Traffic & Transportation

How Do Neighbourhood and Working Environment Affect Green Commuting in China? A Resident Health Perspective

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Original Scientific Paper
Submitted: 15 Aug. 2022
Accepted: 20 Mar. 2023

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Publisher:
Faculty of Transport and Traffic Sciences, University of Zagreb

ABSTRACT

Commuting contributes to high levels of greenhouse gases and air pollution. The recently advocated 'green commuting', i.e. active and public modes of transport, will be conducive to low-carbon and environmentally friendly transport. A baseline goal of urban planning is to promote health; however, few studies have explored the health-related impacts of environments at both ends of the commute on residents' commuting mode choices. To fill the gap, this study proposes to consider the impact of the neighbourhood and working environment on green commuting from a health perspective. Using a sample of 15,886 people from 368 communities in China, three generalised multilevel linear regression models were estimated. Physical and psychological health were combined to further analyse health-related environmental attributes on the commuting choices of residents with different health levels. The results indicate that the working environment exerts more substantial effects on 'green commuting' than the neighbourhood environment, especially for workplace satisfaction. Moreover, we found that a good working environment and relationships will significantly encourage the sub-healthy group to choose active commuting. These findings are beneficial for policymakers to consider focusing on reconciling neighbourhood and working environments and meeting the commuting requirements of the less healthy group.

KEYWORDS

green commuting; commuting mode; neighbourhood environment; working environment; resident health; transportation planning.

1. INTRODUCTION

Commuting is a transportation issue and significant activity in residents' lives [1]. The huge commute demand causes environmental pollution, traffic jams and energy waste [2, 3]. In 2019, China's total annual vehicle emissions were 1.89 MT (million tons) of HC, 7.72MT CO, 7.72 Mt NOx and 0.074 Mt PM [4]. Among them, the automobile is the dominant contributor to pollutant emission, and its emission ratio of the four pollutants exceeds 90%. Eight metropolises have announced policies curbing the purchase of vehicles for private use, as concerns about pollution and traffic congestion have risen around the country since 2017. Although this policy contributes to slowing car growth, it doesn't fundamentally affect the mobility choices of people who already have cars. Green commuting will become even more significant in the future, not only for personal health but also for environmental problems such as global warming and air pollution. Green commuting refers to two types of eco-friendly commuting modes, namely public transport (bus, subway, rail) and active transportation modes (walking, cycling). In this study, we conducted a revealed preference survey (conducting behavioural surveys on commuters' completed modes of transport) to explore the impact of health-related environment attributes on neighbourhoods and work on commuting modes.

One of the most pivotal aspects to consider commuting and the built environment are mutually restrictive and affect each other. Existing studies have shown that features of the built environment have a significant impact on commuting behaviours [5–9]. The sustainable development of cities can be promoted through com-

prehensive treatment of transportation service demand from the perspective of the environment, passengers and society [10]. For cities where walking and transit are the main modes of transportation, better walking and transit facilities can help reduce traffic congestion [11]. In addition, higher urban density helps to reduce the dependence on private cars and increases the possibility of green commuting [7, 12]. Some scholars have also conducted specific studies of the impact of the built environment on active commuting. Specifically, higher street connectivity and urban green rate, as well as good neighbourhood street lighting, have significant promoting effects on commuters' choice of active commuting [13-16], which means physical commuting, including walking and cycling. In addition, according to the subjective feelings of commuters, public transport is mainly selected by commuters who care about environmental factors [17]. For urban planners and decision-makers, it is more valuable to better understand the impact of the urban environment on residents' activities [18]. However, most existing studies consider the overall characteristics of cities, but few focus on the characteristics of neighbourhoods and workplaces.

In addition, commuting behaviour has an important link with health, including psychological and physiological effects [19–21]. Empirical evidence in numerous studies shows that public transport users have lower commuting happiness than car commuters [22, 23]. Compared with passive commuting (motor vehicle commuting), active commuting is more helpful in reducing psychological stress and improving subjective well-being [24, 25], and it can further affect people's performance and mood at work and home. Further, when commuters give precedence to health aspects, they prefer to walk or use bicycles. In addition, active commuting promotes more physical activity, and can significantly reduce the risk of chronic diseases such as obesity, cardiovascular disease and diabetes, allowing commuters to have a longer life expectancy (compared to using motor vehicles) [26]. Compared with active mobility (bicycle), the life expectancy of urban commuters using motorised transport may be shortened [27]. Existing studies mainly focus on the effects of green commuting modes (including walking, cycling and public transit) on the mental and physical health of commuters, but there is still a lack of comparative analysis on how commuting behaviour changes with health level. In summary, the problem of the impact of neighbourhood and workplace environments on the commuting modes for different groups of health level has not been completely resolved, and the existing literature still needs to be supplemented.

Previous studies have shown that green commuting contributes significantly to low-carbon and active commuting is also beneficial to health. Therefore, it is of great significance to improve the environment by encouraging commuters to choose green commuting. Many scholars have studied the factors that influence commuting mode choice. However, few of them have investigated neighbourhood and work effects on commuting modes, especially green commuting modes. The following issues have not been deeply studied:

– The impact from the perspective of the characteristics of neighbourhood and workplace.
– The problem of the impact of neighbourhood and workplace environment on the commuting modes for different health-levels groups.

To address these research gaps, this study investigates the factors that influence the commuting behaviours of Chinese residents from a health perspective. In particular, the study aims to answer the following questions:

– How do the neighbourhood and working environment affect the commuting mode?
– What is the interaction between personal health and commuting?
– What contributions can governments and enterprises make to promote green commuting?

By answering these questions, this research will not only help us to understand the substantive commuting behaviour but also help us analyse the method and practice status of the econometric model. This study makes five contributions:

– Proposing the community and working environment as the research object to study their impact on green commuting;
– Using a generalised multi-layer linear model to comprehensively consider the subjective feelings of residents and the objective existence of the environment, as the environmental contributors;
– Combine BMI and life happiness to classify the health level of commuters;
– For commuters with different health levels, further analyse the impact of the environment on their commuting modes;
– Discuss the implications for policymakers from the empirical results.

The rest of this article is organised as follows. Section 2 gives a description of the data and variables. Section 3 gives a brief review of the methodology and Section 4 presents the results of both detailed analysis and multilevel models. In Section 5, we discuss the main findings and policy implications. The final section summarises the main findings of this study.

2. DATA AND VARIABLES

2.1 Data sources

The data was mainly extracted from the CLDS (Survey of China's Labour Force Dynamics), which was conducted by the Social Sciences Survey Center of Sun Yat-sen University. CLDS focuses on the current situation and changes in China's labour force, covering education, work, migration, health, social participation, economic activities, grassroots organisations and many other research topics as an interdisciplinary large-scale follow-up survey. This survey is nationwide, covering 29 provinces in mainland China, excluding Tibet and Hainan. The sample distribution is shown in *Figure 1*. The survey subject is the entire labour force, encompassing family members aged 15 to 64 in the sample households. In the sampling method, multistage cluster, stratified PPS (probability proportionate to size sampling) is used in multi-stage, multi-level probability sampling proportional to the size of the labour force. In this study, databases at three levels – individual, family and community – were established. After removing the records with irrelevant and missing data, 15,886 individuals from 368 neighbourhoods were used for the analysis in this study. We adopted Bartlett's Test of Sphericity for structural validity analysis. The result shows that the significance of Bartlett's Test of Sphericity is 0.000, thus, the questions have validity.

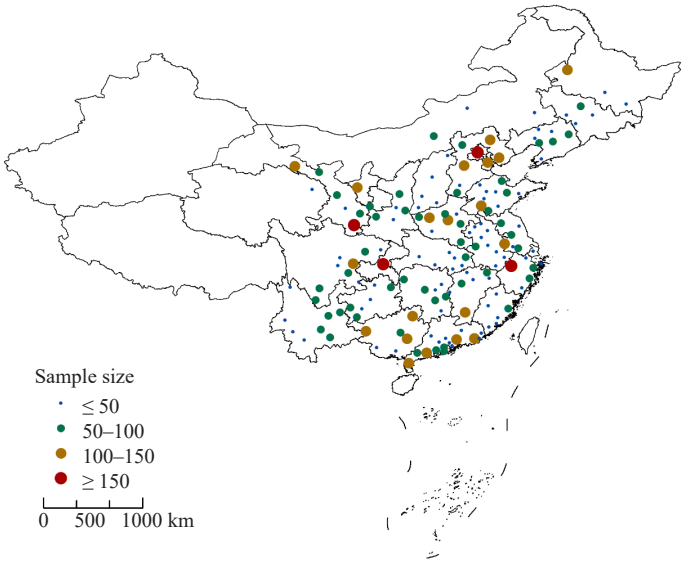

Figure 1 – The sample distribution map

2.2 Variables

The dependent variables are binary variables related to green commuting. Moreover, the commuting modes in this study include walking, cycling, motorcycle, bus, subway, taxis, private cars and working at home (i.e. working online). Among them, walking and cycling require physical labour, so we call them active commuting. Buses and subways belong to public transport, and other modes of transport are non-green commuting modes. In the following analysis, we refer to active commuting as mode 1 and commuting by public transport as mode 2, respectively.

The independent variables were mainly obtained from the community and individual levels, and we further categorised them into two types, namely neighbourhood-related and work-related ones. Previous research has shown that the neighbourhood and work location is of great significance to commuting behaviour. The neighbourhood-related variables include location, internal environment and interpersonal relationships among residents. In contrast, the work-related variables include working location, intensity, length of work and physi-

Table 1 – Descriptive statistics for variables (N=15,886)

Variables	Mean (proportion)	Variables	Mean (proportion)
Neighbourhood-level variables		*Dependent variables*	
Good security (%)	95.38	Traffic modes (%)	
Neighbourhood-owned entertainment venues (%)	11.14	Active commuting	39.84
Neighbourhood-owned fitness facilities (%)	64.40	Passive commuting	61.06
Cleanliness	7.69	Traffic modes (%)	
Environmental pollution in the neighbourhood (%)	17.93	Public transport	5.44
The degree of pollution improvement (after negotiating with the government or relevant enterprises)	1.99	Private transport	94.56
Green coverage rate (%)			
<30%	33.15		
30~60%	29.08		
>60%	37.77	*Control variables*	
Good neighbourhood relations (%)	84.24	Gender (%)	
The location of the neighbourhood (%)		Male	47.55
Urban area	27.17	Female	52.45
Town	8.42	Age	46.47 (SD=14.41)
Suburban area	9.78	Marital status (%)	0.83
Countryside	54.63	Married	Single, divorced, or widowed
Work-level variables		Married	Single, divorced, or widowed
Workplace (%)		Single, divorced, or widowed	Education attainments (%)
City	11.77	Primary school and below	25.03
The country	88.23	Junior high school	33.87
Feel stressed at work (%)	21.37	Senior high school	16.75
Degree of freedom of work intensity (the intensity of the work is determined by oneself)	2.27	College and above	12.58
Usually work overtime	8.19	2017 Annual personal income (Yuan)	39098.95 (SD=67349.83)
Frequency of heavy physical labour	2.10	BMI value	22.40 (SD=4.22)
Frequency of quick-reaction thinking or mental work	2.19	BMI<18.5 (%)	12.01
Satisfied with the working environment	44.26	BMI 18.5~23.9 (%)	54.34
Satisfied with the respect given by others	42.50	BMI>23.9 (%)	33.65
Monthly working hours (days)	23.89 (SD=6.28)	Feel Life happiness (%)	65.79

Notes: City includes urban area and suburban area. The country includes towns and countryside. The suburban area belongs to the urban expansion and transforms the rural areas around the original cities into areas where urban and rural factors are mixed. In addition, towns refer to non-organisational towns that serve as the economic, cultural and life service centres of certain areas in the country which are transitional settlements between rural and urban areas. SD – standard deviation.

cal and psychological experience of an individual at work. Besides, the individual-level variables also include personal attributes (referred to as control variables): age, sex, marital status, education level, annual income, BMI (Body Mass Index) and life happiness. According to the BMI standard in China and personal life happi-

Table 2 – Collinearity statistics table for attributes

	Model 1: Active commuting		Model 2: Commuting by public transport	
	Tolerance	VIF	Tolerance	VIF
Neighbourhood-level variables				
Good security	0.927	1.078	0.927	1.078
Neighbourhood-owned entertainment venues	0.893	1.119	0.893	1.119
Neighbourhood-owned fitness facilities	0.780	1.282	0.780	1.282
Cleanliness	0.920	1.087	0.920	1.087
Environmental pollution in the neighbourhood	0.954	1.048	0.954	1.048
The degree of pollution improvement (after negotiating with the government or relevant enterprises)	0.956	1.046	0.956	1.046
Green coverage rate (ref: <30%)				
30~60%	0.704	1.420	0.704	1.420
>60%	0.666	1.502	0.666	1.502
Good neighbourhood relations	0.919	1.088	0.919	1.088
The location of the neighbourhood (ref: countryside)				
Urban area	0.604	1.657	0.604	1.657
Town	0.888	1.126	0.888	1.126
Suburban area	0.824	1.213	0.824	1.213
Work-level variables				
Workplace (ref: the country)				
City	0.828	1.207	0.828	1.207
Feel stressed at work	0.910	1.099	0.910	1.099
Degree of freedom of work intensity (intensity of work is determined by oneself)	0.795	1.257	0.795	1.257
Usually work overtime	0.811	1.234	0.811	1.234
Frequency of heavy physical labour	0.899	1.112	0.899	1.112
Frequency of quick-reaction thinking or mental work	0.731	1.368	0.731	1.368
Satisfied with the working environment	0.655	1.526	0.655	1.526
Satisfied with the respect given by others	0.658	1.520	0.658	1.520
Monthly working days	0.990	1.010	0.990	1.010
Control variables				
Gender (ref: female)				
Male	0.902	1.108	0.902	1.108
Age	0.589	1.697	0.589	1.697
Marital status (ref: single, divorced or widowed)				
Married	0.687	1.456	0.687	1.456
Education attainments (ref: primary school and below)				
Junior high school	0.672	1.488	0.672	1.488
Senior high school	0.640	1.563	0.640	1.563
College and above	0.479	2.086	0.479	2.086
2017 annual personal income (yuan)	0.910	1.099	0.910	1.099
BMI value (ref: <18.5)				
BMI 18.5~23.9	0.386	2.591	0.386	2.591
BMI>23.9	0.375	2.668	0.375	2.668
Feel life happiness (%)	0.933	1.072	0.933	1.072

Notes: Model 1: 0 = passive commuting, 1 = active commuting; Model 2: 0 = commuting by private transport, 1 = commuting by public transport.

ness, we postulated that residents with normal BMI and self-rated life happiness belong to the health group, while the others belong to the sub-health group. By such division, we are able to explore the role of health conditions in commuting.

2.3 Descriptive statistics

Among the valid data of 15,886 respondents, the proportion of active commuting (39.84%) is smaller than the proportion of passive commuting (61.06%), and the proportion of respondents commuting by public transport (5.44%) is much smaller than that of private transport (94.56%). Detailed data descriptions on the neighbourhood-related and work-related variables are shown in *Table 1*. The control variables are also included.

The collinearity between the variables is analysed by SPSS software, and the results are shown in *Table 2*. It is generally believed that when VIF (Variance Inflation Factor) is greater than 10 (strictly 5), it means that the model has serious collinearity problems, and the tolerance value=1/VIF, or the tolerance value is greater than 0.1 (strictly greater than 0.2), indicating that there is no collinearity. All variables in this study have VIFs lower than 5, so there is no collinearity between the variables.

3. METHODS

The differentiated spatial characteristics of commuting [28, 29] are generally attributed to individual differences and the external environment. The traditional single-level models are only retained at the individual level or environmental level, so it excludes independence among individuals. However, the individuals in the group are also highly correlated. This makes it difficult for the traditional models to reasonably explain the multi-factor impact on commuting [30].

The generalised multilevel linear model is a kind of standard multilevel model, which is designed to deal with first-level dependent variables [31]. Assuming that the dependent variable follows a Bernoulli distribution with success probability, and by using an appropriate link function (e.g. logit), a binary outcome can be associated with a predictor linear variable [28]. Therefore, we use a multilevel logistic regression model to explore the relationship between green commuting and neighbourhood/working environment. Furthermore, the commuting mode will be divided into active commuting and passive commuting according to the degree of motorisation; private transport and public transport according to the property of vehicles.

By analysing the correlation between the neighbourhood and individual work level, we find that individual attributes have similar effects on groups, while social attributes have different effects on groups. So, the social attribute only affects the intercept part of the model, and the slope of the individual attribute is the same.

The individual level of the multilevel model is shown in *Equation 1*, and the neighbourhood level is shown in *Equations 2 and 3*.

$$Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + r_{ij} \tag{1}$$

$$\beta_{0j} = \gamma_{00} + \gamma_{01} Z_{1j} + \mu_{0j} \tag{2}$$

$$\beta_{1j} = \gamma_{10} \tag{3}$$

where Y is the dependent variable, X is the independent variable, β is the slope, γ is the mean, r is the residual, the subscript i represents the first layer of individuals, and the subscript j represents the second level of neighbourhood.

Bringing the neighbourhood level model into the individual-level model results in the final generalized multilevel linear model (*Equation 4*):

$$\log(C_{ij}) = \ln \frac{C_{ij}}{1 - C_{ij}} = \gamma_{00} + \gamma_{pj} Z_{pj} + \gamma_{qj} X_{qj} + \mu_{0j} + \gamma_{ij} \tag{4}$$

where C_{ij} is the probability of respondent i in neighbourhood j commuting to work using active commuting/public transport; γ_{pj} and γ_{qj} are the coefficients at the neighbourhood and individual levels; Z_{pj} and X_{qj} are the independent variables at the neighbourhood and individual levels; μ_{0j} and γ_{ij} are the random effect at the neighbourhood and individual levels.

Table 3 – Multi-level modelling on residents' daily commuting modes

	Model 1: Active commuting		Model 2: Commuting by public transport	
	Coefficient	S.E.	Coefficient	S.E.
Neighbourhood-level variables				
Good security	-0.256	0.225	-0.456	0.286
Neighbourhood-owned entertainment venues	-0.203	0.150	-0.169	0.228
Neighbourhood-owned fitness facilities	-0.175*	0.106	0.200	0.166
Cleanliness	-0.050*	0.028	0.020	0.041
Environmental pollution in the neighbourhood	0.169	0.119	-0.137	0.180
The degree of pollution improvement (after negotiating with the government or relevant enterprises)	0.001	0.211	0.112	0.286
Green coverage rate (ref:<30%)				
30~0%	-0.053	0.119	0.122	0.165
>60%	0.250**	0.114	-0.052	0.166
Good neighbourhood relations	-0.246*	0.129	0.163	0.193
The location of the neighbourhood (ref: countryside)				
Urban area	-0.153	0.127	1.422***	0.175
Town	0.334**	0.168	0.002	0.264
Suburb area	-0.155	0.163	0.743***	0.219
Work-level variables				
Workplace (ref: the country)				
City	0.294***	0.070	1.790***	0.092
Feel stressed at work	0.926***	0.051	0.530***	0.105
Degree of freedom of work intensity (intensity of work is determined by oneself)	0.955***	0.034	-0.403***	0.064
Usually work overtime	0.433***	0.078	0.287***	0.110
Frequency of heavy physical labour	-0.029	0.034	0.160***	0.055
Frequency of quick-reaction thinking or mental work	0.047	0.036	0.147***	0.053
Satisfied with the working environment	0.591***	0.049	0.237**	0.104
Satisfied with the respect given by others	0.123**	0.050	0.227**	0.104
Monthly working hours (days)	0.066***	0.024	-0.068	0.079
Control variables				
Gender (ref: female)				
Male	0.012	0.042	-0.303***	0.088
Age	0.020***	0.002	-0.014***	0.004
Marital status (ref: single, divorced or widowed)				
Married	0.214***	0.066	-0.180	0.116
Education attainments (ref: primary school and below)				
Junior high school	-0.131**	0.051	0.111	0.152
Senior high school	-0.300	0.068	0.538***	0.161
College and above	-0.131	0.091	1.007***	0.172
2017 annual personal income (yuan)	-0.522***	0.047	-0.004	0.037
BMI value (ref: <18.5)				
BMI 18.5~23.9	-0.005	0.066	0.201	0.131
BMI>23.9	-0.093	0.070	0.017	0.145
Feel life happiness (%)	-0.120***	0.044	-0.198**	0.094

*Notes: Model 1: 0 = passive commuting, 1 = active commuting; Model 2: 0 = commuting by private transport, 1 = commuting by public transport. Standard errors in parentheses: *p<.10. **p<.05. ***p<.01. S.E. – standard error.*

4. RESULTS

4.1 Green commuting mode regression

In this article, we focus on the overall impact of environmental variables at the neighbourhood and work levels on commuting. The results of the multi-level modelling on residents' commuting modes are reported (*Table 3*). For Model 1 (passive commuting mode = 0, active commuting mode = 1), among the neighbourhood-level variables, neighbourhood-owned facilities (coef.=-0.175, p<0.1) and cleanliness (coef.=-0.050, p<0.1) are both negatively related to the choice of active commuting. Green coverage rate > 60% was a significant positive correlation (coef.=0.250, p<0.05) for respondents to choose active commuting, and good neighbourhood relations (coef.=-0.246, p<0.1) was a negative correlation for that. Neighbourhoods located in towns are more likely to choose active commuting (coef.=0.334, p<0.05). For the work-level variables, respondents with locations in cities were more likely to choose active commuting (coef.=0.294, p<0.01) than those with locations in the country. Respondents with work stress (coef.=0.926, p<0.01), greater freedom of work intensity (coef.=0.955, p<0.01) and overtime (coef.=0.433, p<0.01) were more likely to choose active commuting. In terms of mental health at work, respondents who were satisfied with their working environment (coef.=0.591, p<0.01) and respect from others (coef.=0.123, p<0.05) were more likely to choose active commuting. In addition, the number of working days per month (coef.=0.066, p<0.01) is positively correlated with the choice of active commuting.

The results of Model 2 (commuting by private transport = 0, public transport = 1) are shown in the columns (4) to (5) (*Table 3*). Among the neighbourhood-level variables, only those of neighbourhood in urban and suburban areas have a significant positive correlation with commuting by public transport, meaning that respondents were more likely to use public transport in urban areas (coef.=1.422, p<0.01) and suburban areas (coef.=0.743, p<0.01) than in the country. Among the work level variables, work in the city (coef.=1.790, p<0.01), high work pressure (coef.=0.530, p<0.01), normal overtime (coef.=0.287, p<0.01), heavy physical labour (coef.=0.160, p<0.01), rapid thinking or mental work (coef.=0.147, p<0.01), satisfaction with the working environment (coef.=0.237, p<0.05), and satisfaction with respect to others (coef.=0.227, p<0.05) all have a positive correlation effect on the choice of public transport commuting. The degree of freedom of working intensity (coef.=-0.403, p<0.01) has a significant negative correlation with the choice of public transport commuting.

4.2 Green commuting modes of different healthy groups

For an in-depth study on the impact of the neighbourhood and working environment on different health groups, we divided the respondents into healthy and sub-healthy groups. The following *Table 4* presents the results of the multilevel modelling of commuting modes for the healthy group (BMI 18.5 to 23.9, respondents who are happy with their lives). Model 3 (passive commuting = 0, active commuting = 1) indicated that the availability of fitness facilities in the neighbourhood made healthy residents less likely to choose active commuting (coef.=-0.297, p<0.05), while the presence of environmental pollution and green coverage rate > 60% promoted residents choosing active commuting (coef.=0.259, p<0.10, coef.=0.293, p<0.05). At the same time, active commuting is more likely to be selected where lived in the towns than in the countryside for the healthy group (coef.=0.458, p<0.05). Healthy group residents working in the city were more likely to choose active commuting (coef.=0.231, p<0.05) than in the country. For the variables of stress at work (coef.=0.841, p<0.01), flexible working intensity (coef.=0.906, p<0.01), working overtime (coef.=0.342, p<0.01), quick thinking or mental work (coef.=0.168, p<0.01) and satisfaction with the working environment (coef.=0.614, p<0.01), the healthy group was more likely to choose active commuting. In addition, monthly working days (coef.=0.097, p<0.01) are positively correlated with active commuting. Heavy physical labour is negatively associated with the choice of motor vehicle for the healthy group (coef.=-0.106, p<0.10).

The results of Model 4 (commuting by private transport = 0, public transport = 1) show that in the cases of good security in the neighbourhood (coef.=-0.647, p<0.10) and a higher degree of pollution improvement (coef.=-0.475, p<0.10), the healthy group was less likely to opt for public transport. Compared to the country communities, urban and suburban residents prefer public transport commuting (coef.=1.294, p<0.01, coef.=0.558, p<0.10). In addition, respondents who worked in cities were more likely to choose public transport than those who worked in the country (coef.=1.824, p<0.01). Perceived stress at work (coef.=0.817, p<0.01), frequent overtime (coef.=0.381, p<0.05), heavy physical labour (coef.=0.170, p<0.10), satisfaction with the work environment (coef.=0.408, p<0.05) and respect given by others (coef.=0.298, p<0.10) were sta-

Table 4 – Multi-level modelling on residents' daily commuting modes for the healthy group

	Model 3: Active commuting		Model 4: Commuting by public transport	
	Coefficient	S.E.	Coefficient	S.E.
Neighbourhood-level variables				
Good security	0.074	0.274	-0.647*	0.382
Neighbourhood-owned entertainment venues	-0.191	0.175	-0.082	0.320
Neighbourhood-owned fitness facilities	-0.297**	0.124	0.141	0.239
Cleanliness	-0.019	0.033	-0.019	0.057
Environmental pollution in the neighbourhood	0.259*	0.140	-0.475*	0.266
The degree of pollution improvement (after negotiating with the government or relevant enterprises)	-0.032	0.244	0.115	0.419
Green coverage rate (ref: <30%)				
30~60%	-0.052	0.139	-0.042	0.229
>60%	0.293**	0.132	-0.111	0.230
Good neighbourhood relations	-0.104	0.153	0.249	0.278
The location of the neighbourhood (ref: countryside)				
Urban area	-0.159	0.155	1.294***	0.253
Town	0.458**	0.191	-0.167	0.378
Suburban area	-0.319	0.194	0.558*	0.315
Work-level variables				
Workplace (ref: the country)				
City	0.231**	0.115	1.824***	0.150
Feel stressed at work	0.841***	0.091	0.817***	0.181
Degree of freedom of work intensity (intensity of work is determined by oneself)	0.906***	0.058	-0.247**	0.109
Usually work overtime	0.342***	0.131	0.381**	0.182
Frequency of heavy physical labour	-0.106*	0.058	0.170*	0.092
Frequency of quick-reaction thinking or mental work	0.168***	0.060	0.123	0.088
Satisfied with the working environment	0.614***	0.085	0.408**	0.180
Satisfied with the respect given by others	0.092	0.086	0.298*	0.179
Monthly working hours (days)	0.072*	0.043	-0.126	0.161
Control variables				
Gender (ref: female)				
Male	0.016	0.072	-0.404***	0.146
Age	0.021***	0.003	-0.019***	0.007
Marital status (ref: single, divorced or widowed)				
Married	0.321***	0.112	-0.166	0.194
Education attainments (ref: primary school and below)				
Junior high school	-0.049	0.087	-0.013	0.262
Senior high school	-0.291**	0.115	0.636**	0.270
College and above	0.014	0.143	1.067***	0.283
2017 annual personal income (yuan)	-0.642***	0.081	-0.033	0.092

*Notes: Model 3: 0 = passive commuting, 1 =active commuting; Model 4: 0 = commuting by private transport, 1 = commuting by public transport. Standard errors in parentheses: *p<.10. **p<.05. ***p<.01. S.E. – standard error.*

Table 5 – Multi-level modelling on residents' daily commuting modes for sub-healthy group

	Model 5: Active commuting		Model 6: Commuting by public transport	
	Coefficient	S.E.	Coefficient	S.E.
Neighbourhood-level variables				
Good security	-0.378	0.236	-0.303	0.316
Neighbourhood-owned entertainment venues	-0.226	0.158	-0.258	0.264
Neighbourhood-owned fitness facilities	-0.113	0.111	0.282	0.190
Cleanliness	-0.064**	0.030	0.028	0.046
Environmental pollution in the neighbourhood	0.114	0.125	0.009	0.199
The degree of pollution improvement (after negotiating with the government or relevant enterprises)	-0.023	0.221	0.186	0.314
Green coverage rate (ref: <30%)				
30~60%	-0.028	0.126	0.230	0.184
>60%	0.224*	0.120	-0.018	0.188
Good neighbourhood relations (%)	-0.310**	0.135	0.086	0.213
The location of the neighbourhood (ref: countryside)				
Urban area	-0.126	0.137	1.498***	0.198
Town	0.267	0.177	0.157	0.304
Suburban area	-0.089	0.171	0.824***	0.243
Work-level variables				
Workplace (ref: the country)				
City	0.312***	0.087	1.819***	0.117
Feel stressed at work	0.969***	0.061	0.428***	0.129
Degree of freedom of work intensity (intensity of work is determined by oneself)	0.986***	0.041	-0.496***	0.080
Usually work overtime	0.475***	0.098	0.224	0.138
Frequency of heavy physical labour	0.011	0.042	0.160**	0.068
Frequency of quick-reaction thinking or mental work	-0.018	0.045	0.155**	0.066
Satisfied with the working environment	0.560***	0.059	0.096	0.128
Satisfied with the respect given by others	0.119**	0.060	0.115	0.129
Monthly working hours (days)	0.066**	0.028	-0.046	0.091
Control variables				
Gender (ref: female)				
Male	0.027	0.051	-0.290***	0.109
Age	0.019***	0.002	-0.010*	0.005
Marital status (ref: single, divorced or widowed)				
Married	0.130	0.081	-0.213	0.145
Education attainments (ref: primary school and below)				
Junior high school	-0.202***	0.062	0.185	0.187
Senior high school	-0.352***	0.084	0.521***	0.199
College and above	-0.270**	0.118	1.032***	0.216
2017 annual personal income (yuan)	-0.478***	0.057	-0.006	0.042

*Notes: Model 5: 0 = passive commuting, 1 = active commuting; Model 6: 0 = commuting by private transport, 1 = commuting by public transport. Standard errors in parentheses: *p<.10. **p<.05. ***p<.01. S.E. – standard error.*

Table 6 – Robustness results of multi-level modelling on residents' daily commuting modes

	Model 1': Active commuting		Model 2': Commuting by public transport	
	Coefficient	P value	Coefficient	P value
Neighbourhood-level variables				
Good security	-0.041	0.305	-0.035	0.040
Neighbourhood-owned entertainment venues	-0.037	0.161	-0.006	0.616
Neighbourhood-owned fitness facilities	-0.032	0.097	-0.001	0.938
Cleanliness	-0.008	0.111	0.002	0.374
Environmental pollution in the neighbourhood	0.030	0.170	-0.010	0.288
The degree of pollution improvement (after negotiating with the government or relevant enterprises)	0.000	0.998	0.006	0.699
Green coverage rate (ref: <30%)				
30~60%	-0.007	0.732	0.005	0.595
>60%	0.047	0.020	-0.002	0.846
Good neighbourhood relations	-0.045	0.060	0.005	0.600
The location of the neighbourhood (ref: countryside)				
Urban area	-0.047	0.056	0.082	0.000
Town	0.052	0.098	-0.011	0.402
Suburban area	-0.040	0.172	0.018	0.138
Neighbourhood-owned gymnasium	0.001	0.978	-0.001	0.936
Work-level variables				
Workplace (ref: the country)				
City	0.045	0.000	0.174	0.000
Feel stressed at work	0.176	0.000	0.024	0.000
Degree of freedom of work intensity (intensity Of work is determined by oneself)	0.183	0.000	-0.012	0.000
Usually work overtime	0.074	0.000	0.024	0.000
Frequency of heavy physical labour	-0.001	0.802	0.001	0.632
Frequency of quick-reaction thinking or mental work	0.004	0.506	0.019	0.000
Satisfied with the working environment	0.108	0.000	0.010	0.014
Satisfied with the respect given by others	0.019	0.025	0.007	0.079
Monthly working hours (days)	0.011	0.008	-0.002	0.299
Control variables				
Gender (ref: female)				
Male	0.003	0.694	-0.015	0.000
Age	0.004	0.000	0.000	0.210
Marital status (ref: single, divorced or widowed)				
Married	0.021	0.046	-0.012	0.017
Education attainments (ref: primary school and below)				
Junior high school	-0.028	0.002	-0.009	0.026
Senior high school	-0.055	0.000	0.003	0.569
College and above	-0.035	0.002	0.069	0.000
2017 annual personal income (yuan)	-0.045	0.000	0.000	0.865
BMI value (ref: <18.5)				
BMI 18.5~23.9	0.000	0.964	0.003	0.577
BMI>23.9	-0.017	0.138	-0.005	0.380
Feel Life happiness (%)	-0.020	0.006	-0.008	0.022

tistically significant and positively correlated with healthy respondents' choice of public transport. However, the greater the degree of freedom of work intensity, the more likely the healthy population is to choose private transport (coef.=-0.247, $p<0.05$).

Table 5 shows the multi-level modelling results of green commuting for the sub-health group (BMI<18.5 or BMI>23.9, or respondents who feel unhappy in life). In Model 5 (passive commuting = 0, active commuting = 1), high cleanliness in the neighbourhood (coef.=-0.064, $p<0.05$) and good neighbourhood relations (coef.=-0.310, $p<0.05$) make sub-healthy residents less likely to choose active commuting. Green coverage rate in the neighbourhood > 60% makes them more likely to choose active commuting (coef.=0.224, $p<0.10$). Workplace in the city, compared with the country for the sub-healthy group, makes residents more likely to choose active commuting (coef.=0.312, $p<0.01$). For the variables of stress at work (coef.=0.969, $p<0.01$), high degree of freedom of work intensity (coef.=0.986, $p<0.01$), frequent overtime (coef.=0.475, $p<0.01$), satisfied with working environment (coef.=0.560, $p<0.01$) and satisfied with respect given by others (coef.=0.119, $p<0.01$), the sub-healthy group is more likely to choose active commuting. In addition, there is a positive correlation between monthly working days and active commuting (coef.=0.066, $p<0.05$).

Model 6 (commuting by private transport = 0, public transport = 1) shows that residents in urban and suburban neighbourhoods are more inclined to choose public transport than those located in the countryside (coef.=1.498, $p<0.01$, coef.=0.824, $p<0.01$). Respondents working in cities are more likely to choose public transport to travel than those in the country (coef.=1.819, $p<0.01$). Besides, the variables of stress at work (coef.=0.428, $p<0.01$), heavy physical labour (coef.=0.160, $p<0.05$) and frequent mental labour (coef.=0.155, $p<0.05$) are positively correlated with commuting by public transport. However, the greater the degree of freedom of work intensity, the more likely respondents are to choose private transport (coef.=-0.496, $p<0.01$).

4.3 Robustness test

In order to test the robustness of the models and avoid the randomness of the results caused by data statistics, a neighbourhood level variable (i.e. whether there is a neighbourhood-owned gymnasium in the community) was added to the baseline database. We chose Models 1 and 2 as representatives to test the robustness. The results are shown in *Table 6*. Compared with the baseline, the positive and negative coefficients of each variable are basically the same. Therefore, it is considered that the basic models, namely Model 1 and Model 2, are robust.

5. DISCUSSION

The results demonstrate that working environment variables have a greater impact on commuting choice than those related to neighbourhood, especially workplace and working environment satisfaction. In addition, we found that increasing the green coverage rate in the neighbourhood could result in an increase in active commuting.

5.1 Neighbourhood-related variables

Residents in cities (urban and suburban areas) are more likely to commute by public transport [30]. Besides, those residents tend to choose active commuting. The main reason is that the resources of public transport are mainly allocated in CBD (Central Business District) areas, where jobs are relatively concentrated and public transport is highly accessible. For the group of residents with collective land ownership (in the country), a large number of residents choose to work locally, leading to a short-distance trip and a higher active commute rate.

We found that the green coverage rate of the neighbourhood is closely related to the commuting mode. Compared with residents who live in a neighbourhood with a rate of less than 30%, residents who live in a neighbourhood with more than 60% are more likely to use active commuting. In addition, as the green coverage rate increases, the likelihood of respondents choosing active commuting first decreases and then rises. A good neighbourhood environment makes commuters more likely to choose active commuting. In addition, when the neighbourhood is located in towns and countryside, the rate is significantly higher, and the correlation coefficient of towns is more significant (coef.=0.141, $p<0.01$), so the possibility of active commuting in the country is further improved by high green coverage rate. *Figure 2* shows the proportion of commuting modes and neighbourhood green coverage rates at different neighbourhood types.

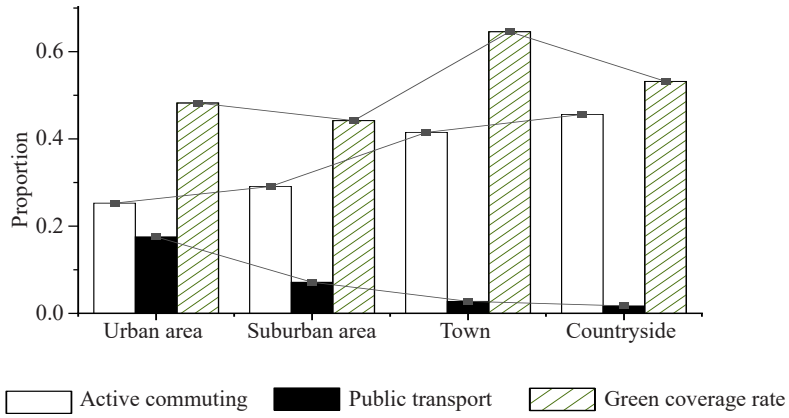

Figure 2 – The proportion of commuting modes and neighbourhood green coverage rate for different neighbourhood types

5.2 Work-related variables

The results show that commuters who work in cities are more likely to choose green commuting. By analysing the correlation between the residential neighbourhood and the workplace, we found that working in cities is significantly positively correlated with neighbourhoods in urban areas (coef.=0.234, $p<0.01$), and negatively correlated with the countryside (coef.=-0.190, $p<0.01$). Compared with the country, cities have comprehensive public transport systems. Besides, urban residents tend to work locally or commute over short distances, and therefore are more inclined to use green commuting methods, namely active commuting (33.08%) and commuting by public transport (26.96%).

The research results of this article show that when respondents are more satisfied with the working environment and respect given by others, they tend to choose green commuting. In addition, commuters with high work pressure and heavy manual labour have a higher tendency to walk or take public transport. Under normal circumstances, pressure and heavy manual labour mainly occur in low-income social groups, so commuting by public transport and active commuting with lower travel costs are their main choices. Further, workers prefer to have a good working environment and colleague relationships (*Figure 3*). So, when a company cannot change the nature of the work, improving their working environment and giving adequate respect will help improve their happiness (coef.=0.168, $p<0.01$, coef.=0.160, $p< 0.01$) while promoting green commuting.

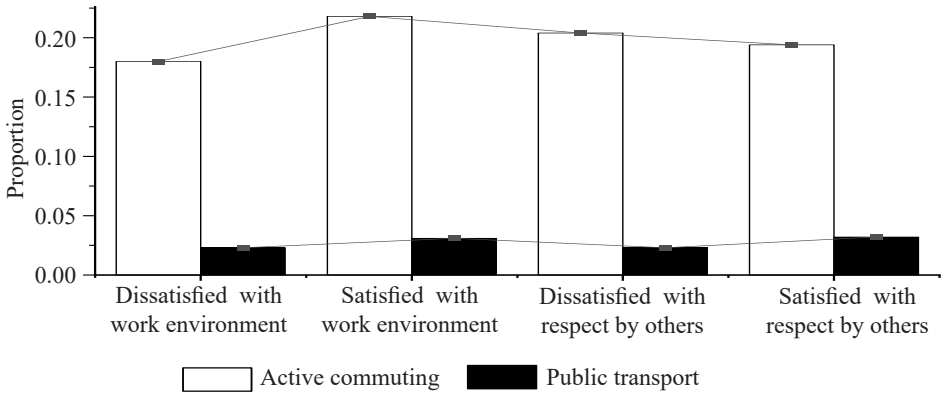

Figure 3 – The proportion of commuting modes in different job satisfaction levels

5.3 Personal level

Compared with the healthy group, the sub-healthy group respondents have a more passive attitude towards choosing active commuting. Among them, active commuting is more significantly affected by the high-level neighbourhood green coverage rate. For the work-related variables, heavy manual labour reduces the possibility of the healthy group choosing to actively commute, while unhealthy people are less likely to participate in physical labour, so it did not have a significant impact on it. Moreover, an excellent working environment and relationships encourage the sub-healthy group to choose active commuting. The sub-healthy group respondents are also more sensitive to working relationships and may be largely affected by the sense of well-being. Respondents with a low sense of well-being felt a harmonious working atmosphere at work, which would

increase their sense of well-being, leading to a greater possibility of choosing active commuting. The research results also show that older respondents are more inclined to use private transport. Given that public transport consumes more physical energy of passengers, the significance of this increases with age. Therefore, it is more reasonable for older commuters to choose private transport. This means that older population needs to be taken into account in terms of promoting greener commuting.

5.4 Policy implications

The research results have direct policy implications for local governments and enterprises to promote sustainable development. For local governments, residents in cities are significantly more likely to choose public transport than in the country, since insufficient public transport systems in the country inhibit sustainable development. Therefore, it is recommended to speed up the improvement of public transport in the country to ensure its residents are able to choose greener commuting modes. Secondly, green environment construction in cities lags significantly compared to the country. In order to improve the physical and mental health of commuters and promote green commuting, it is recommended to increase the green coverage rate of neighbourhoods to about 19%. For enterprises, employees who work in cities are more inclined to choose public transport. Through the implementation of public transport subsidies by companies located in cities, the proportion of employees who choose public transport can further increase. In addition, considering that good relations with colleagues and good working environment can improve the well-being of workers [32], it is recommended that enterprises improve their work environments and respect given to employees in order to promote commuting by public transport.

For respondents with different health levels, the factors that affect their commuting modes are different. It is recommended to improve the level of green coverage rate to benefit the physical and mental health of the sub-healthy group, which also increases the possibility of choosing public transport. Secondly, enterprises should improve the working environment and working relationships of sub-healthy groups, which could increase commuters' happiness and promote active commuting [33, 34]. In summary, it is recommended that neighbourhoods and enterprises take care of sub-healthy groups and create a more harmonious living and working environment for them to promote green commuting.

6. CONCLUSIONS

Research on the impact of residents' commuting is an inevitable part of urban traffic planning. However, most articles mainly focus on the environmental impact of commuting, ignoring the factors related to neighbourhoods and workplaces. The results of this study show that neighbourhood and working environment are significantly related to green commuting. Our results also highlight the importance of high green coverage in the neighbourhood in active commuting, which is related to the greater use of green modes of transport. For urban planners, improving the neighbourhoods and working environments is of great significance in promoting sustainable development. On the one hand, improving the public transport system in the country and increasing the green coverage rate of neighbourhoods can significantly promote green commuting. On the other hand, for enterprises, providing public transport subsidies and building a good working environment are feasible and beneficial policies. In addition, encouraging neighbourhoods and companies to take care of sub-healthy groups has also promoted sustainable development. Overall, this article comprehensively considers the impact of the neighbourhood and working environment on the commuting of different health groups, and puts forward feasible suggestions to promote sustainable development for governments and enterprises. However, there are also certain limitations. In this article, we comprehensively consider the neighbourhood and working environment and interpersonal psychology to study and innovatively combine the BMI value and the sense of happiness in life to comprehensively judge the health level of the respondents. The degree of commuters' reaction to different influencing factors based on their health levels has also been examined. However, the above conclusions have not yet been evaluated from the medical and professional aspects, which can be used to yield more refined and accurate results. Due to the nationwide scope of the questionnaire, it is impossible for individuals to conduct supplementary research. The research method is relatively traditional and the refined level of service, travel distance and multimodal transport have not been considered in the data [35, 36]. Therefore, future research should explore the interrelatedness of travel behaviour with these three factors and effectively enhance travel services through intelligent transportation [37, 38]. Despite the flaws in the research, it helps to understand the impact of our neighbourhoods and work on the commuting behaviour of different health groups.

ACKNOWLEDGMENTS

Thanks for the support by the Postgraduate Research & Practice Innovation Program of Jiangsu Province (No. KYCX21_0142).

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陈俊兰，杜涵上，郑美娜，过秀成（通讯作者）

社区和工作环境如何影响中国的绿色通勤？一个居民健康的视角

摘要：
通勤会导致高水平的温室气体和空气污染。最近倡导的“绿色通勤”模式，即主动和公共交通方式，将有利于低碳和环保交通。城市规划的一个基本目标是促进健康，而很少有研究探讨通勤两端与健康相关的环境对居民通勤模式选择的影响。为了填补这一空白，本研究建议从健康的角度考虑社区和工作环境对绿色通勤的影响。以中国368个社区的15886人为样本，估计了三个广义多水平线性回归模型。将身体健康和心理健康相结合，进一步分析健康相关的环境属性对不同健康水平居民通勤选择的影响。结果表明，与邻里环境相比，工作环境对“绿色通勤”的影响更大，尤其是对工作场所的满意度。此外，我们发现良好的工作环境和人际关系会显着鼓励亚健康群体选择主动通勤。这些发现有利于决策者考虑将重点放在协调社区和工作环境以及满足不太健康群体的通勤要求上。

关键词：
绿色通勤;通勤方式;社区环境;工作环境;居民健康;交通规划。