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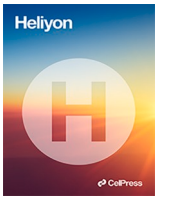

Research article

Individual low-carbon behaviors and influencing factors: Insights from a behavior survey study in China

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ABSTRACT

Climate change is a major global concern. Greenhouse gas emissions that cause global climate change are directly or indirectly affected by human activities. Individual low-carbon behaviors are crucial in reducing CO_2 emissions and improving environmental and ecological health. To effectively promote individual low-carbon behavior, this study designed a questionnaire on the factors influencing individual low-carbon intentions and behavior based on theoretical models of environmental behavior. A total of 2430 valid questionnaires were collected in China. This study focuses on analyzing the impact of demographic characteristics, internal and external factors on individual low-carbon behaviors and their interrelationships. The research shows correlations between internal and external factors in determining low-carbon intention or behaviors. Internal factors-related low-carbon behavior is not closely linked with demographic variables, whereas the external factors-related low-carbon behavior vary significantly by age, residence, education, marital status, occupation, and income. The findings have important implications for designing effective policies to promote low-carbon behaviors, such as creating a more favorable external environment and increasing the use of policy tools for reducing CO_2 emission.

1. Introduction

Climate change is a major global concern. Since the late 19th century, the average surface temperature of the earth has increased by approximately 1.18 °C, primarily due to increased greenhouse gas emissions [1]. Being the most common greenhouse gas, the carbon dioxide (CO_2) concentrations reached 417.9 ppm in 2022, which is 150 % of the pre-industrial level [2]. Global temperatures are expected to rise by more than 3 °C this century, significantly surpassing the goal of the Paris Agreement to limit global warming to well below 2 °C and pursuing 1.5 °C [3,4]. To date, 2023 was the warmest years on recorded [3,5]. Global energy-related CO_2 emissions grew by 1.1 % or 410 Mt in 2023, reaching a new high of over 37.4 Gt, indicating a rapid rebound in energy demand and emissions in many economies, underscoring the risk of a significant increase in CO_2 emissions in the future [6].

Reducing our greenhouse gas emissions is a critical step in slowing the global warming trend. The increasing levels of greenhouse gases in the atmosphere due to human activities are a major driver of climate change [7]. The current warming trend is particularly significant because more than 95 % of it is likely the result of human activities since the mid-20th century, and it is predicted to increase at an unprecedented pace in the next thousands of years [8]. China is a sensitive and significant impacted area of global climate change, with its warming rate found to be notably higher than the global average during the same period. From 1901 to 2022,

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the annual average surface temperature in China showed a significant upward trend, with a warming rate of 0.16 °C per decade [9]. Rising global temperatures have caused more frequent and severe extreme weather events worldwide, including floods, droughts, wildfires, and storms. From 1961 to 2022, the frequency of extreme heat events in China showed a significantly increasing trend [9]. Extreme weather conditions also lead to increased CO2 emissions due to higher cooling and heating demands. Slowing the trend of climate warming is the primary objective of many countries globally to achieve carbon peaking and carbon neutrality.

The behavioral changes of most people are crucial for mitigating climate change. For individuals, CO_2 emissions are mainly caused by direct or indirect energy consumption in daily life. Direct energy consumption includes household energy use and personal transportation, such as lighting, appliances, cooking, space heating, water heating, and by plane etc.; indirect energy consumption and CO_2 emissions mainly occur during the preparation stage before using various products or services, such as the consumption of an ordinary bottle of water, where CO_2 emissions are mainly generated during production and transportation [6,10–12]. Therefore, personal low-carbon-consumption behavior is not only related to the purchase of low-carbon products, but also related to people's daily energy-saving habits, such as turning off lights and controlling the temperature and usage time of air conditioners. The adoption of low-carbon-consumption behavior or habitual low-carbon-consumption behavior may be influenced by personal low-carbon-consumption intentions and various other factors [13].

In recent years, an increasing number of studies have focused on the crucial role of personal behavioral changes in reducing CO_2 emissions, as well as the factors influencing personal low-carbon behavior and policy formulation to promote personal CO_2 emission reduction [14]. What factors affect personal low-carbon behavior? Based on four classic behavioral theories and models, namely the theory of planned behavior, norm-activation model, value–belief–norm theory, and attitude–behavior–external-conditions model [14–20], combined with empirical research by other scholars, it has been found that, in addition to demographic characteristics, the factors that affect personal low-carbon behavior mainly include internal factors (or subjective factors) and external factors (or objective factors) [21]. The internal factors are mainly related to personal characteristics, abilities, and subjective willingness, such as attitude, personal norms, perceived behavior control (PBC), and habit; the external factors mainly refer to interventions that may promote or inhibit personal low-carbon behavior choices, such as social norms, economic, infrastructure, information [21].

Research on internal factors mainly focuses on the impact of different factors on the behavioral intention to adapt/mitigate climate change [22]. For example, a study on Malaysia's low-carbon society showed that subjective norms have the greatest impact on the willingness of respondents to reduce their CO_2 emissions, followed by moral obligations, attitudes, and environmental concerns; however, the effect of PBC was nonsignificant [23]. Another study found that Malaysian consumers' attitudes and PBC significantly affected consumers' intentions to purchase energy-saving appliances, and ethical norms were found to have an important predictive effect on consumers' purchasing intentions [24]. Residents with positive environmental values and more environmental knowledge are more likely to show attitudes, behaviors, and habits that lead to energy-saving activities in their household; energy-saving behaviors may also vary with gender and employment status [25]. For example, regarding the installation of solar power systems, the value one has for the environmental was found to positively influence their ecological lifestyle and intention to install solar power systems, although high installation costs were a major obstacle [26]. For other low-carbon-consumption behaviors, Han et al. [27], found that subjective norms and PBC had positive impacts on the willingness to stay at green hotels. Intentions, attitudes, and PBC were found to have different effects on males' and females' low-carbon-consumption behavior of commuting through bicycle-sharing in China [28]. Positive environmental emotions have a significant positive impact on low-carbon travel [29]. Compared with attitudes and subjective norms, moral obligations sometimes have a stronger ability to predict intentions to conserve energy and adopt behaviors that reduce CO_2 emissions to mitigate global climate change; if a person has a strong moral obligation, then he/she will want to surmount difficulties (e.g. lack of time, money, skills, and other resources) to participate in saving energy and reducing CO_2 emissions [11].

Research on external factors mainly explores which interventions are effective in promoting personal CO_2 emissions. One important external factor often mentioned in related studies is economic incentives. During household energy consumption, many behaviors are habitual; the willingness for behavioral changes was greatest with respect to saving money; however, this kind of behavioral change due to economic incentives is usually short-lived and ceases once the reward is withdrawn [30]. For families with different income levels, subsidy incentives have varying effects on energy saving and the purchase of renewable energy equipment in households; higher household incomes and better familiarity with subsidy incentives can promote the conversion to green attitudes incorporating energy-saving and the purchasing of equipment that use renewable energy [31]. In terms of green travel, the motivation of economy, convenience, and comfort can influence the travel behaviors of residents, leading to a motivation-behavior gap; meanwhile, factors such as gender, age, income, vehicle ownership, travel distance, and government measures can also affect travel behaviors [32]. External factors have a remarkable influence on personal low-carbon-consumption behavior. A questionnaire survey conducted in Beijing showed that situational factors most significantly and effectively affect residents' energy-saving behaviors, and energy-saving behavioral norms were found to determine the relationship between situational factors and behavioral intentions to a certain extent [33]. A survey conducted in Hangzhou, China, proved that background factors such as community environmental initiatives, social capital, local demographics, and architectural characteristics were correlated with pro-environmental behaviors such as garbage sorting [34]. Based on the recognition of Chinese social scenarios, some scholars showed that the types of factors influencing Chinese residents' low-carbon behaviors are mainly classified into self-factors, family and community factors, and situational factors [14,35]. The gap between low-carbon awareness and low-carbon behavior is also mainly affected by these factors, which can either serve as obstacles or motivations. In general, incentives promote public low-carbon behaviors, while obstacles significantly inhibit public low-carbon behaviors [36]. However, for different individuals, whether these influencing factors have the same effect, how different types of influencing factors interact, and other related issues should be further studied to effectively promote personal low-carbon behavior.

Many empirical studies have explored the influence of various internal factors and external factors on the execution of personal low-carbon intentions and behavior. Therefore, determining whether individuals will eventually adopt low-carbon-consumption behavior under various circumstances is very complex. Most current research mainly focuses on the impact of one or a certain type of influencing factors on specific low-carbon behavior, such as the impact of subsidy policies on the purchase of electric vehicles. However, when people face a particular choice, in addition to being restricted by demographic characteristics, internal and external factors also influence each other. While demographic factors play an important role in influencing low-carbon behavior [37], the correlations between attitude process and actual behavior, as well as the moderating effect of societal consumption culture, will affect the occurrence of individual low-carbon-consumption behavior [38]. Social environmental factors can also influence the behavioral expressions of environmentalists, especially environmental-related public behavior, which is influenced by beliefs about how society should organize these behaviors [39].

How to actively and effectively promote and implement low-carbon actions has become a key issue for achieving sustainable development [40]. Existing explanations of personal low-carbon behavior generally explore the role of a single factor, which has certain limitations in promoting the implementation of personal low-carbon behavior as a whole. Limited research has been conducted on the mechanism of the interaction of different factors on personal low-carbon behavior. Fundamentally understanding the gap

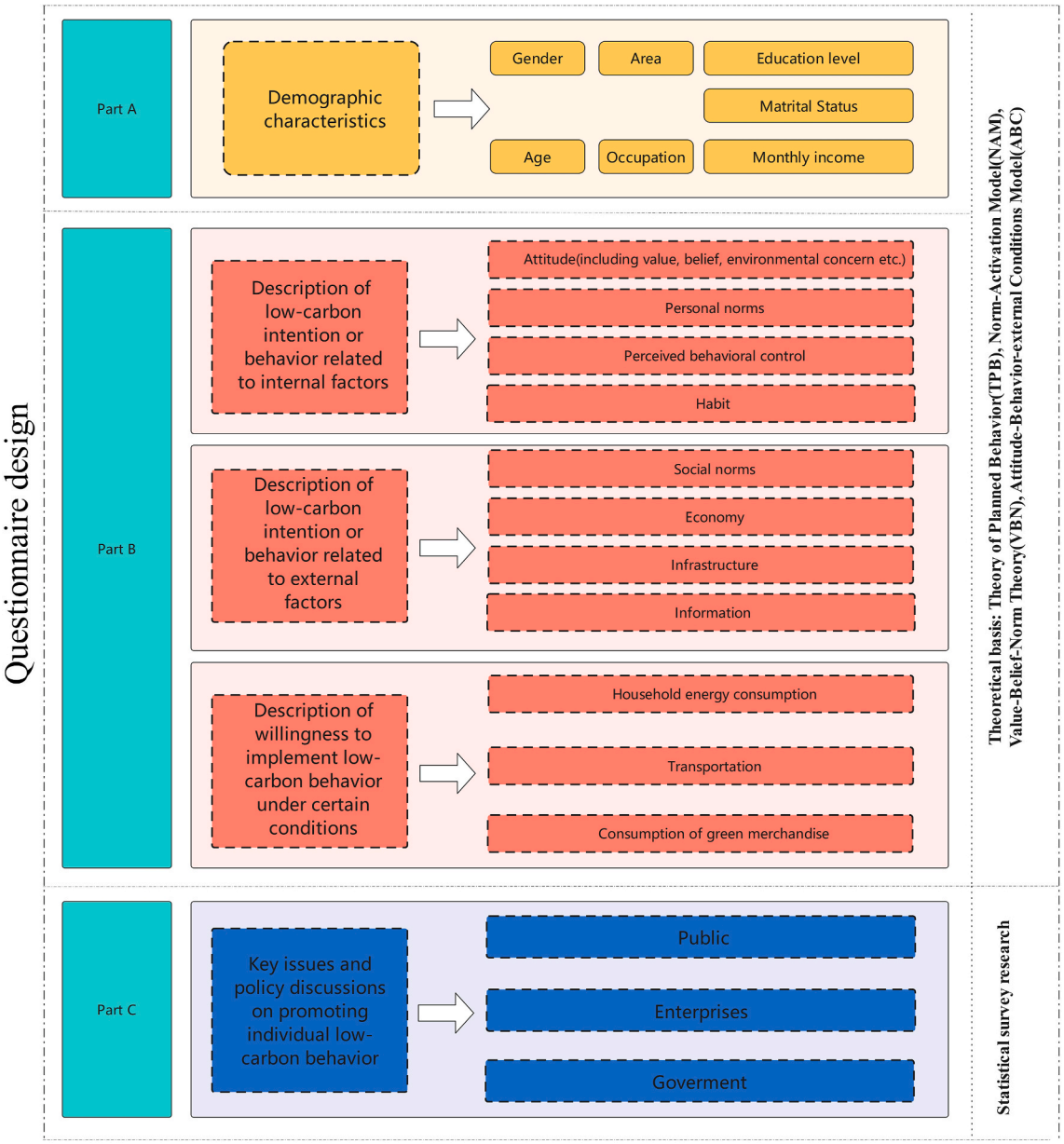

Fig. 1. Questionnaire design and main contents.

between personal low-carbon intention and low-carbon behavior, and understanding the interrelationships between internal and external factors, are of great significance for formulating effective policies to promote personal low-carbon behavior changes.

The aim of this study was to determine the degree of different influencing factors on the implementation of personal low-carbon behaviors and to explore the interrelationships between different factors. The goal was to formulate more effective countermeasures to promote the personal behavioral changes. Through empirical research, this study focused on the following four issues: 1) The role of internal and external factors in promoting low-carbon behavior in individuals; 2) The relationship between demographic characteristics, internal factors, and external factors; 3) The willingness of different groups to implement low-carbon behaviors under the intervention of clear policy conditions; 4) Identifying the main challenges associated with promoting low-carbon behavior in individuals and providing policy recommendations. The material and methods are presented in Section 2, while data analysis and discussion are presented in Section 3 and 4, respectively. Section 5 presents the conclusions and policy implications.

Compared with other studies, this research provides a more comprehensive analysis of the interrelationships between influencing factors that affect individuals' low-carbon behaviors. It also explores whether people's willingness to perform low-carbon behaviors will be stronger when influencing factors are conducive to their implementation. This study extends prior work of other researchers by exploring the correlations among different influencing factors, encompassing a wide range of low-carbon behaviors. The research aims to enhance understanding the relationship between the main factors affecting individual low-carbon behavior and the influencing mechanism of individual low-carbon behavior. By identifying the correlations between internal and external factors and low-carbon behavior, policymakers can tailor interventions to target specific demographic groups and address barriers to adopting low-carbon behaviors. Overall, understanding the complex interplay of factors that influence low-carbon behavior can help policymakers develop more effective strategies to encourage sustainable practices at the individual level, ultimately contributing to efforts to mitigate climate change and reduce greenhouse gas emissions.

2. Material and methods

2.1. Questionnaire design

To determine the influence of demographic characteristics, internal factors, and external factors on personal low-carbon behavior and their relationship, as well as the main factors that promote low-carbon behavior, this study adopted a questionnaire method. The questionnaire design mainly consisted of three parts. Part A involved collecting basic demographic information, Part B involved assessing low-carbon willingness and behavior related to internal and external factors, and Part C mainly involved conducting policy

Table 1
Summary of sample demography (N = 2430).

Background		Frequency	Percentage (%)
Gender	Male	1159	47.7
	Female	1271	52.3
Age	<20	256	10.5
	21–30	806	33.2
	31–40	762	31.3
	41–50	347	14.3
	51–60	192	7.9
	>60	67	2.8
Area	Urban area	1387	57.1
	Rural area	1043	42.9
Education	Junior high school and below	65	2.7
	High school and technical secondary school	334	13.7
	Junior college and higher vocational college	495	20.4
	Bachelor	977	40.2
	Master	381	15.7
	PhD	178	7.3
Marital status	Unmarried	892	36.7
	Married	1434	59
	Other	104	4.3
Occupation	Government department/Administrative agency	143	5.9
	Institutional organization	427	17.6
	Enterprise	900	37
	Freelancing	197	8.1
	Student	688	28.3
	Farming	17	0.7
	Other	58	2.4
Income	<2000	659	27.1
	2001–5000	504	20.7
	5001–8000	579	23.8
	8001–12,000	400	16.5
	12,001–17,000	135	5.6
	>17,000	153	6.3

research on guiding and promoting low-carbon behaviors related to daily consumption (Fig. 1). The basic demographic information collected in Part A included socio-demographic variables, namely gender, age, area, education level, marital status, monthly income, and occupation. Part B mainly contained three sections, describing low-carbon willingness or behavior related to internal factors, low-carbon willingness or behavior related to external factors, and the willingness of individuals to adopt low-carbon behavior. The responses for this part of the questionnaire were based on the Likert scale [41], with all items were measured on a 5-point Likert scale (1: strongly disagree to 5: strongly agree). Part C described the main problems associated with purchasing and habitual consumption behavioral changes in daily activities, as well as possible effective policy recommendations for promoting personal low-carbon behavior. During the process of promoting the transition to personal low-carbon behavior, in addition to the public, the government and enterprises also play influential roles. Therefore, Part C mainly addressed issues related to the three main entities: the public, government, and enterprises.

Based on the theory of planned behavior, norm-activation model, value–belief–norm theory, attitude–behavior–external-conditions model and the results of literature research, Part A and Part B quantitatively analyzed the three types of influencing factors that affect personal low-carbon behavior. It also discussed whether public willingness is enhanced when internal and external factors are conducive to the implementation of low-carbon behaviors. Part C discussed possible suggestions for promoting low-carbon behaviors from three different entities: the public, government, and enterprises, in order to formulate more effective low-carbon policies based on influencing factors.

2.2. Procedure and participants

Before the formal investigation, this study invited relevant experts in the low-carbon field to conduct a pre-survey, and the questionnaire was refined based on their feedback to create the formal questionnaire (the completed questionnaire can be accessed at the website: https://www.wjx.cn/vj/e7wq0f5.aspx). The final questionnaire validated the theoretical framework and addressed key concerns in the low-carbon field. All data were obtained from Wenjuanxing (https://www.wjx.cn), a popular professional survey website in China, through random online distribution, offline surveys, and emails, covering almost all provinces in China. Regions with over 200 questionnaire responses mainly included Beijing, Hubei, Jiangsu, and others.

Initially, the collection of questionnaires began in June 2020. However, due to the outbreak of COVID-19 and the normalization of the epidemic, it was considered that people's perception of low-carbon behavior may have changed. To ensure the authenticity and accuracy of the data, the data collection was extended until June 2023. A total of 2430 valid data samples were obtained in this questionnaire survey, representing 97.9 % of all respondents. Detailed demographic information is presented in Table 1. The sample data is relatively balanced and broadly represents the main groups of energy consumption and carbon emissions in China.

3. Data analysis and results

3.1. Common method bias

In order to minimize common methodology bias (CMB) in this survey, data collection for this study was conducted across various regions of China over an extended period. Additionally, the Harman single-factor test was performed using SPSS Statistics 26 [42,43]. The percentage of variance explained by the first factor was 31.209 %, which is lower than the threshold of 50 %. This suggests that there is no serious CMB in this study.

3.2. Reliability and validity test

Part A mainly consisted of demographic information, while Part B involved a questionnaire survey based on the Likert scale. To ensure the validity of the questionnaire, we used SPSS Statistics 26 to analyze the reliability and validity of Part B. The analysis results are presented in Table 2.

The reliability of the scale passed Cronbach's α test value, confirming the good internal correlation of each item. The Cronbach's α value of 0.819 is higher than 0.7, indicating good internal reliability. According to the Kaiser-Meyer-Olkin (KMO) and Bartlett's test results, the KMO value of 0.960, close to 1, suggests that the data were suitable for factor analysis. Additionally, the Sig value in Bartlett's Test of Sphericity was 0.000, which is less than the significance level of 0.05, indicating that there are correlations between the variables, and factor analysis was possible. Part C was a non-scale survey, mainly focused on potential challenges and effective policy suggestions for the transition to low-carbon behavior. The questions covered household energy consumption, transportation, green consumption, and other behaviors related to people's daily life. The content of the questionnaire is valid and can serve as a useful

Table 2
Reliability and validity test of Part B.

Reliability Statistics			KMO and Bartlett's Test		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items	Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.960
0.819	0.848	26	Bartlett's Test of Sphericity	Approx. Chi-Square	29,272.283
				df	325
				Sig.	0.000

reference for promoting the transition to personal low-carbon behavior.

3.3. Difference analysis

First, we established three new variables to describe the low-carbon behavior (LCB) of individuals, based on the three main sections (as shown in Fig. 1) of Part B of the questionnaire. The new variables were LCB1 (description of low-carbon intentions or behavior related to internal factors, mainly refer to attitude, personal norms, perceived behavior control (PBC), habit, etc., Q9–Q16), LCB2 (description of low-carbon intentions or behavior related to external factors, mainly refer to social norms, economic, infrastructure, information, etc., Q17–Q23), LCB3 (description of the willingness to implement low-carbon behavior under certain conditions, mainly refer to the situation where internal or external conditions are conducive to the implementation of low-carbon behaviors, Q24–Q34). The statistics of the mean and standard deviation of the three new variables are presented in Table 3. Furthermore, we used SPSS Statistics 26 to analyze differences among the LCB1, LCB2, and LCB3 based on the demographic variables using the independent-samples *t*-test and one-way analysis of variance (ANOVA).

The results of the differences among LCB1, LCB2, and LCB3 with respect to gender and area are presented in Table 4, obtained through independent-samples t-tests. LCB2 showed significant differences based on the living area ($P < 0.001$). The mean of LCB2 in urban areas was higher than that in the rural areas, indicating a stronger willingness to adopt low-carbon behavior in urban areas. This could be attributed to greater infrastructure investment and wider access to low-carbon information in urban areas, making it easier to promote the transition to personal low-carbon behavior these areas.

The differences among LCB1, LCB2, and LCB3 with respect to age, education, marital status, occupation, and income were analyzed using a one-way ANOVA (Table 5). According to Table 5, only LCB2 showed significantly differences with age, education, marital status, occupation, and income. This suggests that there were no significant differences in the willingness of people of different ages, educational backgrounds, and incomes to adopt low-carbon behaviors, likely due to the general awareness of climate change and positive environmental attitudes [44]. However, during the actual implementation process, considering the influence of the external environment, such as infrastructure, social norms, time, money and other factors, different groups may exhibit varying behavioral tendencies due to their differences. It is crucial to create favorable external conditions for the implementation of low-carbon behaviors.

3.4. Correlations between variables

To better understand the correlations between the demographic variables and the three variables of Part B of the questionnaire, the coefficients and significance levels were obtained and are presented in Table 6. The analysis revealed significant correlations between LCB1 and LCB2, as well as between LCB1 and LCB3. This suggests that the willingness to adopt low-carbon behavior was correlated with the low-carbon behavioral intentions or actions determined by internal factors as well as with the low-carbon behavioral intentions or actions determined by external factors. Individuals with a positive low-carbon attitude, strong subjective norms, and high perceived behavior control (PBC) are more likely to adopt low-carbon behavior.

3.5. Analysis of key issues in practice

In part C of the questionnaire, we investigated key issues related to daily life, including clothing, food, housing, and transportation, as well as the responsibilities of individuals, enterprises, and governments. The results from the survey sample of 2430 respondents revealed that in terms of household energy consumption, the majority of people (34.24 %) are concerned with the brand of household appliances, followed by the energy efficiency label (30.29 %) and then the price (28.4 %). This indicates that energy-efficient-labeled appliances are not always the first choice for people, and their selection may be influenced by various factors such as household income, size, and living area [45]. Regarding real estate, individuals primarily opt for properties with green building certification due to the suitability of green buildings for human settlement and their positive ecological functions, which are beneficial to health (51.4 %); the potential for cost savings in terms of water, electricity, gas, and other expenses (49.22 %); as well as the reduction in deed tax and stamp tax when purchasing a house (38.6 %) were also significant factors influencing the choice of green buildings. In addition, knowing how to accurately classify different wastes (35.97 %) and placing wastes at a few fixed locations (20.99 %) have become the main difficulties associated with waste sorting and recycle. In terms of transportation, the decision to purchase new energy vehicles was influenced by their environmental friendliness compared to fuel vehicles (32.1 %), lower operating costs (31.77 %), and available subsidies (25.8 %). However, concerns about insufficient battery life (55.29 %), the lack or inconvenience of charging infrastructure (52.94 %), and the long charging time (39.76 %) were the main reasons for not opting to purchase new energy vehicles. This is consistent with previous studies, which have indicated that monthly income, financial benefits, infrastructure readiness,

Table 3
The statistics of the means and standard deviations for LCB1, LCB2, and LCB3.

	LCB1	LCB2	LCB3
Mean	28.495	21.980	41.310
Std. deviation	4.290	3.674	6.544
Minimum	9	7	11
Maximum	40	35	55

Table 4
Analysis of the differences among LCB1, LCB2, and LCB3 with gender and living area.

		N	Mean	Std. Deviation	t	Sig. (2-tailed)	95 % Confidence Interval of the Difference	
							Lower	Upper
LCB1	Male	1159	28.534	4.312	0.428	0.669	−0.267	0.416
	Female	1271	28.460	4.271				
	Urban	1387	28.603	4.098	1.427	0.154	−0.094	0.596
	Rural	1043	28.352	4.530				
LCB2	Male	1159	21.908	3.795	−0.930	0.353	−0.431	0.154
	Female	1271	22.046	3.560				
	Urban	1387	22.866	3.632	14.264	0.000	1.780	2.347
	Rural	1043	20.803	3.389				
LCB3	Male	1159	41.243	6.752	−0.482	0.630	−0.649	0.393
	Female	1271	41.371	6.350				
	Urban	1387	41.461	6.100	1.313	0.189	−0.174	0.878
	Rural	1043	41.109	7.089				

Table 5
Analysis of differences among LCB1, LCB2, and LCB3 with age, education, marital status, occupation, and income.

		Sum of Squares	df	Mean Square	F	Sig.
Age	LCB1	66.167	5	13.233	0.719	0.609
	LCB2	3332.085	5	666.417	54.850	0.000
	LCB3	375.406	5	75.081	1.756	0.119
Education	LCB1	41.846	5	8.369	0.454	0.810
	LCB2	6348.341	5	1269.668	116.426	0.000
	LCB3	102.995	5	20.599	0.481	0.791
Marital status	LCB1	25.37	2	12.685	0.689	0.502
	LCB2	4012.379	2	2006.190	169.236	0.000
	LCB3	6.045	2	3.022	0.071	0.932
Occupation	LCB1	133.135	6	22.189	1.206	0.300
	LCB2	5378.213	6	896.369	79.252	0.000
	LCB3	307.874	6	51.312	1.199	0.304
Income	LCB1	267.565	5	53.513	2.919	0.012
	LCB2	3605.315	5	721.063	59.904	0.000
	LCB3	289.964	5	57.993	1.355	0.238

Table 6
Correlations between demographic variables and LCB1, LCB2, and LCB3.

	1	2	3	4	5	6	7	8	9	10
Gender	1									
Age	−0.071[a]	1								
Area	0.007	−0.118[a]	1							
Education	0.003	−0.154[a]	−0.303[a]	1						
Marital status	−0.024	0.659[a]	−0.013	−0.240[a]	1					
Occupation	0.088[a]	−0.305[a]	0.030	0.061[a]	−0.444[a]	1				
Income	−0.120[a]	0.462[a]	−0.134[a]	0.026	0.488[a]	−0.504[a]	1			
LCB1	−0.009	0.015	−0.029	−0.007	0.000	0.033	−0.005	1		
LCB2	0.019	−0.211[a]	−0.278[a]	0.399[a]	−0.338[a]	0.249[a]	−0.224[a]	0.065[a]	1	
LCB3	0.010	0.040[b]	−0.027	0.021	0.007	0.018	0.013	0.689[a]	0.008	1

[a] Significant at the 0.05 level.
[b] Significant at the 0.01 level.

environmental concerns, and policy preferences strongly influence purchase intentions [46,47].

Of all the respondents, 44.44 % believed that the government is the institution that plays the largest role in stimulating changes in personal behavior, followed by social networking sites and media (30.78 %) and enterprises (21.15 %). However, when some companies make different decisions, they may affect individual low-carbon consumption. For example, 42.06 % of the respondents believe that disposable toiletries in hotels could be provided, but would require an extra charge for use to reduce guest use, whereas 31.93 % of the respondents believe that it should be provided for free, and 19.84 % of the respondents believe that they should not be provided to avoid wasting resources. If all hotel companies do not provide or charge for the use of disposable toiletries, the consumption of disposable products can be reduced to a certain extent, and this may also promote changes in the behavior and habits of travelers. When information is available, personal finance and investment (stocks, savings, funds, etc.) may be affected by the type of products a company provides. Moreover, 31.11 % of the respondents consider an industry and its environmental impact as an important

consideration for finance and investment, whereas 34.12 % of respondents focus more on the impact that investment products have on the environment and ecology in terms of finance and investment risk, and 28.19 % of the respondents only consider their income level, regardless of the industry in which the products are invested and its impact on the environment and climate change. In other words, the more environmentally friendly a company is, the easier it is to obtain more investment. Governments, individuals, and enterprises are closely linked and influence each other during the process of low-carbon development. It is crucial to formulate effective policies and find ways to encourage individuals to adopt low-carbon behaviors.

4. Discussion

4.1. The impact of demographic characteristics on internal and external factors

The survey results of the entire questionnaire clearly show that demographic variables have a certain impact on individual low-carbon behavior. Differences in low-carbon behavior are observed across different groups based on age, gender, income, education, and other variables [48]. Demographic characteristics may directly or indirectly affect internal factors or external factors related to the execution of low-carbon behaviors. The analysis of the Likert scale indicates significant differences in demographic variables regarding low-carbon intentions or behaviors related to external factors. Factors such as personal norms (the expectation of individuals to perform certain actions in specific circumstances) and PBC (individual ability to overcome obstacles and express behavior) did not vary with the demographic variables, suggesting that effective public service announcements related to climate change are influential, as respondents express concern about climate change and willingness to implement low-carbon behavior [49]. Regarding low-carbon intentions or behaviors related to internal factors (LCB1), all respondents (N = 2430) largely recognize the severity of climate change and feel obliged to take actions to reduce CO_2 emissions (Mean = 4.29, SD = 0.853). However, public knowledge about CO_2 emissions may not fully align with these values, indicating a need for more education on the impact of daily activities on CO_2 emissions and the behaviors that contribute to reducing them. For example, people are not entirely clear about the CO_2 emissions generated by their daily behavior (Mean = 3.69, S.D. = 0.910). While people are aware of climate change issues, they are not fully aware of the impact of one's daily activities on CO_2 emissions, and which behaviors contribute to reduce CO_2 emissions. Colleges, enterprises, and governments should focus more on the popularization of the methods and skills to reduce CO_2 emissions rather than solely providing theoretical knowledge [50].

In terms of low-carbon intentions or behaviors related to external factors (LCB2), significant differences are observed with age, living area, education, marital status, occupation, and income. This may be because the effects of these factors on the implementation of low-carbon behavior are more easily influenced by external conditions. There is no difference among the demographic variables in the surveys on low-carbon behavior willingness related to individuals' daily lives (LCB3). Relatively speaking, once convenient conditions are provided, everyone was more willing to adopt low-carbon behavior. For example, after providing carbon labels, individuals were willing to buy relatively low-carbon products (Mean = 4.01, SD = 0.832) to work on staggered peak hours (Mean = 4.05, SD = 0.873), and use green packaging or shared courier boxes (Mean = 4.05, SD = 0.852). The implementation of these policies can effectively promote carbon emission reduction in the field of personal consumption. Therefore, creating more conducive conditions for the implementation of low-carbon behavior plays an important role in promoting the change of public behavior.

4.2. The impact of internal and external factors on low-carbon intention or behavior

Internal factors such as attitude and personal norms positively influence the transformation of individual low-carbon behavior. Habit, an important influencing factor among internal factors, may indeed be one of the most significant obstacles to behavioral changes (Mean = 2.57, S.D. = 1.218), and it varied greatly among individuals. Although 29.63 % of the respondents know what to do to reduce their carbon footprint, overcoming personal habits remains challenging for them; 18.19 % of all the respondents remained neutral. Therefore, it is crucial to consider effective ways to make behavioral habits more environmentally friendly.

External factors such as social rules, economic elements, infrastructure, and information may be more likely to show individualized differences. This may be due to external factors being more influenced by demographic variables. Through the survey, it is observed that once specific and feasible conditions are provided, the public willingness to participate in low-carbon activities is relatively high. For instance, the infrastructure in urban areas and rural areas will inevitably differ considerably. However, LCB1 and LCB3 are still determined by individual subjective intentions to a certain extent. It is worth highlighting the important role of economic elements, that is, the role of material rewards, in promoting behavioral change may not be as important as commonly believed. For example, 35.31 % of all surveyed respondents have differing opinions from the view that material rewards are more conducive to behavioral changes than spiritual rewards, and 29.42 % remain neutral.

A detailed survey on the choices of different income groups in the questionnaire revealed interesting insights. Taking the purchase of household appliances as an example, different income groups prioritize various factors. The group with a monthly income of 2000 and below consider energy efficiency labels, brands, and prices, in this order; the group with a monthly income of 2001–5000 consider price, brand, and energy efficiency label, in this order; the group with a monthly income of 5001–8000 consider brand, price, and energy efficiency label, in this order; the group with a monthly income of 8001–12,000 consider brand, price, and energy efficiency label, in this order; the group with a monthly income of 12,001–17,000 consider brand, energy efficiency label, and price, in this order; and the group with a monthly income of 17,000 or more consider brand, price, energy efficiency label, in this order. It is observed that price is not the most significant concern in all groups. Besides focusing on the quality of the product brand, individuals may be more concerned about the long-term use cost (energy efficiency label). Therefore, subsidizing the promotion of energy-saving products or

rewarding buyers may not always be effective. Encouraging consumers to pay more attention to the long-term usage cost may be more conducive to their choice of low-carbon products. Hence, effectively utilizing economic incentives is crucial. In comparison to existing research, the findings highlight the complexities of individual low-carbon behavior. Internal factors such as habits and personal norms pose significant challenges to behavioral changes, while external factors are influenced by demographic variables and individual preferences.

4.3. The role of governments and enterprises in promoting individual low-carbon behavior

Governments and enterprises play critical roles in encouraging individual low-carbon behavior. Government is recognized as the key institution in driving changes in personal behavior. However, as discussed in most studies, monetary incentives may not necessarily promote public low-carbon behaviors [51,52]. To achieve more effective results in current low-carbon lifestyles, such as waste classification and the promotion of new energy vehicles and other low-carbon products [53,54], it may be necessary to devise more flexible policies and accelerate the advancement of low-carbon technology to solve the obstacles to adopting low-carbon behavior. For example, promoting new energy vehicles may be more effective than subsidies by solving key issues such as insufficient battery life and the inconvenience of charging infrastructure. The finding from LCB3 also show that creating more favorable conditions is conducive to the adoption of low-carbon behavior. Continuing to promote climate policy in depth, cultivating positive environmental sentiments, and reinforcing public responsibility and skills to address climate change concerns are essential prerequisites for promoting public low-carbon behaviors [55].

Enterprises have important social responsibilities in promoting carbon emission reduction and carbon neutrality. In addition to implementing low-carbon transformation and practice within their own businesses, they should pay more attention to how to promote public low-carbon behavior through enterprise products. For example, adopting carbon labels and improving the public understanding, acceptability, and credibility of carbon labels, to further increase consumers' willingness to purchase low-carbon products [56]. Furthermore, deeper low-carbon technology changes in manufacturing firms [57] and policy optimization in the service industry can effectively promote the change of public low-carbon behavior [58]. The findings underscore the importance of both government and enterprise roles in promoting low-carbon behavior. The need for flexible policies and technological advancements to address barriers to adopting low-carbon behaviors were emphasized. Additionally, fostering positive environmental sentiments and reinforcing public responsibility and skills are essential for promoting low-carbon behaviors.

5. Conclusions and policy implications

5.1. Conclusions

To effectively promote the transition to and practice of low-carbon behavior by individuals, this study meticulously designed and conducted a comprehensive questionnaire survey, encompassing demographic characteristics, internal and external factors influencing personal low-carbon behavior. The results show that:

(1) Low-carbon intentions or behaviors determined by internal factors exhibit no significant variance across demographic variables. Notably, personal habits emerge as a pivotal internal factor that may hinder the adoption of low-carbon behaviors.
(2) Low-carbon intentions or behaviors determined by external factors differ significantly with in age, living area, education, marital status, occupation, and income. This underscores the potential for promoting the transition to personal low-carbon behavior through targeted changes in the external environment.
(3) There are correlations between internal and external factors that determine a person's low-carbon intention or behavior, and the willingness to change behavior is also related to internal factors. The gap between low-carbon intentions and behavior may be attributed to the influence of external factors; different individuals show greater differences.

By elucidating these intricate relationships between internal and external factors, the study not only provides valuable insights into the multifaceted nature of low-carbon behavior but also emphasizes the critical need to consider diverse influences in promoting sustainable practices. This comprehensive analysis underscores the significance of addressing both internal and external factors to effectively facilitate the adoption of low-carbon behaviors, thereby contributing to the advancement of sustainable and environmentally conscious practices.

5.2. Policy implications

Based on the analysis of questionnaire responses and interview results, the following suggestions are made on how to promote personal low-carbon behavior:

(1) To facilitate the transition of different groups to low-carbon behaviors, policy-makers should consider creating effective incentives tailored to different demographic groups to encourage a reduction in CO_2 emissions. Material and spiritual rewards may affect different groups differently. Understanding these differences is crucial for promoting low-carbon behaviors across diverse populations.

(2) To promote low-carbon behavioral changes, public environmental education should be strengthened to raise awareness, values, and beliefs related to climate change. Drawing attention to CO2 emissions from daily activities can help inculcate a sense of responsibility towards reducing carbon footprints.
(3) Governments and enterprises should work towards creating an external environment that promotes low-carbon activities. While there may still be a gap between low-carbon intentions and actual behavior, building easier-to-use infrastructure and providing the public with more concrete choices will provide an external environment that is more conducive to accelerating the transition to low-carbon lifestyle.
(4) Increase the use of policy tools for reducing CO_2 emissions, such as carbon tax, carbon labeling, and capping of total CO_2 emission. While specific policies such as consumption-related carbon taxes are not currently acceptable to everyone, policymakers can optimize the policy design based on a comprehensive policy framework. For example, governments could start by designing pilots that replace punishment with rewards [59,60]. Additionally, enhancing public participation and understanding of low-carbon information can aid in promoting the implementation of low-carbon behaviors.

5.3. Limitations

The study has certain limitations that should be addressed in future research. The majority of respondents participated in this study randomly online, and the lack of one-on-one in-depth interviews due to limited research funding may have impacted the precision and accuracy of the information. Future research should explore other survey methods and conduct in-depth surveys and records of populations with diverse demographic backgrounds to enhance the robustness of the findings. Furthermore, the scope of internal or external factors related to individual low-carbon behavior in the questionnaire was relatively narrow. In order to avoid too many questions affecting people's willingness to answer, this study only selected specific elements that have a significant impact on personal low-carbon behavior from internal and external factors, and designs a limited number of questions for each factor. Future research should delve into specific elements among the internal and external factors to more effectively design corresponding policies aimed at promoting individual low-carbon behaviors. This will help in gaining a more comprehensive understanding of the dynamics influencing low-carbon behavior and in developing targeted interventions to encourage sustainable practices.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Tiantian Wang: Writing – original draft, Methodology, Investigation. **Bo Shen:** Writing – review & editing, Methodology, Investigation. **Tingting Ma:** Writing – review & editing, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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