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The Effect of Public Traffic Accessibility on the Low-Carbon Awareness of Residents in Guangzhou: The Perspective of Travel Behavior

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Abstract: The demand for transportation among urban residents in China is increasing in tandem with the nation's population growth, rising consumption levels, and increasing car ownership rates. Breaking the existing high-carbon travel practices and reshaping positive low-carbon awareness represents an inevitable way to change existing transportation structures and reduce urban traffic congestion and carbon emissions. A mediating effect model was employed and we found that community satisfaction is an essential variable in the effect of traffic accessibility and travel behavior on low-carbon awareness. First, the impact of residents' zero and low-carbon actions on their low-carbon awareness is mediated by community satisfaction. Furthermore, compared to high-income groups, community satisfaction exerts a robust mediating influence on low-income groups. The mediating effect of community satisfaction on the relationship between residential proximity to commercial centers and low-carbon awareness among individuals with low incomes is evident. Based on these findings, this paper explores the heterogeneity and associated measures of low-carbon awareness among residents. The conclusion of this study provides suggestions to promote residents' low-carbon awareness by improving their travel experience from the perspective of community construction, providing scientific reference and a basis for the formulation of transportation policies for low-carbon city construction.

Keywords: low-carbon awareness; travel behavior; public traffic accessibility; community satisfaction; mediating effect

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1. Introduction

The population, consumption level, and car ownership level of Chinese cities are rapidly increasing, and the transportation demand and car travel proportion of urban residents are also increasing [1]. However, the rapid growth of urban transportation demand and the widespread use of cars have introduced many problems and challenges to Chinese cities, such as environmental pollution, traffic congestion, and carbon emissions [2–4]. The level of carbon emissions attributed to the transportation sector is closely related to the level of economic development. The proportion of carbon emissions in the transportation sector of developed countries to total emissions is generally high, e.g., 33% in the United States and 25% in the United Kingdom [5]. However, developing countries such as China are experiencing rapid development, and their transportation demand and carbon emissions from the transportation sector are rapidly increasing [1]. In September 2020, at the 75th United Nations General Assembly, the Chinese government announced that China would strive to achieve a national peak in carbon emissions by 2030 and achieve "carbon neutrality" by 2060 [6]. In order to avoid sprawl and car-related pollution, residents need to be guided to shift from a high-carbon car-oriented mode of travel to a low-carbon mode of

transport oriented towards public transport, walking, and cycling [7]. The United Nations decided to designate 3 June as World Bicycle Day [8], and the original intention of this decision is that promoting cycling can help residents understand the benefits of low-carbon action and increase their low-carbon awareness. Therefore, methods to enhance residents' low-carbon awareness and guide them to use low-carbon transportation have become issues of concern for policymakers. To formulate effective policies to enhance residents' low-carbon awareness and promote low-carbon travel methods, it is necessary to deeply understand the factors that affect low-carbon awareness, which will help further reduce carbon emissions in a reasonable and effective manner.

Previous research on the relationship between low-carbon awareness and behavior mainly focused on the micro scales, involving aspects such as travel demand [9], travel modes [10], urban form [11], and individual characteristics [12]. Meanwhile, theories from various disciplines [13–16] have been used to explore the relationship between awareness and behavior. Many studies have shown that residents' low-carbon awareness, to some extent, affects their travel modes [17–19]. For example, residents with strong low-carbon awareness tend to choose more electric vehicles and promote sustainable consumption [20,21]. Meanwhile, in recent years, scholars have noted that behaviors may influence residents' subjective awareness to a certain extent and that the more that residents perceive low-carbon travel to be convenient, the greater the likelihood that they will choose low-carbon travel, with a consequent increase in low-carbon awareness [9]. Although scholars have conducted a series of explorations on the impact mechanism between low-carbon awareness and travel behavior [18,22,23], there are still some limitations. First, there is insufficient discussion on the mediating effect between travel behavior and low-carbon awareness. Research has found that improving the traffic environment and community services can increase residents' community satisfaction and further affect residents' travel methods and low-carbon awareness [9,24]. Second, considering the influencing factors of low-carbon awareness is not comprehensive enough; there is a lack of extensive exploration of low-carbon awareness from both internal and external factors. In addition, the specific definition of low-carbon awareness still needs to be improved. In an endeavor to fill these gaps, on the one hand, this study provides a concrete definition of low-carbon awareness from the perspective of values, attitudes and knowledge. On the other hand, in order to comprehensively explore the impact mechanism between low-carbon awareness and travel behavior, this paper considers the impact of public traffic accessibility and explores the potential mediating effect of community satisfaction. In addition, this paper provides a scientific and reasonable reference for adjusting low-carbon policies, low-carbon-oriented community construction, and optimizing traffic management measures in Guangzhou. The findings in this paper have significant theoretical and practical significance for promoting low-carbon awareness among urban residents and constructing a low-carbon environment.

The rest of this paper is organized as follows: Section 2 provides a review of the existing literature pertaining to low-carbon behavior, low-carbon awareness, and influencing factors. Section 3 highlights the data resources and modeling methods used in this paper. Section 4 presents a mediating effect model of the effect of public traffic accessibility and travel behavior on low-carbon awareness. Section 5 presents the discussion and conclusion derived from the findings and policy proposals for the future.

2. Literature Review

2.1. Low-Carbon Awareness and Low-Carbon Behavior

Low-carbon awareness is an abstract concept lacking a specific definition, but some scholars try to describe environmental awareness as a multidimensional structure [25,26]. It is generally believed that there are three prerequisites for low-carbon awareness, namely values, attitudes, and knowledge. Values mainly represent environmental values, that is, a person's ecological worldview [27], which can be divided into biospheric, anthropocentric, and self-worth [28,29]. Low-carbon attitudes are mainly aimed at low-carbon issues and issue-related things. According to previous studies, people with good low-carbon attitudes

are more inclined to participate in environmental protection activities [30,31]. Low-carbon knowledge is considered to be an important basis for low-carbon awareness, and a large number of studies have explored the important role of low-carbon knowledge in the formation of low-carbon awareness [32–34]. Based on previous research, this study defines low-carbon awareness as a state of the combined action of values, attitudes, and knowledge that tends to reduce energy consumption and carbon emissions, ultimately promoting environmental sustainability.

Low-carbon behaviors include private low-carbon behaviors and public low-carbon behaviors. Private low-carbon behaviors mainly include low-carbon consumption behaviors and the use and processing of products and services that have a positive impact on the environment [14]. Public low-carbon behaviors mainly affect the environment indirectly through public policies or the low-carbon behaviors of others, such as supporting environmental policies and encouraging others to participate in environmental protection activities [21]. Based on the definition and classification of low-carbon behaviors in the literature, low-carbon behaviors in this study specifically refer to low-carbon travel behaviors, that is, actively adopting transportation modes that can reduce CO_2 emissions during travel, such as taking buses, subways, cycling, and walking. A study has shown that urban residents can usually take three measures to achieve the purpose of low-carbon travel: changing travel modes, shortening travel distances, and reducing the number of long-distance travel events [35]. The low-carbon travel behavior of urban residents is an important prerequisite to realize low-carbon transportation and sustainable development in the urban sector.

Low-carbon awareness and low-carbon behaviors play an important role in promoting environmentally friendly development, but there have been debates on the correlation between the two factors [36–38]. Scholars in many fields have used the theory of planned behaviour [13], value–belief theory [14], the attitude–behavior–external conditions model [15], and the distributed cognition theory [16] to explore the relationship between traveling behaviors and low-carbon awareness. Residents' low-carbon awareness is vital in travel mode choice [20,39]. Increased environmental awareness, such as recognizing the dangers of environmental pollution, can reduce residents' choice of private car travel [37]. Most individuals think lowering carbon emissions is a far-off issue since they do not think it will immediately influence their lives [22,23]. We aim to investigate what role a community's built environment plays in influencing awareness of low-carbon behavior and to promote a positive public understanding of carbon reduction from the perspective of behavior guidance from low-carbon-oriented community construction. In addition, most studies focus on awareness determinism, with relatively little discussion on the impact of behavior on awareness. More research needs to be conducted on the effect of travel behavior on low-carbon awareness. Some scholars have noted that behavior may influence residents' subjective awareness to a certain extent, and when residents realize that low-carbon travel is more convenient, they are more likely to choose low-carbon travel, thus increasing low-carbon awareness [9]. This paper considers the influence of travel behavior on low-carbon awareness to explore further the deeper relationship between travel behavior and low-carbon awareness.

2.2. Influencing Factors of Low-Carbon Awareness

The factors affecting residents' low-carbon awareness can be categorized into internal and external factors. Internal factors include the individual's psychological state, values, low-carbon knowledge, and personal norms. Some studies believe that an individual's low-carbon awareness is shaped by their values and beliefs about the environment [38]. Varela-Candamio et al. show that improving citizens' knowledge of global warming can effectively improve citizens' low-carbon awareness [40]. External factors include the natural environment (e.g., geographical location, natural resources, and climatic conditions) [41] and the social environment (e.g., infrastructure, policy guidelines, cultural history, and interpersonal relationships) [42,43]. It is generally believed that external factors have a

stimulating effect on the low-carbon awareness of the residents [44,45]. Taking interpersonal relationships as an example, some studies have shown that people are generally beneficially influenced by the low-carbon awareness of family members, friends, and colleagues [46,47]. In addition, traffic accessibility significantly affects residents' low-carbon awareness. Urban infrastructure and spatial patterns guide residents' transportation and housing choices and influence their travel behavior patterns [48]. Zhang et al. found that the closer a residential area is to a bus stop, the more residents in the area tend to adopt public transportation and low-carbon lifestyles [49].

Theodori believes that community satisfaction refers to residents' satisfaction with community functions and the quality of commercial, childcare, medical, and other public services around their homes [50]. It has been shown that community satisfaction affects residents' travel behavior and low-carbon awareness to a certain extent. Improving the transport environment and public transport support can encourage urban residents to choose low-carbon traveling modes [9]. Community services and a high-quality environment can improve residents' low-carbon awareness and knowledge [24].

Significantly, in previous studies, researchers mainly conducted an in-depth analysis of the influencing factors of low-carbon awareness in the fields of psychology and social economics. However, there are few studies on the impact of the external environment such as an environment built upon low-carbon awareness. Enough attention should be paid to comprehensively measure the influencing factors of low-carbon awareness in the future to improve residents' low-carbon awareness and promote the sustainable development of cities. In addition, existing studies have yet to explore whether there is a mediating role between low-carbon awareness and travel behavior. Therefore, this study investigated whether the community satisfaction variable mediates public traffic accessibility and travel behavior in low-carbon awareness.

3. Materials and Methodology

3.1. Case Study

Guangzhou, in the south-central region of Guangdong Province, enjoys a prime urban location. It is one of the major cities in the Greater Bay Area of Guangdong, Hong Kong, and Macao. In this study, 30 sample communities located in the urban core of Guangzhou were selected. These communities are Huangpu, Haizhu, Baiyun, Liwan, Yuexiu, Tianhe, and Panyu (Figure 1). Guangzhou's urbanization rate increased from 25.71% at the end of 1984 to 86.48% in 2022 due to the city's rapid economic development [51]. In recent years, Guangzhou has controlled the growth rate of automobile ownership to gain the time and space needed to implement a transit-priority strategy. According to recent data, as of the year 2022, the population of permanent residents in Guangzhou reached a total of 10.12 million individuals. Additionally, it has been projected that the number of cars in Guangzhou will amount to 3,309,000 units [52]. Since 2012, the operational distance of the Guangzhou Metro has witnessed a notable surge, escalating from 236 to 611 km, thereby surpassing the objective of doubling the mileage [52]. The central city of Guangzhou possesses a more concentrated transport road network. It assumes a more significant number of transport functions, rendering the study of the central city more representative compared to the peripheral areas. This study explores the specific influence mechanisms of public traffic accessibility, travel behavior, low-carbon awareness, and community satisfaction on carbon emissions from transportation. As such, it can be a valuable resource for government departments in formulating carbon reduction strategies.

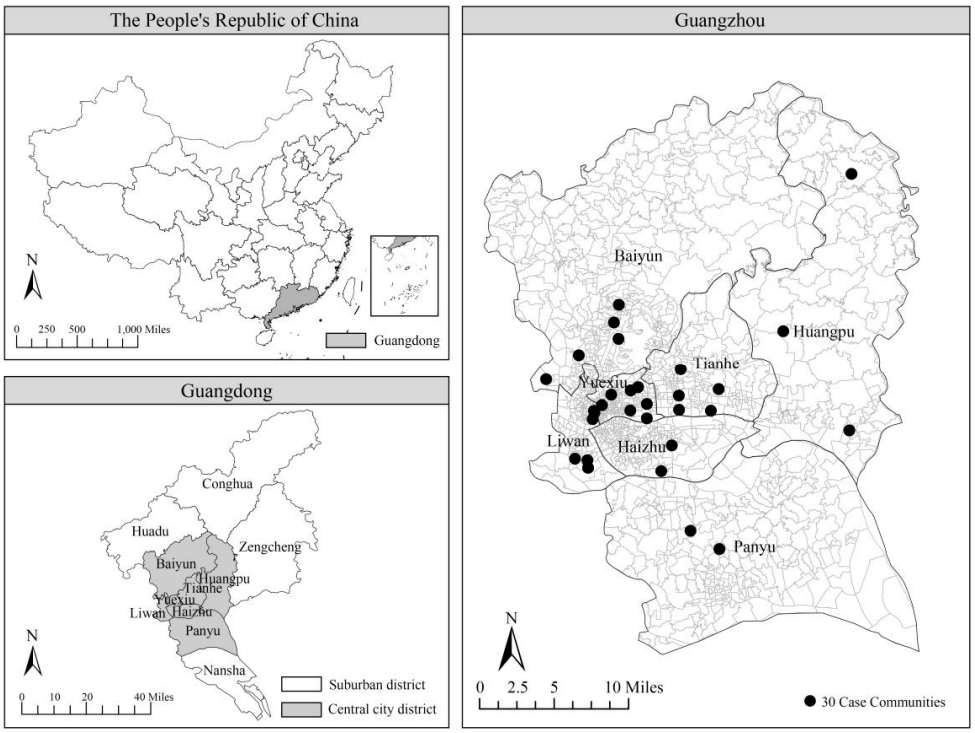

Figure 1. The locations of Guangzhou and their studied communities in the central city district.

3.2. Data Sources

The primary data source in this study was derived from the "Guangzhou Residents' Green and Low-Carbon Travel Survey", a questionnaire-based research initiative conducted between July and September 2022 across 30 communities in Guangzhou. A stratified probability-proportional scale sampling (PPS) technique was employed to ensure the representativeness and typicality of the research. This method involved randomly selecting 30 sample communities that possess the characteristics of the central urban area of Guangzhou. These districts encompass the six major types of residential areas found in China. A random selection of 30–70 households was made from each chosen neighborhood using equidistant sampling based on the door number information gathered during the pre-survey—the survey instrument comprised two distinct sections. The initial section of the questionnaire gathered fundamental data regarding the sociodemographic attributes of the participants, encompassing details such as age, education, gender, and income. Furthermore, the questionnaire encompassed an examination of the travel behavior of the residents, their level of satisfaction with the community, and their awareness of low-carbon practices. This included an assessment of the frequency of residents' travel modes, their attitudes toward low-carbon policies, and their satisfaction with the community. Ultimately, 1496 valid questionnaires were collected as a part of this survey.

Table 1 presents the descriptive statistical data derived from the collected samples. The distribution of the respondents' gender is relatively equitable, with males and females accounting for 47.6% and 52.4% of the sample, respectively. The mean age of the participants is 33.69 years. The data show that 82.6% of respondents are non-Communist Party members. There are notable disparities in marital status, employment, and lower educational attainment between individuals belonging to high-income and low-income categories. The high-income demographic consists primarily of married individuals, most of whom are employed in office-based occupations and possess advanced educational credentials.

Table 1. Sociodemographic characteristics of the sample.

Variables	Total	Low Income	High Income
Age (years)			
Mean value	33.69	34.14	33.41
Gender (%)			
Female	52.4	62.6	41.1
Male	47.6	37.4	58.9
Marital status (%)			
Single	43.4	30.94	37.90
Married	55.7	27.30	60.49
Divorced	0.9	0.75	0.64
Political affiliation (%)			
Communist Party member	17.4	10.1	21.8
Non-Communist Party member	82.6	89.9	78.2
Employment (%)			
Unemployed	76.2	56.0	4.4
Employed	23.8	44.0	95.6
Education (%)			
Lower education	19.05	36.30	9.10
Middle and lower education	17.31	23.96	13.60
Middle and higher education	26.60	22.87	29.12
Higher education	29.68	16.88	37.58
Hukou status (%)			
Nonlocal	31.0	41.1	24.9
Local	69.0	58.9	75.1

Note: (1) Low income means monthly income <5000 RMB and high income means monthly income ≥5000 RMB. (2) Hukou status means the Chinese household registration system.

3.3. Research Methods

3.3.1. The Research Framework

This paper investigates the effect of public traffic accessibility and travel behavior on citizens' low-carbon awareness. In addition, we propose a framework to address the relationship between public traffic accessibility, travel behavior, community satisfaction, and low-carbon awareness, as shown in Figure 2. The underlying logic is that travel behavior influences residents' low-carbon awareness and may be mediated by community satisfaction, which influences low-carbon awareness as well, i.e., community satisfaction plays a mediating effect in the relationship between travel behavior and low-carbon awareness.

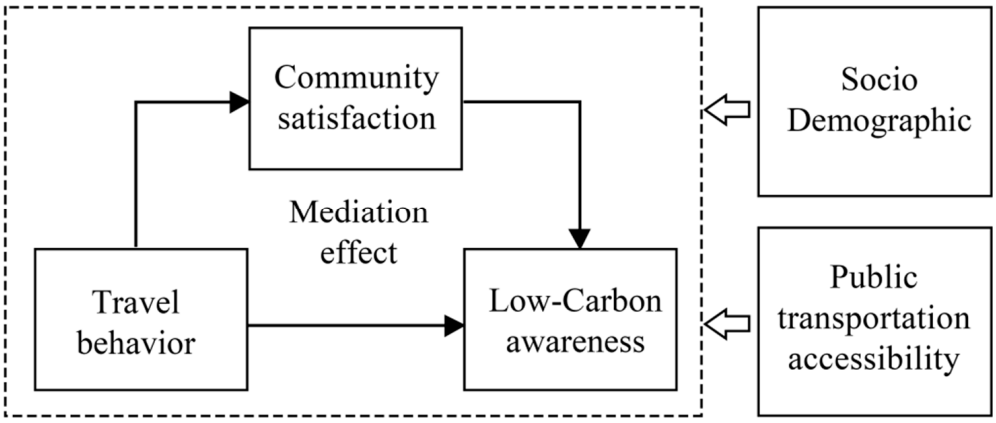

Figure 2. Conceptual framework.

3.3.2. Model Construction

Based on the proposed conceptual framework, a regression model was used to quantify the effects of individual factors, travel behavior, and public traffic accessibility on citizens' low-carbon awareness. The functional form of the linear regression model is as follows:

$$Y_{ij} = \alpha_1 + \eta X_j + \beta_1 Z_{ij} + \gamma_1 W_{ij} + \mu_{ij} + \varepsilon_{1ij}\,, \quad (1)$$

where Y_{ij} represents the low-carbon awareness of individual i in community j; X_j represents the variables for the public traffic accessibility of community j; Z_{ij} represents the variables for the sociodemographic characteristics of resident i of city j; W_{ij} represents the variable for the travel behavior of resident i of community j; η represents the total effect of the independent variables; β_1 represents the coefficient of the sociodemographic characteristics; γ_1 represents the coefficient of the travel behavior; α_1 represents the intercept; μ_{ij} represents the residual of the sociodemographic characteristics; and ε_{1ij} represents the residual of the travel behavior.

Based on the theoretical framework, we applied a stepwise approach [53] and bootstrap [54] in stata16.0 to test the mediating role of community satisfaction between travel behavior and low-carbon awareness. We first used linear probability modeling (LPM) to regress the dependent variable (low-carbon awareness) on the independent variable (travel behavior and public traffic accessibility). Next, we used LPM to regress the mediating variable (community satisfaction) on the independent variable (travel behavior). We then used LPM to regress the dependent variable onto both the independent and mediating variables. Mediation occurs when the dependent variable is influenced by both the independent variable and the mediator and when the mediator is influenced by the independent variables [55]. In addition, we used the bootstrap method to test whether other indicators have a mediating effect.

3.4. Variables and Measures

3.4.1. Travel Behavior

We defined the behavior indicators by referring to Bai's article on individual low-carbon behavior [56]. This study employs the concepts of zero-carbon action, low-carbon action, and high-carbon action to examine travel behavior (Table 2). Zero-carbon action is measured by "I walk when I go out" and "I travel by bicycle"; low-carbon action is measured by "I travel by subway" and "I travel by bus"; high-carbon action is measured by "I travel by cab" and "I travel by car." For each item, a 5-point Likert scale was used to measure the degree of frequency, where five means "frequently" and one means "never", to measure whether residents' travel behavior is characterized as low-carbon.

Table 2. Measured variables of travel behavior.

Constructed Dimensions	Variables	Specific Variables
Travel behavior	Zero-carbon action	I walk when I go out I travel by bicycle
	Low-carbon action	I travel by subway I travel by bus
	High-carbon action	I travel by cab I travel by car

3.4.2. Community Satisfaction

Community satisfaction was measured by five parameters: community services, school childcare, shopping and commercial facilities, transportation conditions, and property management. This measurement aims to assess the satisfaction level among residents regarding the community facilities that provide support. The Kaiser–Meyer–Olkin (KMO) value of the scale in this work is 0.818, and the Bartlett sphere test is significant. The Cronbach's α of community satisfaction is 0.802 (Table 3), which indicates good reliability

of the questionnaire. In this study, the responses were measured on a scale of 1 to 5, representing the following levels of agreement: strongly disagree, disagree, neutral, agree, and strongly agree, respectively. There is a positive correlation between the scale score and the level of safety reported by the respondent.

Table 3. Measured variables of community satisfaction and low-carbon awareness.

Constructed Dimensions	Cronbach's α	Cronbach's α Based on Standardized Terms	Variables
Community satisfaction	0.802	0.803	Community services
			Schools and childcare
			Shopping and commercial facilities
			Transportation conditions
			Property management
Low-carbon awareness	0.859	0.865	Low-carbon consumption is a healthy way
			Low carbon is important to our living environment
			Outraged at the waste of energy
			Low-carbon consumption is something to be proud of
			Wasting energy is shameful behavior
			Know how to reduce carbon emissions
			To protect the environment, you will use a more environmentally friendly way of traveling
			I'll focus more on low-carbon consumption if there's a carbon tax

3.4.3. Low-Carbon Awareness

Jia et al. developed a specific scale to measure low-carbon awareness [22]; this work draws on their research scale on low-carbon awareness, and the scale was strictly revised according to the program for use. The residents' level of low-carbon awareness was assessed using a set of questions that were designed to measure their understanding and beliefs regarding low-carbon consumption. The KMO value of the scale in this work is 0.874, and the Bartlett sphere test is significant. The Cronbach's α of low-carbon awareness is 0.859 (Table 3), which indicates good reliability of the questionnaire. These questions included statements such as "Low-carbon consumption is a healthy way", and "Low carbon is essential to our living environment". Additionally, the questionnaire included items that aimed to gauge respondents' attitudes toward energy waste, such as "Being indignant about wasting energy behavior", "Low-carbon consumption is something to be proud of", and "Wasting energy is a shameful behavior". Furthermore, participants were asked about their knowledge of carbon emissions reduction strategies and their willingness to adopt more environmentally friendly modes of transportation to protect the environment. For each question, the available responses ranged from 1 = "Strongly Disagree" to 5 = "Strongly Unified". Subsequently, the scores of these projects were summarized and low-carbon awareness scores were calculated.

3.4.4. Public Traffic Accessibility

We referred to the research conclusion of Zhang et al. [49] and selected the distance to the commercial center, the distance to the nearest subway station, and the nearest bus stop as indicators of public traffic accessibility. These indicators were used to measure the traffic accessibility of the community, as shown in Table 4. Distance to the commercial center refers to the distance of the community from the commercial center of the administrative district,

which reflects the community transportation location to a certain extent. The distance to the nearest subway station and the distance to the nearest bus stop can help determine whether the community has convenient transportation.

Table 4. Measured variables of public traffic accessibility.

Constructed Dimensions	Variables
Public traffic Accessibility	Distance to the business left Distance to the nearest subway station Distance to the nearest bus stop

Note: the data are from AMAP (https://www.amap.com (accessed on 7 October 2022)).

4. Results and Analysis

4.1. Descriptive Analysis of Travel Behavior and Low-Carbon Awareness

Regarding travel behavior, the mean values for zero-carbon action, low-carbon action, and high-carbon action among residents of Guangzhou are 6.810, 6.978, and 5.756, respectively. In Table 5, the total score for zero-carbon, low-carbon, and high-carbon action reached a maximum value of 10. The average total score of community satisfaction of Guangzhou residents is 18.455 (out of a maximum of 25 points); there are five items, and the average value of each item is 3.691 (in the questionnaire, 4 = "satisfied"). This result indicates that actual residents are satisfied with the community's amenities.

Table 5. Score of each variables.

	Low-Carbon Awareness	Zero-Carbon Action	Low-Carbon Action	High-Carbon Action	Community Satisfaction
Mean	33.382	6.810	6.979	5.756	18.455
Min	8.000	2.000	2.000	2.000	6.000
Max	40.000	10.000	10.000	10.000	25.000
S.E.	4.456	1.821	1.877	1.323	3.078

In contrast to others, Guangzhou residents' low-carbon awareness had a higher mean score of 33.382 for each item (out of a maximum of 40 points), there were eight items, and the mean for each item was 4.172 (in the questionnaire, 4 = "unified"). The mean of the total scores for the high-income and low-income groups are 32.520 and 33.446, respectively. The *t*-test results for the differences between high-income and low-income groups are statistically significant, as the significance (Sig.) of income is higher than 0.5 for Levene's test and less than 0.05 in the first row of the *t*-test (Table 6). The low-carbon awareness of low-income groups seems stronger. Research has found that residents prefer shorter travel times and lower transportation costs, while low-income groups prefer low-carbon travel methods [57]. The following section further delves into the impact mechanism of low-carbon awareness and explores whether travel behavior affects low-carbon awareness through community satisfaction by considering other control variables in the regression model, revealing the impact mechanism of behavior on awareness.

Table 6. Independent sample *t*-test results for low-carbon awareness.

Dependent Variable: Low-Carbon Awareness					Levene's Test		*t*-Test			
Demographic		Mean	S.E.	Mean of S.E.	F	Sig.	t	Sig. (Two Tail)	Mean	S.E.
Age	<60 years	33.402	4.463	0.118	0.266	0.606	0.811	0.417	0.465	0.574
	≥60 years	32.937	4.299	0.542			0.840	0.404	0.465	0.554
Gender ***	Female	33.736	4.354	0.156	0.000	0.995	3.231	0.001	0.743	0.230
	Male	32.993	4.537	0.170			3.225	0.001	0.743	0.230

Table 6. *Cont.*

Dependent Variable: Low-Carbon Awareness					Levene's Test		*t*-Test			
Demographic		Mean	S.E.	Mean of S.E.	F	Sig.	t	Sig. (Two Tail)	Mean	S.E.
Marital status **	Unmarried	33.658	4.369	0.168	0.031	0.861	2.177	0.030	0.503	0.231
	Married	33.155	4.516	0.158			2.184	0.029	0.503	0.230
Political affiliation **	Non-Communist Party member	33.273	4.465	0.127	1.816	0.178	−2.069	0.039	−0.628	0.303
	Members of Chinese Communist Party	33.900	4.384	0.271			−2.094	0.037	−0.628	0.300
Employment	Unemployed	33.183	4.577	0.243	0.155	0.694	−0.969	0.333	−0.262	0.271
	Employed	33.445	4.418	0.131			−0.951	0.342	−0.262	0.276
Education	Lower education	33.171	4.337	0.170	2.813	0.094	−1.616	0.106	−0.375	0.232
	Higher education	33.546	4.542	0.157			−1.625	0.104	−0.375	0.231
Hukou status	Nonlocal	33.226	4.562	0.212	1.738	0.188	−0.908	0.364	−0.226	0.249
	Local	33.453	4.408	0.137			−0.896	0.370	−0.226	0.252
Income **	Low-income	33.446	4.407	0.118	0.115	0.734	2.170	0.030	0.516	0.238
	High-income	32.520	5.028	0.498			2.166	0.030	0.516	0.238

Note: **, and *** represent significance levels of 1%, and 0.1%, respectively.

4.2. Effects of Travel Behavior and Community Satisfaction on Low-Carbon Awareness

A three-step methodology was employed to investigate the initial research inquiry [53,58]. In Model 1, without a mediation variable, the relationship between travel behavior and residents' low-carbon awareness is strong and statistically significant (Table 7). A positive correlation exists between zero-carbon action and low-carbon action and residents' low-carbon awareness. Conversely, a negative correlation exists between high-carbon action and residents' low-carbon awareness. For every point increase in low-carbon action, residents' awareness of low-carbon practices demonstrates a corresponding increase of 0.489 points.

Table 7. Regression models for low-carbon awareness for the entire sample.

	Low-Carbon Awareness	Community Satisfaction	Low-Carbon Awareness
Public traffic accessibility			
Distance to the business center	−0.200	−0.957 **	0.217
Distance to the nearest subway station	−1.123 **	−0.418	−0.937 **
Distance to the nearest bus stop	0.378	0.434	0.188
Travel behavior			
Zero-carbon action	0.489 ***	0.223 ***	0.390 ***
Low-carbon action	0.472 ***	0.158 ***	0.403 ***
High-carbon action	−0.463 ***	−0.087	−0.424 ***
Sociodemographic			
Age	−0.007	−0.004	−0.005
Gender (reference group: male)			
Female	0.865 ***	0.228	0.766 ***
Marital status (reference group: single)			
Married	–0.568 *	–0.072	–0.537 *
Divorced	–1.991 ***	0.192	–2.076 ***
Political affiliation (reference group: Communist Party member)			
Non-Communist Party member	–0.504	–0.056	–0.481

Table 7. *Cont.*

	Low-Carbon Awareness	Community Satisfaction	Low-Carbon Awareness
Employment (reference group: Unemployed)			
Employed	–0.180	0.333	–0.326
Education (reference group: lower education)			
Middle and lower education	–0.047	–0.094	–0.007
Middle and higher education	–0.320	0.078	–0.355
Higher education	0.387	–0.232	0.489 *
Hukou status (reference group: local)			
Nonlocal	0.090	0.252	–0.022
Income (reference group: low-income)			
High income	0.790 **	–0.039	0.805 **
Mediator variable			
Community satisfaction			0.442 ***
Constant	29.620 ***	16.350 ***	22.390 ***

Note: *, **, and *** represent significance levels of 5%, 1%, and 0.1%, respectively.

Similarly, an increase in low-carbon actions causes a rise of 0.472 points in residents' low-carbon awareness. Conversely, an escalation in high-carbon actions yields a decrease of 0.463 points in residents' low-carbon awareness. Hence, promoting zero-carbon behavior can effectively enhance residents' awareness of low-carbon practices, surpassing the impact of both low-carbon and high-carbon behaviors.

In Model 2, the regression analysis reveals that the independent variables of zero-carbon action and low-carbon action, which represent travel behavior, significantly reflect community satisfaction, as measured by the mediation factor. A quantitative analysis shows that an increment of 1 point in zero-carbon action is associated with a corresponding increase of 0.223 points in community satisfaction. Similarly, a 1-point increase in low-carbon action is linked to a 0.158-point increase in community satisfaction. The findings of this study indicate that individuals who engage in lower-carbon travel behaviors tend to exhibit higher levels of satisfaction with their community, evidenced by the data presented in Table 7.

Compared with Model 1, when travel behavior and community satisfaction are included in the same model (Model 3, the dependent variable is low-carbon awareness), the zero-carbon action and low-carbon action in travel behavior are still significant. However, their effects on low-carbon awareness decrease: the value of the coefficient of zero-carbon action decreases from 0.489 to 0.390, and the coefficient of low-carbon action decreases from 0.472 to 0.403. This result confirms that the intermediary indicator of community satisfaction influences the relationship between travel behavior and low-carbon awareness [59].

Using the bootstrap method to test whether other indicators have a mediating effect [54], it was found that the distance from the commercial center has a mediating effect on low-carbon awareness. Although the regression results of this indicator are not significant in Model 1, mediation validation found that the distance from the commercial center has a mediating effect on low-carbon awareness (Table 8), which is due to the suppression of community satisfaction [60]. Specifically, community satisfaction has an inhibiting effect, with each unit of increasing commercial center distance resulting in a corresponding decrease of 0.957 in the residents' community satisfaction, positively correlated with low-carbon attitudes. Although the distance from the commercial center may not directly impact low-carbon awareness on the surface, it has been found through testing that the longer this distance, the lower the community satisfaction of residents, thereby resulting in a negative impact on low-carbon awareness. This conclusion is consistent with previous research findings; residents living in areas with sufficient facilities and a high land-use mix often have low-carbon daily travel, and their low-carbon awareness level is higher [49]. Therefore, residents can often complete short commutes by walking or cycling to meet their daily needs. At the same time, zero-carbon and low-carbon transportation is more

economical than high-carbon transportation. Therefore, this convenient and economical approach can better promote their positive emotions toward low-carbon awareness. In the community, if the facilities are less than perfect, residents may find it challenging to complete their daily life more conveniently through zero-carbon and low-carbon action and even have a poor experience with zero-carbon and low-carbon travel. These factors may increase their resistance to low-carbon awareness, thus promoting their choice to travel by car to reduce their travel time cost.

Table 8. Bootstrap results for the entire sample.

Variables	Coefficient	Estimate	S.E.	Z	$p > z$
Distance to business left	Indirect effect	–0.587	0.183	–3.210	0.001
	Direct effect	–0.134	0.491	–0.272	0.785
	Total effect	–0.720	0.524	–1.375	0.169
Distance to the nearest subway station	Indirect effect	0.248	0.207	–1.530	0.126
	Direct effect	1.312	0.507	–2.589	0.010
	Total effect	1.560	0.542	–2.878	0.004
Zero-carbon action	Indirect effect	0.132	0.026	4.980	0.000
	Direct effect	0.455	0.059	7.733	0.000
	Total effect	0.586	0.061	9.537	0.000
Low-carbon action	Indirect effect	0.099	0.025	3.920	0.000
	Direct effect	0.463	0.057	8.178	0.000
	Total effect	0.561	0.060	9.407	0.000
High-carbon action	Indirect effect	–0.003	0.033	–0.100	0.924
	Direct effect	–0.220	0.081	–2.711	0.007
	Total effect	–0.223	0.087	–2.568	0.010
Gender	Indirect effect	0.101	0.078	1.290	0.198
	Direct effect	0.642	0.215	2.986	0.003
	Total effect	0.743	0.230	3.231	0.001
Married	Indirect effect	–0.114	0.084	–1.360	0.173
	Direct effect	–0.389	0.216	–1.799	0.072
	Total effect	–0.503	0.231	–2.177	0.029
Divorced	Indirect effect	0.204	0.425	0.480	0.631
	Direct effect	–1.211	1.160	–1.044	0.296
	Total effect	–1.006	1.241	–0.811	0.417
High income	Indirect effect	0.028	0.082	0.340	0.734
	Direct effect	0.488	0.222	2.198	0.028
	Total effect	0.516	0.238	2.170	0.030

This conclusion suggests that travel behavior directly affects residents' low-carbon awareness and indirectly affects residents' low-carbon awareness through the mediating effect of community satisfaction. The effect of residents' community satisfaction on low-carbon awareness displays a positive feedback effect: the higher the residents' satisfaction with the community, the stronger their low-carbon awareness. In addition, research has found through testing that the relationship between the distance between communities and business centers and low-carbon awareness is influenced by community satisfaction. The farther the distance, the lower the residents' community satisfaction, which negatively impacts low-carbon awareness.

We also found that the distance to the nearest subway station negatively impacts residents' low-carbon awareness. For every additional point of subway station distance, their low-carbon awareness point decreases by 1.123. This result may be attributed to the reduced public traffic accessibility in the community with increased distance. Residents' willingness to choose low-carbon travel modes thus decreases, which leads to a decrease in low-carbon awareness [9]. In addition, the study also found that females have higher low-carbon awareness, which is consistent with previous studies [10].

Regarding education, groups with higher education levels have higher low-carbon awareness, which may be because low-carbon publicity in schools gives residents a deeper understanding of environmental pollution, thus a higher low-carbon awareness [56,61]. Previous studies have found that residents with high levels of education are more inclined to use more energy-efficient and low-carbon electric vehicles [12]. In addition, the study also found that the higher income of the residents, the higher their low-carbon awareness. This result is understandable; environmental attitudes and situational factors can impact individual environmental behavior [15] and an increase in income may increase their environmental demand, so low-carbon awareness also increases.

4.3. Travel Behavior and Low-Carbon Awareness: The Income Division

The empirical results comparing the two subsample models using the same methodology as the entire sample are presented in Table 9. This study presents a comparative analysis examining the correlation between travel behavior and low-carbon awareness among individuals of high-income and low-income backgrounds.

Table 9. Regression subsample for income division.

	Low-Income			**High-Income**		
	Low-Carbon Awareness	**Community Satisfaction**	**Low-Carbon Awareness**	**Low-Carbon Awareness**	**Community Satisfaction**	**Low-Carbon Awareness**
Public traffic accessibility						
Distance to business center	−1.288	−1.166 *	−0.831	0.462	−0.869	0.818
Distance to the nearest subway station	−1.962 ***	−0.328	−1.847 ***	−0.397	−0.545	−0.131
Distance to the nearest bus stop	1.201 **	0.469	1.022 *	−0.348	0.331	−0.498
Travel behavior						
Zero-carbon action	0.581 ***	0.285 ***	0.463 ***	0.440 ***	0.180 ***	0.360 ***
Low-carbon action	0.575 ***	0.199 ***	0.494 ***	0.436 ***	0.146 **	0.368 ***
High-carbon action	−0.443 ***	−0.123	−0.393 ***	−0.460 ***	−0.062	−0.431 ***
Sociodemographic						
Age	−0.010	−0.001	−0.010	0.010	−0.012	0.0153
Gender (reference group: male)						
Female	0.532 *	0.213	0.454 *	1.074 ***	0.222	0.980 ***
Marital status (reference group: single)						
Married	−0.807	−0.139	−0.758	−0.590 *	0.005	-0.594 *
Divorced	−1.962 **	−0.565	−1.708 *	−2.293 ***	1.334 *	−2.909 ***
Political affiliation (reference group: Communist Party member)						
Non-Communist Party member	−0.953	−0.309	−0.841	−0.353	0.032	−0.371

Table 9. *Cont.*

	Low-Income			High-Income		
	Low-Carbon Awareness	**Community Satisfaction**	**Low-Carbon Awareness**	**Low-Carbon Awareness**	**Community Satisfaction**	**Low-Carbon Awareness**
Employment (reference group: unemployed)						
Employed	−0.521	0.196	−0.603 *	0.697	0.541	0.458
Education (reference group: lower education)						
Middle and lower education	0.165	−0.032	0.177	−0.296	−0.090	−0.272
Middle and higher education	−0.243	0.284	−0.359	−0.456	0.001	−0.467
Higher education	−0.355	−0.167	−0.280	0.502	−0.277	0.615 *
Hukou status (reference group: local)						
Nonlocal	0.355	0.406	0.180	−0.090	0.065	−0.117
Mediator variable						
Community satisfaction			0.411 ***			0.454 ***
Constant	29.270 ***	15.950 ***	22.750 ***	29.390 ***	16.630 ***	21.850 ***

Note: *, **, and *** represent significance levels of 5%, 1%, and 0.1%, respectively.

For the model without a mediation factor (community satisfaction), travel behavior strongly and significantly predicted residents' low-carbon awareness (Table 9): zero-carbon action, low-carbon action, and low-carbon awareness were positively correlated, while high-carbon action was negatively correlated. In the model with the mediation factor as the dependent variable, zero-carbon action and low-carbon action were also significantly positively correlated with community satisfaction: residents with lower carbon travel behavior had higher satisfaction with the community. When the independent variable (travel behavior) and mediation factor (community satisfaction) were included in the same model as the dependent variable, the impact of zero-carbon action and low-carbon action was significantly reduced, although it remained significant. These results indicate that the mediating effect of community satisfaction seems reasonable for both groups, consistent with the findings of the entire sample: travel behavior not only directly affects respondents' low-carbon awareness but also indirectly affects their low-carbon awareness through the mediating effect of community satisfaction.

The zero-carbon action coefficient for low-income groups decreased from 0.581 to 0.463, and the zero-carbon action coefficient for high-income groups decreased from 0.440 to 0.360 when the mediation factor was included (Table 9). This result indicates that community satisfaction has a more significant impact on low-income groups. In addition, the bootstrap method was used to test whether other indicators in the high-income and low-income group models have a mediating effect. It was found that the distance from the commercial center has a mediating effect on the low-carbon awareness of low-income groups (Table 10), which is consistent with the overall situation and is even more apparent considering that the mediating proportion reached 97%. However, this phenomenon only exists in the model of low-income groups. The zero-carbon action, low-carbon action, and distance from commercial centers of low-income groups are mediated by community satisfaction. In contrast, only the zero-carbon behavior and low-carbon behavior of high-income groups are mediated by community satisfaction (Table 11). Therefore, community satisfaction is essential to low-carbon awareness, especially among low-income groups.

Table 10. Bootstrap results for the low-income group.

Variables	Coefficient	Estimate	S.E.	z	$p > z$
Distance to business left	Indirect effect	−0.589	0.282	−2.090	0.036
	Direct effect	−0.015	0.786	−0.019	0.985
	Total effect	−0.605	0.839	−0.721	0.471
Distance to the nearest subway station	Indirect effect	−0.145	0.341	−0.430	0.671
	Direct effect	−1.991	0.763	−2.609	0.009
	Total effect	−2.136	0.818	−2.613	0.009
Distance to the nearest bus stop	Indirect effect	0.217	0.283	0.770	0.444
	Direct effect	0.595	0.772	0.771	0.441
	Total effect	0.812	0.826	0.983	0.326
Zero-carbon action	Indirect effect	0.151	0.038	3.961	0.000
	Direct effect	0.513	0.098	5.243	0.000
	Total effect	0.664	0.102	6.532	0.000
Low-carbon action	Indirect effect	0.111	0.040	2.760	0.006
	Direct effect	0.541	0.089	6.094	0.000
	Total effect	0.653	0.093	7.003	0.000
High-carbon action	Indirect effect	−0.010	0.055	−0.190	0.853
	Direct effect	−0.187	0.140	−1.341	0.180
	Total effect	−0.197	0.150	−1.32	0.187
Gender	Indirect effect	0.117	0.132	0.890	0.374
	Direct effect	0.489	0.364	1.345	0.179
	Total effect	0.606	0.389	1.557	0.119
Divorced	Indirect effect	−0.148	0.620	−0.240	0.812
	Direct effect	−0.781	1.587	−0.492	0.622
	Total effect	−0.929	1.701	−0.546	0.585

Table 11. Bootstrap results for the high-income group.

Variables	Coefficient	Estimate	S.E.	Z	$p > z$
Zero-carbon action	Indirect effect	0.121	0.030	3.980	0.000
	Direct effect	0.436	0.074	5.920	0.000
	Total effect	0.556	0.077	7.213	0.000
Low-carbon action	Indirect effect	0.089	0.031	2.890	0.004
	Direct effect	0.413	0.073	5.639	0.000
	Total effect	0.502	0.077	6.490	0.000
High-carbon action	Indirect effect	0.001	0.038	0.027	0.978
	Direct effect	−0.227	0.100	−2.278	0.023
	Total effect	−0.226	0.107	−2.120	0.034
Gender	Indirect effect	0.102	0.101	1.020	0.310
	Direct effect	0.876	0.271	3.230	0.001
	Total effect	0.978	0.290	3.377	0.001

Table 11. *Cont.*

Variables	Coefficient	Estimate	S.E.	Z	$p > z$
Married	Indirect effect	−0.118	0.106	−1.110	0.266
	Direct effect	−0.242	0.278	−0.871	0.384
	Total effect	−0.360	0.297	−1.213	0.225
Divorced	Indirect effect	0.617	0.614	1.00	0.315
	Direct effect	−1.532	1.702	−0.900	0.368
	Total effect	−0.915	1.819	−0.503	0.615

These statistical data demonstrate the existence of income segmentation in terms of mediation effectiveness. This heterogeneity may be related to the positive feedback mechanism of community satisfaction, which strongly affects residents' low-carbon awareness. Compared to high-income individuals, low-income individuals receive more positive feedback from community satisfaction, strongly influencing residents' low-carbon awareness. Previous studies have reported that because economic income is a prerequisite for residents' lives, low-income residents bear more significant economic pressure, affording lower carbon consumption and more vital low-carbon awareness of energy use [49]. In addition, urban infrastructure affects residents' living behavior patterns. Areas with sufficient infrastructure have better low-carbon awareness among residents, consistent with previous research [49,62]. Therefore, improving community facilities can make residents' travel economically convenient and encourage them to adopt more low-carbon modes of transportation.

5. Discussion and Conclusion

5.1. Discussion

This study explores which factors affect low-carbon awareness and whether there is a mediating effect of travel behavior and public traffic accessibility on residents' low-carbon awareness. However, only some studies to date have mentioned the importance of awareness and behavior in residents using different transportation modes [17–19]. To improve residents' low-carbon awareness, encourage low-carbon behavior, and provide recommendations for creating green, low-carbon communities, it is necessary to conduct more in-depth research to explore the impact mechanisms of low-carbon awareness.

Our findings contribute to a deeper understanding of the relationship between travel behavior and low-carbon awareness. First, residents' travel behavior positively impacts low-carbon awareness and is influenced by the intermediary indicator of community satisfaction. Zero-carbon action and low-carbon action correlate positively with residents' low-carbon awareness, while high-carbon action negatively correlates with residents' low-carbon awareness. This result means that the lower the carbon content of residents' travel methods, the stronger their low-carbon awareness. Some studies reported that residents' awareness of low-carbon environment is related to their travel modes [17,57], and residents who choose low-carbon travel often pay more attention to the impact of personal behavior on the environment and the public and have a more vital awareness of low carbon [21].

Second, this study found that low-income individuals received more positive feedback from community satisfaction. The distance from the commercial center also influences the low-carbon awareness of low-income groups through social satisfaction. Residents living in areas with sufficient facilities and high land-use structures often have low-carbon daily travel, and their low-carbon awareness level is high [49]. Therefore, improving community facilities can make residents' travel more economically convenient and encourage them to adopt more low-carbon transportation methods. Meanwhile, regarding public traffic accessibility, reducing the distance between commercial centers can enhance residents' low-carbon awareness through the mediating effect of community satisfaction and is mediated by social satisfaction. The distance between the community and the subway station has a

negative impact on residents' low-carbon awareness, but no mediating effect was detected. Previous studies reported that residents are more likely to choose low-carbon travel if they feel it is more convenient [9]. As the distance between the community and the subway station increases, the public traffic accessibility decreases, decreasing low-carbon awareness. The reason for this phenomenon may be that residents in areas with denser coverage of public transportation services are more likely to use more low-carbon travel modes, and low-carbon awareness in those regions is also higher [63]. The research results indicate that improving the external environment, such as transportation and community facilities, significantly enhances residents' low-carbon awareness, which is significant for constructing low-carbon cities in China's mega cities and the Guangdong Hong Kong Macao Greater Bay Area. In addition, different sociodemographic characteristics differently impact residents' low-carbon awareness. The female population has a higher low-carbon awareness, consistent with previous research [10]. Regarding education, groups with higher levels of education have higher low-carbon awareness, which may be due to receiving environmental education and promoting sustainable consumption habits, such as purchasing electric vehicles [20,64]. The higher the income group, the higher their low-carbon awareness. They have high requirements for environmental ecology, cherish their surroundings, and possess stronge environmental awareness [65].

However, this study also has some limitations and can be improved upon. On the one hand, due to the cross-sectional nature of our data, we could not analyze the factors that affect low-carbon awareness in various time periods, because travel behavior and low-carbon awareness may involve a long-term dynamic, including feelings and related behaviors that change with the evolution of low-carbon policies. On the other hand, due to data limitations, we have limitations in the classification of research subjects. Therefore, future research should further refine the research subjects and pay more attention to the differences in low-carbon awareness of different groups of people, while at the same time increasing the diversity of low-carbon awareness research data, employing more comprehensive and accurate models and methods to explore the impact mechanism of low-carbon awareness, and providing scientific reference for global low-carbon city decision making.

5.2. Conclusions

This study uses evidence from a survey of 1496 respondents in Guangzhou in 2022 to analyze the low-carbon awareness of Chinese urban residents. We explored the impact of residents' willingness to travel on their low-carbon awareness, mainly focusing on how residents' community satisfaction mediates this relationship. In addition, a comparison was made between the high-income and low-income groups in Guangzhou regarding low-carbon awareness levels and mediation mechanisms. We made the following findings through the stepwise regression of mediation modeling. First, travel behavior positively impacts residents' low-carbon awareness, and their community satisfaction mediates the impact of travel behavior on low-carbon awareness. Second, low-income individuals receive more positive feedback from community satisfaction. There is a mediating effect between the distance between low-income communities and commercial centers and low-carbon awareness, which is influenced by community satisfaction. These findings contribute to a deeper understanding of the relationship between travel behavior and low-carbon awareness. People with low-carbon travel behavior tend to have higher satisfaction with the community and more vital low-carbon awareness to maintain their community living environment. Public transportation has the advantages of convenience and economy, so low-income groups prefer low-carbon modes of transportation, so they often have more vital awareness of low carbon. In this sense, when studying low-carbon awareness, the heterogeneity of different income groups deserves more attention.

These findings provide new policy entry points for constructing low-carbon cities and transforming residents' lifestyles. Based on the above findings, we propose the following policy recommendations:

Firstly, the role of the community is of utmost importance in fostering awareness and understanding of low-carbon practices, and the intention of residents to choose low-carbon commuting modes is indirectly influenced by policy factors [66]. Thus, the primary focus of urban governments' community policies and urban governance should be on improving support services within the community, enhancing residents' satisfaction with their living environment, and promoting residents' awareness of low-carbon practices. Secondly, it is imperative for communities to actively engage in the organization of low-carbon education and publicity initiatives to enhance low-carbon awareness effectively. Residents are more likely to opt for low-carbon and public transportation when they know about the environmental impact associated with such modes of transportation [67]. Meanwhile, improving the public traffic accessibility of the community can encourage residents to travel low-carbon. We suggest that the municipal authorities add shared bicycles and electric shuttle buses at subway stations to solve the "last mile" travel problem [34]. Furthermore, community committees must prioritize ensuring equitable access to community public services and convenience facilities among diverse income groups. Promoting this equality can foster a sense of community satisfaction among residents, consequently bolstering their awareness and commitment to low-carbon practices.

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