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The Impact of Built Environment on Commuting Behavior

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Abstract

It has become a hot topic for scholars in urban planning and related fields to optimize the built environment of cities to guide the healthy development of cities, reduce the use of cars, and thus reduce transportation carbon emissions. The conclusions on the choice of built environmental factors and the direction and extent of their influence on residents' commuting behavior are not consistent. The research methods are different, but almost all the studies have found that:1)the built environment factors have different degrees of influence on residents' commuting behavior;2)Considering such factors as socioeconomic attributes and residents' self-selection;3)The influence of the built environment of the working place is different from that of the residence.

Keywords

Built environment, Commuting behavior, Traffic behavior, Multinomial logit models.

1. Introduction

With the rapid development of China's economy and the rapid advancement of urbanization, the urban population and urban scale are expanding rapidly, resulting in the continuous extension of commuting time and commuting distance of residents, and deepening the dependence of large city residents on car travel. Urban land use layout is the root of urban traffic demand. Optimize land use and urban spatial structure to create a green traffic oriented urban built-up environment and encourage residents to choose green travel.

The characteristics of different travel modes and vehicles determine the travel distance, accessibility and convenience. Different leading modes of traffic travel act on urban space, forming corresponding urban characteristic forms, and also present different morphological characteristics in terms of land layout. For example, the TOD(Transit-Oriented Development) planning concept refers to the development of land with moderate or higher density around the main public transport stations, and the provision of residential, employment and commercial service facilities within the walkable range, which is conducive to shortening the commuting time and promoting the sustainable traffic development of the city[1].

Urban built environment refers to the man-made environment provided for human activities. Its core concerns urban land use and urban space design. In daily life, people seldom complete a trip for the pleasure of travel. Usually, the trip is a purposeful and planned trip. At this time, they will be faced with traffic choices, but we will all consider a trip with maximum utility, that is, the most convenient, economical and efficient trip. We will not want to choose a travel mode that is congested, crowded and expensive. People's choices are determined according to their effectiveness. Any factor that changes the relative attractiveness of available traffic choices will affect traffic choices[2]. In some aspects, the layout of urban built environment determines the spatial distribution of residents' activities, and once formed, it is difficult to change, which has a "locking effect" on Residents' travel behavior decisions.

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2. Research method

2.1. Variable selection

The research on urban built-up environment includes a wide range of contents, and the research scale includes three levels: macro, meso and micro. The macro level focuses on the national or urban level, the meso level mainly takes the urban block as the unit, and the micro level mainly starts from the perspective of the traffic community. Cervero and kockelman proposed that the measurement index of urban built environment is "3D" element [3]: density,diversity,design. In recent years, the four dimensions of destination accessibility, distance to transit, demand management and demographics have been added, and the urban built environment elements have been gradually expanded into "7D" elements [4]. Although the demographic attribute is not a part of the urban built-up environment in essence, it is usually used as a control variable in the study of travel mode selection. Based on this, other built-up environment elements are superimposed to study the mixed influencing factors. The characteristics of built environment include residence and employment. The variables selected in this paper include individual social attribute characteristics, commuting characteristics and built-up environment characteristics. The specific meanings of variables are shown in Table 1:

Table 1: Variable feature selection and description

	Author	Variable name	Variable description
Individual social attribute		Gender	Male / female
		Age	18-25/26-35/36-55/56 and above
		Education	Junior high school or below / Senior High School (vocational college, vocational high school, etc.) / undergraduate or junior college / graduate student or above
		Occupation	Enterprise employees / Freelancers / Individual industrial and commercial households / Personnel of government institutions
		Monthly income	0-2000/2001-5000/5001-10000/10001 and above
		Family size	1/2/3/4 and above
		Car ownership	Yes / No
	Sunbindon g et al	Nature of residence	Self owned houses / Units / Rent houses
		Family employment	1/2/3 and above
		Number of minors in the family	0/1/2 and above
Built-up environm ent		Population density	Number of permanent residents / Land area (ten thousand people /km^2)
		Employment density	Employment / Land area (ten thousand people /km^2)

		Land use mix	Mixed information entropy of residential, commercial, public service facilities and urban traffic land
		Road network density	Length of road network / Land area (km/km^2)
		Distance to city center	Space straight-line distance from the starting place of work and residence to the destination (km)
		Distance to bus stop	Space straight-line distance from the starting place of work and residence to the nearest bus stop (m)
		Employment accessibility	OD cost matrix from residence to work place (min)
	Sunbindong et al	Transportation land ratio	Transportation land area / Total street area
		Intersection ratio	Ratio of the number of intersections to the total number of intersections in the street
	Zhangyanji et al	Walking safety	4-point scale: high =4 ~ low =1
		Riding Lane Security	4-point scale: high =4 ~ low =1
		Sense of safety in crossing the road	4-point scale: high =4 ~ low =1
		Shade coverage	4-point scale: high =4 ~ low =1
Commuting		Commute Distance	Linear distance from residence to work place (km)
Dependent variable		Commuting mode	Walking / Public transport / Bicycles and mopeds / Cars

2.2. Econometric model

In order to study the relationship between the built environment and the choice of commuting modes of residents, and to explore the impact of urban built environment on different commuting modes of residents, a multinomial logit model is proposed to meet the research requirements, and there is no requirement for data normality. Therefore, this paper constructs a multinomial logit model equation, as follows:

$$\text{Logit}\ (P_1/P_2) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k \quad (1)$$

Where: Logit (P_1/P_2) is the natural logarithm of the probability ratio of any two commuting modes; X_1 refers to the characteristics of built environment; X_2 refers to the characteristics of individual socio-economic attributes; X_3 is the one-way commuting distance; β_t is the parameter vector, where t=0,1,2,3.

Taking the car commuting mode as the reference for the three commuting modes of walking, bicycle/moped and public transport, the following equation is constructed on the basis of formula (1) for specific regression analysis:

$$\text{Ln}(P_{walk}/P_{car}) = \beta_{w0} + \beta_{w1} X_1 + \beta_{w2} X_2 + \cdots + \beta_{wk} X_k \quad (2)$$

$$\text{Ln}(P_{bike}/P_{car}) = \beta_{b0} + \beta_{b1} X_1 + \beta_{b2} X_2 + \cdots + \beta_{bk} X_k \quad (3)$$

$$\text{Ln}(P_{transit}/P_{car}) = \beta_{t0} + \beta_{t1} X_1 + \beta_{t2} X_2 + \cdots + \beta_{tk} X_k \quad (4)$$

2.3. Collinearity diagnosis

When there is a high correlation between two or more independent variables, the multicollinearity problem will arise. In this case, the model estimation is prone to bias, resulting in the inability to obtain accurate results. Therefore, the existence of multicollinearity should be tested before model analysis. At present, the main methods used to test multicollinearity problems are varianceinflation factor diagnosis method and tolerance value method. The expression of variance expansion factor is:

$$\mathrm{VIF}_i = \frac{1}{1-R_i^2} = \frac{1}{Tolerance_i} \tag{5}$$

Where R_i^2 is the complex correlation coefficient of independent variable i for regression analysis of other independent variables. When $\mathrm{VIF}_i > 10$, it indicates that there is a serious multicollinearity relationship between independent variables. When $\mathrm{VIF}_i < 5$, it indicates that the multicollinearity problem between independent variables can be ignored [5]. The tolerance value is the reciprocal of VIF. The larger the tolerance value is, the smaller the variance expansion factor is. The value is between 0 and 1. The closer the tolerance value is to 1, the weaker the collinearity between independent variables. The commuting mode variable is taken as the dependent variable of the model, and the individual social attribute variable, travel characteristic variable, residence and work place built environment variable are taken as the independent variables. Zhang[6] tested that the variance expansion factor of all variables did not exceed 5, and there was no serious collinearity Sun[7] considered that education and income are highly collinear, and that income has a more direct impact on Residents' commuting mode choice, and finally removed the education variable from the empirical test model.

3. Impact of built environment characteristics on commuting

Using the above multiple logit regression models, analyze the impact of each variable in the built environment on Residents' commuting travel modes, obtain the selection probability of residents' commuting travel modes according to the built environment, and analyze the action direction and intensity of each variable. In this paper, several variables with prominent influence are selected for analysis.

3.1. Density

Land use density is one of the most frequently studied built-up environmental factors. It can be divided into two categories according to the type of land, namely, residential population density and employment density. Many scholars have discussed the impact of land use density on commuting behavior.

Although many scholars choose different indicators when studying the relationship between density and commuting behavior, they all find that density has an important impact on commuting behavior. It has been considered that econtec[8] proposed that the high-density development mode may make the starting point and destination of travel closer, thus shortening the travel distance. Chatman concluded that the high-density environment will reduce the possibility of choosing the commuting mode by car. The high-density shops and service facilities near the workplace may make it easier for residents to carry out personal business activities on foot before, after and after work, thus reducing the use of vehicles [9]. Some scholars also believe that the built environment will have a negative effect on travel behavior. Crane believes that high-density areas may increase rather than reduce vehicle driving, because shorter driving distances may reduce average driving costs and increase vehicle usage[10]. Tana[11] studied the relationship between the built environment and the commuting travel of Beijing suburban residents by car. The research results show that the commuting by car is affected by the built environment of the residence and the workplace. The

increase of the commercial density of the residence and the decrease of the construction density lead to the reduction of the commuting by car. Zhao[12] found that increasing the population density of the residence and the setting of public transport can be more effectively applied through the research in Beijing, Residents use more public transport and non motorized commuting, and the probability of commuting by car will be reduced. Based on the activity perspective, chenbowen studied the impact of the built environment on the commuting efficiency of Guangzhou residents. The research results show that the built environment of high-density employment areas will significantly improve the commuting efficiency of residents, while the built environment of high-density residence can not improve the commuting efficiency[13]. Zhu[14] used the smart phone software daynamica developed by the University of Minnesota to collect commuting data. Through multiple logit regression models, they obtained the population density of the workplace, the distance from the city center, the population density of the residence, the density of the road network, and the number of bus lines, to some extent, will have a certain impact on commuting. At the same time, the commuting distance is significantly positively correlated with car commuting. The built environment of the workplace has a great impact on the choice of commuting modes of residents. However, some scholars have found that after adding variables such as distance from CBD, bus line density, parking lot and parking space, the influence of density is significantly reduced; Only changing the density will not have a significant impact on the operation of traffic. Bertaud a et al. Found that when the population and employment are concentrated, the per capita traffic demand will be minimized, and the average travel distance can be minimized. Although the concentration of employment places will form a strong traffic flow during daily commuting, which is easy to lead to serious traffic congestion, from another perspective, it will produce an orderly and manageable traffic flow, which can be regulated through traffic policies. For example, p+r parking lot, bus lane, etc.

3.2. Diversity

Diversity is the main factor affecting urban spatial distribution, which has a profound impact on the daily production and life of residents. It is specifically characterized by land use mix degree or job housing balance index. The impact of land use mix on traffic travel is to make the starting point and end point of residents' travel close to each other. On the premise of meeting people's various travel needs, social activities can be realized in a small area, so as to restrain the demand for car travel.

Zegras [15] studied the relationship between the built environment of Santiago de Chile and the use of motor vehicles. The results show that improving the land use mix can increase the choice of walking, cycling or other public transport, and significantly reduce the dependence on and ownership of household cars. Acker[16] on the basis of controlling the socio-economic attributes of individual families, used the structural equation model to show that the number of vehicles selected for commuting travel will decrease with the increase of the land use mix degree of residence, and the commuting travel time will increase to a certain extent. The land use mix degree can have an impact on commuting behavior, but the impact on vehicle availability, vehicle use, commuting distance and commuting time must be considered at the same time. Antipova[17] took Baton Rouge region of the United States as the research area. The research results found that the work living balance was negatively correlated with the commuting travel distance and time. Improving the work living balance was conducive to reducing the commuting travel distance and time. Some domestic scholars have proposed that on the basis of controlling the characteristic variables of individual social attributes, Ding[18] used the Bayesian multi-level cross classification discrete selection model in the study of the relationship between the built environment and commuting travel choice. The results show that the improvement of land use mix around the residence can promote residents to choose

slow traffic or public transport when traveling. Taking Beijing as an example, dangyunxiao and other [19] people used the multi-layer linear model to obtain that the land use mix of residence and workplace has an impact on the distribution of residents' work and residence, and has a greater impact on the workplace. The improvement of land use mix will alleviate the separation of residents' work and residence, thus reducing residents' cross regional commuting behavior. The more abundant and diverse the facilities near the residence, the residents will consider walking more, because the rich surrounding facilities and the diversity of functions will enable the various travel purposes such as commuting, shopping and leisure to blend with each other in a small spatial scale, and stimulate the walking behavior of users.

3.3. Design

The design includes the road network layout, road connectivity, route directness and other road network characteristics in the urban built environment, which directly affect the traffic accessibility in the urban road network and thus affect the travel choices of residents. In recent years, with the deepening of the connotation and concept of healthy city, green travel has become a research hotspot. Therefore, urban design should create a more perfect walking environment.

American scholars believe that compact, high-density and diversified design is conducive to shortening commuting time or distance, guiding residents to choose green travel modes such as walking, cycling or public transport, and reducing the use of private cars in commuting behavior. Many scholars have analyzed the impact of urban design layout on commuting. For example, Zhang[20] found in his research on Boston, the United States that with the increase of intersection ratio in residence, residents are more inclined to choose slow traffic for commuting. Schwanen[21] found that the choice of residence environment and commuting travel mode may be interrelated. They believe that the road connectivity near the residence is higher, and the grid road design can promote residents to choose green commuting mode. Wu[22] and others believe that there is a significant correlation between the design of road network layout in urban structure and the degree of residents' travel choice of public transport. In urban design, the urban layout is continuous and smooth, the grid network road layout is appropriate, and the pleasant non-motorized travel environment provides residents with a safe, comfortable and green travel environment [3,21].

3.4. Accessibility

Accessibility is a key indicator of urban built-up environmental factors. It indicates the proximity of residents to travel destinations or public transport facilities, including destination accessibility and accessibility to a certain mode of transportation. The research scale of destination accessibility can be divided into regional and local. It is often measured by the distance to the Employment Center (urban CBD) or the destination. The accessibility measurement indicators of transportation modes are usually the distance to public transport stations (accessibility to public transport stations, accessibility to the subway) and the density of public transport stations.

3.4.1. Destination accessibility

Ding studied the relationship between the built environment and commuting behavior in Washington, D.C., and found that when the distance between the residence and the urban center is large, the probability of residents choosing motor vehicles to travel increases[23]. Secondly, Acker's research on Belgium found that there is a significant positive correlation between the distance between the workplace and CBD and the commuting time of residents. The farther the workplace is from the urban center, the longer the commuting time of residents[16]. Acker and witlox used the structural equation model to analyze the relationship between the distance between residence and urban center and car use. The results show that the distance between

residence and urban center has a significant positive impact on family car ownership, but has no significant impact on car commuting[24]. In the study of Changchun by yinchaoying, a domestic scholar, the accessibility of residential public transport is measured by the number of bus stops in the traffic zone. The results show that by increasing the density of public transport stops, residents will not consider the time and distance of walking when traveling, and will easily accept public transport, which will have an impact on car travel. The farther away the residence is from the city center, considering the time cost, residents usually choose a safe way [25]. Employment accessibility has a significant impact on Residents' choice of slow travel and bus commuting travel modes, but the direction of impact on them is different. In the comparison model between public transport travel and car travel, it is found that the longer the OD cost time, the residents are more inclined to choose public transport for commuting and reduce the use of car travel. The main reason is that the road congestion leads to poor accessibility between work and residence, which weakens the advantages of car travel and improves the probability of public transport travel. In the comparison model of slow traffic travel and car travel, it is found that the longer the OD cost time, the more likely the residents are to commute by car, and the less likely they are to walk or bike.

3.4.2. Public transport accessibility

With regard to the accessibility of public transport, Chen Found in their research on New York, the higher the accessibility from the residence to the bus station or subway station, the less likely residents are to choose to commute by car. The farther the work place is from the public transport station, the longer the commuting distance[26]. Zhang Yanji's research on Fuzhou found that the arrangement of compact public transport lines in the employment area, people will choose more public transport during commuting, which is also conducive to promoting slow commuting behaviors such as walking and cycling[6]. Bernick[27] found in their empirical research on typical areas in the United States that the closer the distance between the place of residence and employment and the rail transit station, the higher the probability of public transport travel. Moreover, the proximity of bus and subway stations is conducive to walking behavior, and the densification of bus lines in employment areas will also promote walking and non motorized travel, which proves that the strategy of bus priority plays a certain role[12].

4. Impact of other factors on commuting

4.1. The impact of individual social attributes on commuting

The urban built environment is the material basis for the daily life of urban residents. The built environment needs to consider the needs of residents. The urban infrastructure construction is to facilitate residents. When choosing a living place, people will consider the surrounding construction, which has a fundamental impact on commuting behavior. However, the impact of individual social attributes and other factors on commuting can not be ignored. For example, family income, gender, age, occupation, educational background, number of family employees, car ownership, number of family children, lifestyle, travel preference and other factors [28]. If these potential influencing factors are ignored, the correctness of the conclusion will be affected in some aspects. However, due to the different regional characteristics and selection scales, the influence degree and direction of individual social attributes on Residents' commuting behavior will also be different.

For example, Holtzclaw Took Chicago, Los Angeles and San Francisco as research cases and found that the higher the average household income, the higher the possibility of residents using cars to travel and the longer the travel distance[29]. In Sandow's research on Sweden, binary logistic regression analysis was used to study individual commuting behavior. It was found that individual social attribute factors had a significant impact on commuting behavior. Women's commuting distance was shorter than men's, residents with low income also had

shorter commuting distance, and residents with higher education level had longer commuting time [30]. Domestic studies have also found similar conclusions. For example, in Cao's research on Guangzhou, when using structural equation model to analyze the relationship between residents' attributes, residential location and residents' travel behavior, he came to a conclusion that residents' attributes and residential location have a decisive impact on Residents' travel behavior. Residents with higher incomes tend to choose higher cost travel modes [31]. In Liu's research on Beijing, the relationship between socio-economic attributes and commuting time is analyzed by regression model. The results show that there is a significant relationship between gender and commuting time, and the commuting time of men is significantly shorter than that of women. The commuting time of skilled workers is longer than that of ordinary workers [32]. Dang, Dong and others believe that the distribution of work and residence plays a decisive role in commuting behavior, and there will be an obvious difference in the socio-economic attributes of residents. The separation of work and residence of high-income residents is more obvious than that of low-income residents[21]. The results of the model of Sun[7] verify that the residents of self-owned housing are more willing to use car commuting than renting. The residents aged 31-40 are more likely to choose car commuting. The middle-aged residents aged 31-40 have certain work experience and material foundation, and will be more willing to choose car commuting. In terms of families, families with minors are more likely to choose cars. Families with minors will take more account of their children's quality of life. It is more convenient to go to and from school, seek medical treatment and even make up lessons in spare time, which greatly improves the efficiency.

4.2. Influence of self-choice of residence on commuting

Self-choice of residence means that residents will choose a suitable place to live according to their travel preferences and living habits when choosing their residence. For example, citizens who usually like walking will tend to choose a community with a good walking environment [33]. At this time, the traffic behavior of residents is not mainly affected by the built environment, but the personal preference plays an important role. In some cases, individual travel preference has a great impact on commuting behavior, even exceeding the impact of the built environment. Therefore, if the self-selection mechanism exists but is not considered, the conclusion of the impact of the built environment on the commuting mode needs further research.

Cao[34] took five communities in the twin cities of Minnesota as a case study, investigated the built environment of the neighborhood, and found that both the built environment of the community and the travel attitude have a significant impact on the travel mode. In the suburban community, the attitude of being close to public transport has a greater impact on the commuting behavior than the built environment of the community, while in the urban community, their impact is more balanced. Mo[35] used the potential cluster analysis method to model, and found that people who like to travel by car have a negative attitude towards public transport and bicycle travel. When they enjoy the convenience, they do not choose to travel by slow traffic, while residents who often use public transport have a positive attitude towards traveling by car. When they feel that the cost of the whole process of travel is acceptable, they often use private cars. Chen[36] added the living environment to the theoretical framework that the three variables of behavior attitude, subjective norms and perceived behavior control determine the travel behavior intention. Through analysis, it is concluded that the above factors have significant positive effects on the behavior intention, the living environment also has significant positive effects on the behavior attitude and subjective norms, and the living environment has both direct and indirect effects on the public transport travel behavior intention. Zhang[6] added several factors to consider the urban road environment, such as the

sense of safety in walking, the sense of safety in crossing the road, and the degree of shade coverage, in order to make up for the neglect of individual perception in the study.

5. Conclusion

Several studies have analyzed the impact of built-up environment variables and residents' family socio-economic attributes on Residents' commuting travel mode choices through multiple logit regression models, and obtained that residents' commuting travel mode choices are different under different built-up environments. A few studies include the impact of residents' self selection mechanism. Considering the degree of preference of individuals is a method to control the impact of self selection mechanism, but further research is needed. The main conclusions are as follows:

(1) The urban built-up environment has a significant impact on the commuting mode of residents. The built-up environment in the residence has a greater impact on the daily travel of residents than that in the workplace. Land use density has a significant impact on commuting behavior, but different countries and cities have different requirements for land density. Different cities have different urban spatial structures. The built environment with higher land use mix and employment accessibility will promote residents' green travel and reduce the use of cars.

(2) There are many factors considered for individual socio-economic attributes, which is also the complexity of human being as a social organism. When making traffic behavior decisions, it is affected by various internal and external conditions such as time and space, family, life cycle, social structure and so on.

(3) Future research should analyze all the impacts of 7D elements. Traffic management demand is an important aspect of modern traffic planning. More in-depth research is needed on the built environment of the workplace. If the built environment of the workplace is not considered, it will lead to the uncertainty of the geographical background. In many studies, the North, Shanghai and Guangzhou are mostly taken as the research objects, and the universality of the conclusion is uncertain.

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