions are as follows:

Females exhibit significantly stronger negative perceptions of PSBE safety and comfort than males, with e-bikes further amplifying these differences due to their speed and volume characteristics. Traditional safety elements such as night lighting show limited impact on Chinese females' cycling willingness, whereas intersection sign optimization notably enhances their cycling probability. Driven by care responsibilities, females adopt a multi-purpose trip pattern that significantly boosts their cycling likelihood. They are also more inclined than males to detour to avoid noise and narrow lanes, a tendency exacerbated by e-bikes. Overall, e-bikes—by altering speed experience and physical-technical interactions—heighten females' sensitivity to accessibility (lane width) and comfort (noise), underscoring their pivotal role in gender-focused cycling research.

6.2. Limitations

This study had several limitations. First, it had a relatively small sample size and a limited geographical context. The Gulou District in China was selected as the research area as it has a larger cycling population and is representative of older urban areas in China. However, the high facility accessibility, high road network density, and coverage of bicycle lane separation facilities in Gulou District, Nanjing, may weaken the effects of facility accessibility, road accessibility, and safety. Therefore, caution should be exercised when generalizing the conclusions to low-density cities.

Second, there was sample selection bias. Since this study focuses on the subjective experience of SBE among cyclists, non-cyclists are not included in the sample. This limits the exploration of the important question of "what SBE elements can motivate non-cyclists to choose cycling". In addition, shared bicycle users are not included in the research objects, resulting in a relatively high proportion of frequent cyclists in the sample, which may affect the accuracy of the study on gender differences in cycling behavior influenced by PSBE to a certain extent.

Third, PSBE indicators were selected according to objective SEB factors to enhance the applicability of the analysis results for guiding design practices. However, this study was based on the perceived differences between men and women in the same SBE factor

without delving into specific variations in objective SBE factors. Consequently, a definitive analytical pathway connecting the objective SBE factors with PSBE and cycling behavior was not established in this study.

This was an initial exploration of the PSBE on the cycling behavior of female e-bike riders. Based on these findings, further studies could expand the sample scope and employ quasi-experimental designs that control for additional variables to assess the multiple impacts of SBE on female cycling behavior, thereby providing valuable insights into the design of SBE to promote gender equality while facilitating e-bike trips.

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