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Factors affecting low-carbon travel behavior of urban residents: Based on the theory of planned behavior and structural equation model

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ABSTRACT

With the rapid development of urbanization and motorization, the number of automobiles in China's cities has increased dramatically, which has caused a series of problems such as urban road traffic congestion, increased energy consumption and urban air pollution, which have become more and more serious and become hot issues of concern to the entire society. Urban residents, as the main body of low-carbon travel, play a vital role in energy conservation and emission reduction of urban transportation. This paper reviews the existing research results and draws on a large and growing body of literature to propose the extension theory of planned behavior, to study the influencing factors of low-carbon travel choices of residents in China's four first-tier cities. The study employs distribution of 3,000 network questionnaires and the collection of micro-survey data, to interpret urban residents from the traveler's personal attributes, travel attributes, environmental attitudes, subjective norms, behavioral attitudes, behavioral control and other aspects of the traveler's personal attributes. At the same time, it will also provide practitioners with practical and feasible policy recommendations.

Keywords: Low carbon travel awareness, Low carbon travel behavior, Urban residents, Structural equation modeling

NONMENCLATURE

Abbreviations	
APEN	Applied Energy
Symbols	
n	Year

1. INTRODUCTION

In this paper, through the combing of low-carbon consumption, low-carbon travel, consumer behavior theory, and other related research, we build a conceptual model of urban residents' low-carbon travel awareness and behavior influencing factors based on the theory of planning behavior and propose the research hypothesis of response. Data were collected through an online questionnaire survey, the statistical software SPSS and AMOS were used to analyze the sample, and the proposed hypothesis was tested using the structural equation model.

2. PAPER STRUCTURE

2.1 Introduction

With urbanization and rapid economic growth, the problem of environmental pollution is becoming more and more serious. In the past few years, climate change and CO2 emission have attracted worldwide attention. In 2007, China became the world's largest CO2 emitter, a status it maintains today. Up to 80% of the increase in CO2 emissions witnessed since 2008 can be attributed to China[1]. Cities produce over 70% of the global CO2 emissions that result from energy use and thus play a key role in climate mitigation and adaptation[2].

Transport is a major contributor to various environmental externalities, including most notably greenhouse gas emissions and local air pollution[3], [4]. In 2016, the transport sector accounted for a quarter of total emission, around 8 GtCO2, 71% larger than in 1990. The highest absolute increase was on the road, while in relative terms, bunkers increased the most (navigation & aviation). The transport sector has become the third-largest emitter of carbon dioxide after the industrial sector and the building sector, which is reportedly

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responsible for one-fourth of energy-related CO2 emissions and China is responsible for the largest increase in transport emission between 2000 and 2016[5]. Travel by individuals accounts for a large part of the growth in regional carbon emissions and PM2.5 emission[6]. Shifting the research perspective from the macro to the micro-individuals is very important[7]–[9]. Low-carbon travel behavior as a kind of consumer behavior, the origin of the concept is the green transportation system, which is a kind of diversified transportation system aimed at reducing environmental pollution, reducing resource waste, easing traffic congestion and promoting sustainable social development, the main travel modes include walking, bicycles, buses, public rail transit and so on. It is essential to understand what motivates people to employ low-carbon transportation.

The rest of the paper is structured as follows: firstly, the factors influencing residents' low-carbon travel behavior are organized by reviewing the previous literature, then a questionnaire is designed and placed online, and the collected data are cleaned and organized, then the factors influencing residents' low-carbon travel behavior are explored through an ordered probit model, and a robustness test is conducted. For further analysis, the article also designs the model based on the theory of planned behavior and uses structural equation modeling to explore the factors influencing the low-carbon travel behavior of urban residents. At the end of the paper, the findings and policy implications of motivating individuals' willingness to travel green are discussed.

2.2 Literature review and hypotheses

It is now well established from a variety of studies about low carbon travel, with existing research focused on two main areas: first, the macro perspective of urban agglomeration and urban public transport infrastructure; the second, the analysis of the influencing factors from the perspective of the micro-subject consumer. By reviewing the existing literature, current research from the residents' perspective focuses on their characteristics and the factors that influence their consciousness[10]. Existing research focuses on individual demographic factors, including gender, age, income, education and family size, etc.[11]–[14],

Currently, research on low-carbon travel mostly uses the Rational Choice Theory[15], Attitude-Behavior-Context (ABC) Theory[16], Value-Belief-Norm Theory[17], [18], and Theory of Planned Behavior[19]–[21]. Among these theories, the Theory of Planned Behavior is the best option for studying low-carbon travel behavior[22]. It is also widely used in various studies of low-carbon travel behavior[23], [24].TPB holds that a person's behavioral intention is determined by a positive evaluation of the behavior (attitude), social pressure that encourages the behavior (subjective norm), and the perceived ease of conducting the specific behavior (perceived behavioral control)[25].

This paper is based on the theory of planned behavior and considers the above socio-demographic and psychological factors to analyze the factors that influence the low-carbon travel behavior of urban residents.

2.3 Methods and hypotheses

The data of this paper is obtained from a micro-survey using a questionnaire which was designed and distributed online to obtain information about the low-carbon travel behavior of urban residents.

In the results analysis section, since the dependent variable of the regression is the frequency of low-carbon travel behavior of urban residents, a scale of response pattern of, never=1, seldom=2, sometimes=3, usually=4, always=5 was adopted. With the increase of Numbers, the probability of low-carbon travel of respondents is higher, so both the ordered probit model and the ordered logit model are applied for the regression in this paper[26].

To better analyze the factors influencing low-carbon travel, this paper chooses to use structural equation modeling. Structural equation modeling (SEM), first proposed by the Swedish statistician Joreskog, was first applied in the 1970s and rapidly developed in the 1980s, and is now widely used in education, psychology, economics, and many other theories.

One of the most salient features of structural equation modeling is that it is theoretically a priori and thus essentially SEM is a model validation technique. For most researchers, due to their knowledge and other limitations, it is often difficult to determine whether the proposed model structure is consistent with the objective situation, especially when some variables (e.g., attitudes, happiness, etc.) are inherently difficult to measure. This is especially the case when some variables (e.g., attitudes, happiness, etc.) are difficult to measure on their own. Traditional analysis methods are not effective in solving this problem, but structural equation modeling can deal with this problem well because it integrates path analysis and factor analysis. Besides, SEM can deal with the relationship between multiple independent and dependent variables simultaneously, analyze direct and indirect effects between latent

variables, and allow for measurement error, which amounts to a new analytical method for researchers.

Based on a summary of existing research, this paper proposes the following hypothesis:

H1: Low carbon behavior intention has a positive effect on low carbon behavior

H2: Attitude has a positive effect on low carbon behavior intention.

H3: Subjective norm has a positive effect on low carbon behavior intention

H4: Perceived behavioral control has a positive effect on low carbon behavior intention

H5: Outcome evaluations have a positive effect on attitudes

H6: Environmental knowledge has a positive effect on perceived behavioral control

H7: The service level of urban public transport has a positive effect on Perceived behavioral control

2.4 Data

2.4.1 Random survey

A random survey was conducted in four major cities in China: Beijing, Shanghai, Guangzhou and Shenzhen. A total of 3000 questionnaires were distributed, and after eliminating invalid questionnaires, 2183 questionnaires were finally used for analysis. The effective recycling rate was 72.8%. The research was conducted during a period of 9 months from July 2019 to March 2020.

The questionnaire is an online survey that is completed on the "Questionnaires Treasure" platform. It was set up by a company that specializes in data research, processing and storage, covering 346 prefecture-level cities and 1.1 million users. The "Questionnaire Treasure" platform has been utilized for several research studies online[27], [28].

We selected four cities for the survey, Beijing, Shanghai, Guangzhou and Shenzhen. The basic statistics of the four cities are listed in Table1. As megacities with rapid economic development in China, these four cities have a concentrated population, perfect public transportation infrastructure and sound service system. These four cities have a large number of rail transit lines, dense rail transit stations, high coverage of bus lines, and relatively strong convenience and comfort for urban residents to choose low-carbon travel, so it is of high representative significance to study the factors influencing the low-carbon travel awareness of residents in these four cities, and of reference significance to other city governments in setting up and guiding low-carbon travel policies.

2.5 Results and discussion

2.5.1 Common method bias test

All the variables in this paper are answered by the same respondents at the same time, and the data obtained may be subject to common method bias, which is avoided by taking precautionary and posterior analysis approaches to reduce the effect of common method bias[26]. During the research process, voluntary and anonymous participation was used and experts in the relevant fields were invited to give their opinions and suggestions on the set-up of the questionnaire.

Secondly, in terms of post hoc testing, this paper uses Harman's one-factor test to assess the impact of common method bias, exploratory factor analysis of the measured items of all variables, and the variance explained by the first factor extracted is 48.3%. Less than 50%, which indicates that no single factor explains the vast majority of the variance, i.e., the common method bias of the data in this paper is not significant.

2.5.3 Summary of sample demography

A questionnaire-based survey was conducted, which was completed by 2,813 respondents from four first-tier cities (Beijing, Shanghai, Guangzhou, and Shenzhen). The main group of respondents was more male (1343, 61.5%) than female (840, 38.5%), and the respondents were concentrated in the age group of 21-40 years old, accounting for 88.4% of the respondents. More than 50% of the respondents had an undergraduate education, 1772 respondents had a driver's license (81.2% of the total), and the occupations of the respondents included student (98, 4.5%), state personnel (253, 11.6%), private and foreign employees (886. 40.6%), public service/institution (321, 14.7%) ,self-employed/private owners (376, 17.2%) ,freelancer (118, 5.4%) and other practitioners (131 (6.0%) .78.4% of the respondents' households owned at least one car. Besides, the study also classified the respondents into different income brackets based on their income. In this regard, most of the respondents (713 people, 32.3%) belonged to the upper-middle-income class (about 9001 RMB/month), followed by the middle-income class (5001-9000 RMB/month), with 1117 people (51.2%) belonging to this class. And the personal attributes of the respondents differ little from city to city

2.5.4 Basic results

In this section, we will analyze the factors influencing the low-carbon travel behavior of urban residents. Since all variables are normally distributed, the ordered probit

model is used. We adopt the methods of regression by adding more variables in the model. The regression results are shown in Table 1.

With Table 1, we can see that low-carbon travel behavior is positively related to low-carbon travel intentions with a coefficient of less than 1 and is significant at the 1% significance level. By comparing each column, this positive effect is robust in all cases, but the coefficient decreases as the number of control variables increases. Previous studies have shown that people's willingness to protect the environment affects environmental behavior[29], and a coefficient less than 1 indicates that there is a gap between low-carbon travel intentions and low-carbon travel behavior, and intention of low-carbon travel does not translate into absolute (thus,100%) low-carbon travel behavior as the coefficient becomes smaller as the control variables increase, indicating that there are other factors that affect low-carbon travel behavior.

From the results in Table 1, it can be seen that the effect of gender (male = 1, female = 2) on low-carbon travel behavior is significantly positive, which indicates that women may be more likely to practice low-carbon travel behavior relative to men, which is consistent with the findings of[12], women may be more likely than men to be actively involved in improving the environment. Age and low-carbon travel behavior of city residents has a non-linear relationship, this is also consistent with previous research[11], [14]. Increased educational attainment of individual residents significantly enhances their choice of low-carbon travel behavior. The main reason is that people with higher levels of education are more knowledgeable about the environment and are more likely to take action to support environmentally friendly behavior[30]. An increase in personal income will significantly reduce low-carbon travel behavior, choosing to travel green will have a positive impact on both environmental protection and resource waste, low-carbon travel can also save money compared to private car travel or taxi travel, but it will result in a waste of time, for people with higher incomes are willing to spend more to choose a private car or taxi travel to save time.

Increasing travel distances significantly increase low-carbon travel behavior. This result doesn't fit well with common sense, possibly because the people who filled out our questionnaire are residents of four large cities, where traffic can be relatively congested, especially during commute times to and from work. At the same time, these four large cities have well-developed subway systems, so if the daily commute is far away, choosing a green way of travel like the subway will save time and costs.

A positive coefficient indicates that people with a driver's license are more likely to travel green, probably because 81.2% of our sample have a driver's license, and this lack of uniform distribution affects our subsequent regression results. An increase in the number of private cars owned by households significantly reduces individual low-carbon travel behavior, as the presence of private cars increases the travel options of urban residents.

An increase in the level of concern about environmental pollution (CEQ) and perceived environmental pollution (EP) in the city will significantly increase low-carbon travel behavior, because urban residents can perceive low-carbon travel as a good thing for the environment, and vehicle exhaust emissions are an important source of urban air pollution[31].

Concern about urban traffic congestion (TC) would significantly reduce low-carbon travel behavior among urban residents. The main reason for this is that the more concerned residents are about congestion, the more residents want to stay away from such congestion, and the biggest advantage of public transportation is that it can save costs, but similar to the bus, in a congested city, more time will be wasted for commuters, so the residents who care about urban congestion will be more antipathy to public transportation, which also to some extent reduces its willingness to choose low-carbon travel. The advocating of low-carbon travel by the government of the city will effectively increase the frequency with which residents choose to travel green. The government's proactive and effective call to action will increase the knowledge of urban residents about green mobility, and previous studies have shown that government propaganda is crucial in promoting residents' environmental awareness[32].

2.5.5 Robustness checks

Before proceeding to further analysis, a robustness check is conducted. We begin with ordered logit first and results are presented in Table 2. It can be observed that the signs and the significance levels of all the coefficients are almost the same as that in Table 1. Because the assumption on the distribution of the residual term is different between ordered logit model and ordered probit model, it is normal that the values of the coefficients are different. Therefore, we deem that the results we get in the previous part are robust and credible.

2.5.6 Estimations of structural equation and hypotheses' results

To further explore the factors influencing low-carbon travel behavior, we used structural equation modeling to analyze the relevant factors.

To evaluate the extent to which the measurement items of this research measure structural variables, this paper conducted correlation analyses and tests of content validity and structural validity, and validation factor analysis of key variables using structural equations. And all the results show that the data is fitting for SEM. Figure 2 illustrates the SEM frame:

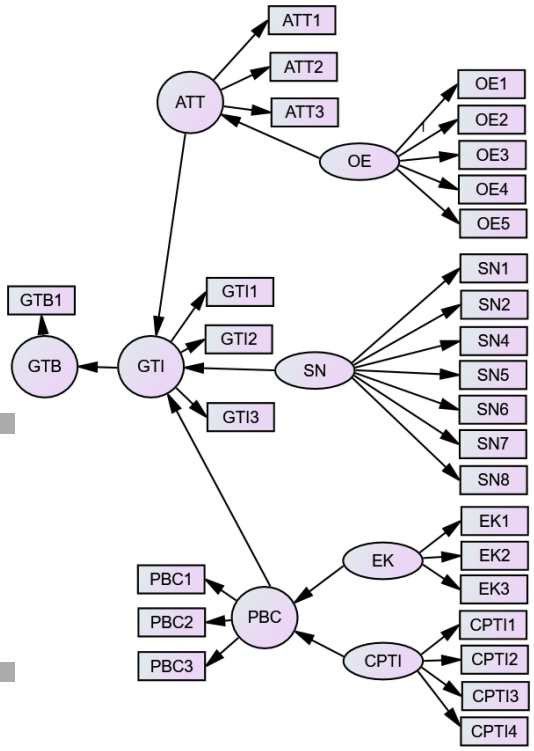

Fig 1 SEM estimation results

We used Amos 24.0 to analyze the data, and to understand the differences between the different clusters, we analyzed the full sample, but also different genders and different city groups, and the results are shown in Table 3. The first seven rows of Table 3 validate the seven hypotheses in this article, and the results show that low-carbon travel intention has a significant positive effect on low-carbon travel behavior, with a standardized coefficient of 0.384, which is significant at the 1% level. The main reason for this may be that women are more environmentally conscious and have better environmental behavior than men, and there are some differences between cities.

Subjective norm, attitude and perceived behavioral control all had significant positive effects on low-carbon travel intention, with perceived behavioral control having the greatest effect. Attitude followed by the least influence of subjective norm, in group differences, female groups subjective norm will be higher than male groups, which indicates that women are more susceptible to the influence of the surrounding groups, among cities, Shanghai has the smallest coefficient, followed by Beijing, Shenzhen is the largest, which indicates that Shanghai and Beijing residents have a stronger sense of autonomy in making 'decisions' and are more likely to be made with one's ideas in mind rather than clinging to the ideas of the group around them. The effect of attitude on low-carbon travel intention also differs between groups, with male groups significantly more likely to have positive attitudes towards low-carbon travel than female groups, possibly because male groups will experience more of the congestion, high costs, and other negative aspects of non-low-carbon travel. Perceived; the significant positive effect of behavioral control on low-carbon travel intention differs in the group, exactly opposite to the subjective norm, and it can be seen that people who make more self-conscious decisions will be more mobile and efficient in making decisions. The evaluation of the results significantly and positively increases urban residents' attitudes about green mobility with a coefficient close to 1, suggesting that urban residents' attitudes towards green mobility are largely derived from the evaluation of the results. The influence of environmental knowledge and completeness of public transport infrastructure on perceived behavioral control shows the same trend across group differences.

2.6 Conclusions and policy implications

First, the low-carbon travel behavior of urban residents is mainly influenced by demographic factors, travel attributes, urban transportation and environmental conditions, and individual behavior theory.

Secondly, an increase in the education level of the individual will lead to a greater choice of environmentally friendly behaviors, such as low-carbon travel behavior. Women will be more likely to choose low-carbon travel behaviors relative to men, but an increase in personal income and an increase in the number of private cars owned by households will lead to a decrease in the choice of low-carbon travel behaviors. The longer the commuting distance, the more urban residents will choose low-carbon travel to save time and money, but in congested urban environments, residents will choose to

take taxis or other alternative behaviors to save time and money.

Third, the degree of concern about the state of environmental pollution in the city, the perceived worsening of environmental pollution will promote the urban residents' option for low-carbon travel behavior, government propaganda in the residents on low-carbon travel behavior exerts a positive promoting role.

Fourth, based on the Theory of Planned Behavior, we find that the low-carbon travel behavior of urban residents is mainly influenced by low-carbon travel intention, which in turn is mainly influenced by subjective norm, attitude and perceived behavioral control, on the evaluation of outcome, it will significantly contribute to residents' attitudes towards low-carbon travel, and the environmental knowledge and completeness of public transport infrastructure will also significantly contribute to the perceived behavioral control of urban residents towards low-carbon travel.

The analysis of the article's findings leads to the following policy recommendations to promote low-carbon travel behavior choices among urban residents.

First, increase the completeness of public transport infrastructure, to provide residents with convenient, fast and comfortable low-carbon travel can effectively increase the awareness of residents for low-carbon travel. The specific means include 1. Increase the operating routes, operating frequencies and stops of urban buses and urban rail transit; 2. Consider the distance of each public transport station from major shopping areas, schools, airports and other public places in urban planning; 3. Expand the operating hours of urban public transport, so that city residents can choose low-carbon travel behavior at any time; 4. Optimize urban public transport Internal environment to improve the comfort level of residents choosing to travel green; 5. Add non-motorized lanes and sidewalks to the urban infrastructure development process.

Second, focus on using administrative tools to control non-low-carbon travel behavior. An increase in the number of private cars will reduce the low-carbon travel behavior of urban residents, and consideration can be given to restricting the purchase of private cars by city residents through city fuel tax increases and raising the purchase threshold of private cars, thus promoting their low-carbon travel behavior. Congestion of the city will also make residents choose faster non-low-carbon travel modes, and consideration can be given to the city's private car restriction policy to ease urban traffic congestion. This, in turn, drives residents to choose transit and other modes of travel.

Third, since urban residents' awareness of low-carbon travel is mainly influenced by subjective norms, and both education level and environmental knowledge can effectively promote low-carbon travel behavior, low-carbon travel behavior of urban residents can be guided by government propaganda and celebrity effect. The main ways are as follows: 1. Incorporate environmental education and publicity into the daily primary and secondary education, so that children start to establish environmental awareness from an early age; 2. To encourage influential experts and scholars, literary stars to carry out environmental publicity, to form a demonstration effect; 3. The community to actively hold environmental knowledge popularization work and environmental awareness of publicity; 4.Through television advertising and environmental propaganda slogans, to create an atmosphere of low-carbon travel shared by the whole society.

2.7 References

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Note： We do not want to include our paper in the conference proceedings