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IMPACTS OF THE BUILT ENVIRONMENT ON TRAVEL BEHAVIOUR IN URBAN VILLAGES: A CASE STUDY OF SHENZHEN, CHINA

YU LE

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Impacts of the Built Environment on Travel Behaviour in Urban Villages: A Case Study of Shenzhen, China

Yu Le

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Certificate of originality

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Abstract

With the increase of urban sprawl and commuting distance deriving from the job-housing separation in large cities, the amount of transportation carbon emission is sharply raising. It has become an urgent need to reduce the urban transport energy consumption and to encourage sustainable public transit. In contrast to the travel demand management measures, urban built environment plays a positive role on green travel mode promotion. Therefore, the built environment is considered as an essential method to decrease the auto dependency thereby encouraging people to choose public transit.

Urban renewal provides opportunities to improve the urban transport structure during the process of built environment improvement. In turn, the urban transport improvement also accelerates the pace of urban renewal, and further optimize land use and urban layout structure. The reciprocal relationship between urban renewal and transport is applicable to the situation of renewal of urban villages in China especially. Therefore, it is necessary to clarify the impact of different elements of the built environment on travel behaviour under the background of urban villages' renewal. This thesis reviews the impacts of built environment on travel behaviour and latest topics relating to urban villages qualitatively. From the microscopic perspective of individual travel behaviour, the analytical frameworks are proposed to investigate travel behaviour in terms of public transit choice and DiDi commuting trips.

In Chapter 4, this thesis focuses on the impact of the built environment of urban villages on residents' public transit choice behaviour. Basically, without considering the methodological bias of residential self-selection and spatial dependence, the built environment has shown significant effect on public transit choice behaviour for urban villages, which is quite different from that for commodity housing. Using data of residential travel survey in Shenzhen, China in 2014, the results in Chapter 4 indicate that mixed

land use generates an adverse effect on public transit choice, a surprising outcome which is contrary to previous common conclusions particularly.

Considering the effect of residential self-selection, Chapter 5 develops a SEM-Mixed logit model and elaborates settings of the endogenous and exogenous variables, as well as the mediation effect. It is found that after considering the self-selection effect, the influence of density, mixed land use and transit availability on travel distance, travel time and transit mode choice in urban villages are still significant. For urban villages, transit availability matters greatest for public transit promotion. However, the negative effect of density on transit mode choice and none effect of mixed land use are unusual as previous findings. This is partly because of relatively low income, low car ownership, and less elastic travel demand of dwellers in urban villages.

Considering the effect of spatial dependence, a Spatial Durbin Errors Model is established incorporating the spatial lag and spatial error in Chapter 6. Traveling information is employed from DiDi ride-sourcing company in morning and evening peaks as ride-sourcing commuting trips in Shenzhen from urban villages' areas and workplaces, and built environmental variables were scaled within travel analysis zones (TAZs). Results show that impacts of built environment on ride-sourcing commuting are different between job-housing locations with more influential factors in residential locations (urban villages), while larger influential magnitude in working locations where the magnitude is more than twice than that of residential locations. Besides, it is more effective to hinder ride-sourcing commuting and promote green traveling modes by increasing bus stops due to its spatial spill over effect.

The findings provide some insights into transit-oriented urban renewal. When transforming urban villages, emphasis should be put on enhancement of transit availability, and the mixed land use could be put in the last consideration with limited time and funds. This thesis contributes to the knowledge by addressing a special type of neighbourhood in order to narrow down the research gap in this domain. The findings help

to suggest effective measures to satisfy public transit demand efficiently and also provide a transit-oriented perspective for urban regeneration.

Keywords: built environment, urban village, public transit, residential self-selection, spatial dependence, commuting

Publications arising from the thesis

1） **L. Yu**, B. Xie*, E. Chan. Exploring Impacts of the built environment on transit travel: distance, time and mode choice, for urban villages in Shenzhen, China. Transportation Research Part E: Logistics and Transportation Review,132,2019. (SCI/SSCI, IF=4.253, JCR Q1)

2） **L. Yu**, B. Xie*, E. Chan. How does the built environment influence public transit choice in urban villages in China? Sustainability, 11 (1),2018. （SCI/SSCI, IF=2.592, JCR Q2）

3） **于乐**,谢秉磊,张鹍鹏,孙宇.职住地建成环境对网约车通勤出行影响研究[J].交通信息与安全,2019,37 (06):149-155.（北大中文核心）

4） **L. Yu**, B. Xie*, E. Chan, L. Jin, K. Zhang. Impacts of built environments on public transit choice behaviour: Comparison between urban villages and commodity housing in Shenzhen, China. The 6th International Conference on Transportation and Space-time Economics, Beijing, 2018.

5） **L. Yu**, B. Xie*, K. Zhang, L. Jin. Research on the influence of built environment of “urban village” on travel mode choice in Shenzhen. The 17th COTA conference International Conference of Transportation Professionals, 2017.

6） L. Jin, H Wang*, B. Xie, **L. Yu**, L. Liu. A User Exposure based Approach for Non-Structural Road Network Vulnerability Analysis. PLOS ONE, 12 (11), 2017. （SCI, IF=2.776, JCR Q2）

7） B. Xie, Y. Sun, Xiaolong Huang, **L. Yu**，Gangyan Xu*. Travel Characteristics Analysis and Passenger Flow Prediction of Intercity Shuttles in the Pearl River Delta on Holidays. Sustainability,12 (18), 2020.

8）Examining the impacts of residential self-selection on travel behaviour: a comparison between urban villages and formal residences. (in preparing， intend to submit to Sustainable Cities and Society)

9) The role of spatial dependence effect in mediating the built environment for regeneration of urban villages. (in preparing，intend to submit to Building and Environment)

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1. Introduction

1.1 Research background

The built environment is composed of various buildings and places that have been constructed or reconstructed by humankind (Ewing & Cervero, 2010). It is a combination of land use patterns, transportation systems, and a series of elements related to urban design that can affect residents' activities. After the industrial revolution, with the increase in population and the demand for housing, western cities entered a period of large-scale suburbanization. During the progress of suburbanization, the urban built environment has gradually changed, and the disorderly expansion of the city has brought about many urban problems, such as traffic jams, environmental pollution, and hollowing of the city center (Xinyu Cao, Mokhtarian, & Handy, 2009).

Throughout the world, cities are facing common challenges relating to urban sprawl. Urban traffic problems have become increasingly prominent in this process. Compared with policies or methods from a single perspective of traffic demand management, to reshape transportation structure to confront with massive traffic problems, guiding travel demand from the aspects of urban planning like land use and urban morphology, coordinating the development of urban planning and urban transport planning are becoming fundamental ways to solve urban transport problems. It has been an international tendency to seek solutions from integrating land use and transport for sustainable urban development (Hu, Erika Fille, Kee Khoon, Gih Guang, & Monterola, 2016; Taromi et al., 2015; Vale, 2015). Fundamentally, the increasing contradiction between motorized traffic demand and resource constraints in urban transportation urged the government no longer simply to provide transportation infrastructure, but more importantly, to guide travel behavior through urban planning methods to realize efficient and sustainable development of modern society.

Among the elements of urban planning, the urban built environment implicitly guides people's travel habits. More importantly, the urban built environment has a certain "lock-down effect" on residents' travel behaviour (Ding, Wang, Liu, Zhang, & Yang, 2017). Travel behaviour is determined by the spatial structure and functional layout of built environment at the macro level. Therefore, the optimization of the urban built environment is regarded as important means to shape a low-carbon urban spatial structure, guide the green and low-carbon travel patterns of residents, and deal with climate change problems.

Research on the relationship between built environment and travel behaviour was born in the 1960s during the process of American urban renewal to meet the needs of urban expansion and development (Bravo, Briceño, Cominetti, Cortés, & Martínez, 2010; Loo, Chen, & Chan, 2010). By the 1980s, the shortcomings of US highway construction brought about gradually, like air pollution, climate change and other issues caused by over-reliance on car trips. Meanwhile, driven by car traffic, large-scale suburbanization emerged, which in turn, has triggered more car trips (Farooq & Miller, 2012). Under this situation, the traditional predictive supply model gradually cannot meet the needs of traffic demand management. Scholars have begun to think about the feasibility of using traffic and land use policies as government intervention methods. If the government applies urban planning methods to shorten the distance between residence and travel destination, can it reduce car trips (Aditjandra, 2013; Börjesson, Jonsson, Berglund, & Almström, 2014; Waddell, 2011)? Since then, the research on the relationship between the built environment and travel behaviour has gradually evolved to explore the mechanism of influence. According to the research of Ewing and Cervero (2010), there had been more than 200 reported studies on the topic regarding impacts of the built environment impact on travel behaviour up to 2010 (Ewing & Cervero, 2010) and the debate on this research topic is still receiving growing attention from multiple disciplines' frontiers. In the 1980s, the concepts of "compact city", "smart growth”, and “new urbanism” believed that diversified land use and the public transportation-oriented built environment were conducive to reducing travel distances and promoting sustainable urban development (Xinyu Cao et al., 2009). As a result, the relationship between the built environment and transportation has gradually become a research focus on the area of urban planning, urban geography and other disciplines. Many planning scholars believe that a “green travel-oriented” built environment, that is, mixed land use, high-density development, pleasant walking environment, and convenient public transportation system can effectively reduce dependence on private cars (Hong, Shen, & Zhang, 2013; Lamíquiz & López-Domínguez, 2015; Sun, Ermagun, & Dan, 2017; L. Zhang, Nasri, Hong, & Shen, 2012).

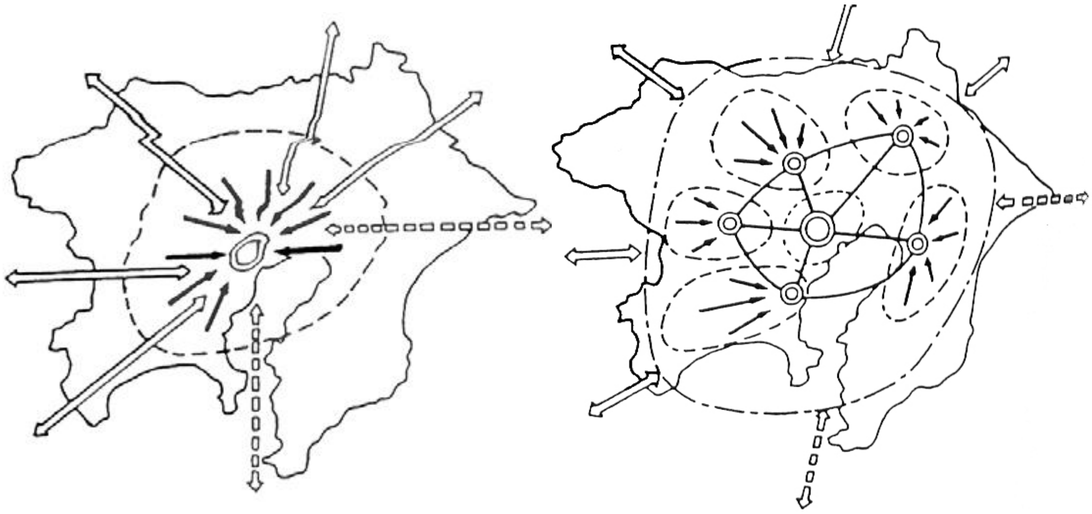


Figure 1 Travel distribution under mono-centric and polycentric urban form

As mentioned above, urban renewal provides opportunities for traffic improvement, and traffic improvement also accelerates the pace of urban renewal, further optimizing land use and urban layout structure. Urban renewal and traffic improvement can promote each other and interact as both cause and effect. Urban renewal must be carried out scientifically and orderly under the control of traffic planning. As an important driving force for urban renewal and a key leading force in the direction of urban development, transportation should be given sufficient attention in urban renewal. Therefore, it is necessary to clarify the impact of different elements of the built environment on travel behaviour under the background of urban renewal.

China is one of the largest countries experiencing large scale of urban renewal. In many areas of China, especially large and medium-sized cities undergoing accelerating urbanization, as one of the main targets of urban renewal, the need for renewal and regeneration of “urban villages” is particularly urgent. As an informal residential community, the urban village shows many inconsistencies with the development of the city. Traditional renewal of urban villages often adopt demolition and reconstruction ways, which play an important supporting role in improving land use efficiency and promoting sustainable urban development (Lai & Tang, 2016; Y. Lin, De Meulder, Cai, Hu, & Lai, 2014). However, as a low-cost living space, urban villages accommodate a large number of newly-increased urban employment populations and emigration populations from areas with high housing costs, which improved the flexibility of urban development. At the same time, the high-density population concentration of urban villages has relieved the trend of job-housing imbalance, and hence reduced the overall transportation cost of the city. Therefore, the urban village plays a role of a double-edged sword; the problem of urban villages cannot be solved blindly by demolition. Nowadays, differentiated and diversified renewal strategies are developing, and gradually the proportion of demolishment and reconstruction of urban villages are limited, which is constructive to encourage the comprehensive renovation and functional regeneration of urban villages to promote the organic and effective urban renewal.

(a)Urban villages (b) Commodity housing
Figure 2 Visual comparison between urban villages and commodity housing

Therefore, under the circumstances, new questions are arising in the research field of the relationship between travel behaviour and the built environment. Although many related studies have been conducted in the context of developed societies, the situation in China has not been understood explicitly or sufficiently. So far, there is little research on the interaction between urban village and traffic structure optimization, especially on the built environment characteristics, residents travel characteristics and the relationship between the built environment and residents travel behaviour involved in the process of the renewal of urban village. China is witnessing unprecedented urban development and regeneration over the past few decades. The regenerations in residential built environment and neighbour type have resulted in changes to jobs-housing relationships and ultimately daily travel demand, which has provided an important context for studies of the built environment and travel behaviour in urban China. In view of this, this research attempts to conduct theoretical analysis and empirical research on the influential mechanism of the built environment on travel behaviour in the context of urban village reconstruction in China to explore the relationship between built environment and travel behaviour. The research aims to explore an effective way to improve conditions of transport system by guiding the regeneration of the built environment in urban villages, which would help to provide better decision support for the organic renewal of urban villages and transport planning policies.

1.2 Research aims and questions

This dissertation intends to focus on the urban village, which is one of the most remarkable regenerations in neighbourhood type in China, to examine its distinctive features and the uniqueness of the associations between travel behaviour and the built environment. This study aims at not only deeper investigating the impacts of the built environment on travel behaviour, but also conducting a targeted urban form in China to fill a vacancy in this research domain. This study helps to better understand the mechanism underlying the built environment behaviour relationship by systematically exploring the relationships and their relative effects on active travel behaviour. In specific, this study aims to address the following.

(1) To identify the characteristics of travel behaviour of residents living in urban villages, and the particularity of built environment of urban villages.

(2)To understand the causal relationships of the residential built environment and travel behaviour in urban villages, and the difference compared to the relationship between built environment and travel behaviour in commodity housing.

(3)To analyse the factors that affect the travel behaviour of low-income people in urban villages, and reveal the travel behaviour decision-making mechanism of residents in urban villages.

(4)To identify the methodological bias that deviating the results of relationship between built environment and travel behaviour.

(5)To provide policy implications for transport and urban planning policymakers as a policy basis to better encourage public transit instead of car travel on the one hand, and on the other hand, to provide a valid support for urban planners to predict the movement of population in the process of urban regeneration.

Accordingly, several research questions have been developed corresponding to the research objectives, regarding the uniqueness, difference and application of this research.

(1) Does the common sense that people utilize public transit more and reduce automobile travel in urban neighbourhoods characterized by higher-densities, mixed land uses, and high connectivity fit the situation of urban villages?

(2) How to identify the causal relationship between the built environmental elements and the characteristics of travel behaviour in urban villages? Which of the built environmental factors are key factors affecting the travel behaviour in urban villages and which method more reasonable and reliable?

(3) Compared with the commodity housing, do the built environment variables of urban villages have stronger or weaker impacts on the travel behaviour, and are the influential factors different between urban villages and commodity housing?

(4) After considering the effect of the bias effect, like residential self-selection and spatial dependence, does the built environment still be significantly influential? How will the impact of the built environment on travel behaviour change in urban villages?

1.3 Definition and explication

1.3.1 Urban village

The term "urban village" ("chengzhongcun" in Chinese) refers to the situation where the city ends up encircling the village during urban expansion in China. Most of the farmland has been expropriated and urbanized, and only the villagers' original homesteads remain and controlled by the villagers (Yuting Liu, He, Wu, & Webster, 2010). Soaring real estate prices in the surrounding city reduce the possibility of an eventual expropriation and redevelopment of the area. In the meantime, the original residents make a good profit from renting rooms, mostly to migrant workers who have restricted access to formal urban housing, due to the high prices, and the lack of stable jobs and tax returns. Housing conditions are precarious, and villagers are not keen to invest much money, hoping for an eventual expropriation. Usually, the aborigines reconstructed their original cottages into multilayer buildings under poor quality arbitrarily without authorization from governments (see Figure1).

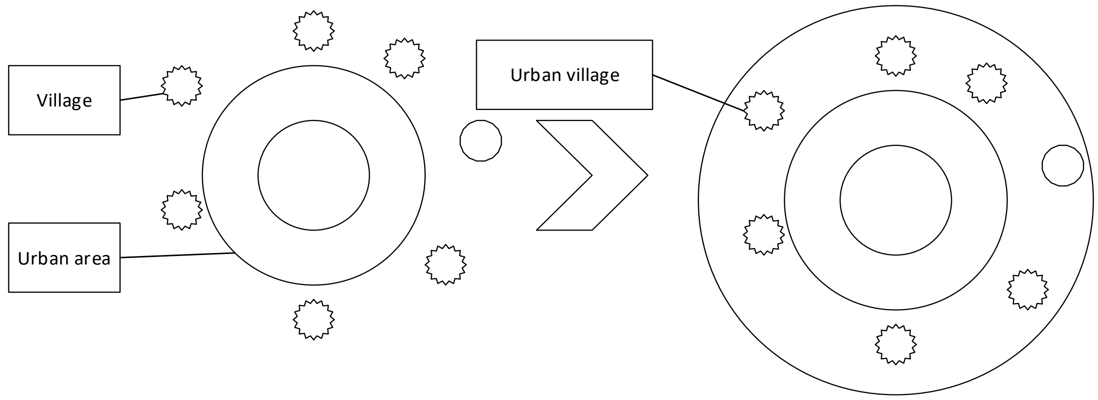


Figure 3 The evolution of the urban village

The large proportion and wide distribution of urban villages have determined its significant role in the urban transport system. Accordingly, the rising conflict between residents' travel demand and supply of transport facilities and service, both for commuting or non-commuting, has brought about concern and challenges to the administrative departments. It is convinced that to provide solutions for the travel problems for residents in urban villages could make a great contribution to alleviating urban transport problems at least from a short-term perspective (Hao, Geertman, Hooimeijer, & Sliuzas, 2013). On the other hand, in the long term urban villages are confronted with urban regeneration which is a complicated mission in the context of contemporary urbanization associated with various aspects where transport impact is one of the most important consideration. To accomplish regeneration of urban villages without traffic disturbance, it is crucial to understand the regular travel demand from the aspect of built environment of urban villages and reveal the in-depth causal relations. More importantly, if the urban village is up against demolish, where will the original residents be relocated and how will they choose a new residence is matters of much concern. To answer these questions, it is helpful to investigate how their daily travel behaviour relate to their residential built environment because travel behaviour, especially commuting behaviour is highly associated with choice of residential location apart from individual socio-demographic characteristics, and the built environment is an outward manifestation of residential locations. Therefore, to understand the impact of the built environment on travel behaviour in urban villages acts as the basis to provide solutions for urban transport problems and also suggestive reference for the movement of urban population so urban planner can make preparation in advance to avoid disorders.

Although the urban village is located in the urban area, it is independent of the urban planning and management system. It is a kind of urban informal residential community formed by self-development and self-evolution by the aborigines (L. H. Li, Lin, Li, & Wu, 2014). It is also a unique phenomenon in the rapid urbanization process in China. The problem of urban villages is an increasingly prominent problem that hinders urban development. It has a great relationship with the speed of urbanization, the quality of urbanization, the scientific and intensive use of urban and rural land resources, the adjustment of urban industrial structure, urban ecology, and urban modernization. Therefore, it is a major issue in China's sustainable economic and social development. With the further acceleration of the process of urbanization, the uneven development between regions, the gap between the rich and the poor and the gap between urban and rural areas have further widened, the problem of urban villages has become more and more complex, and the difficulty of solving them has become more and more difficult. The reconstruction of urban villages is an inevitable process of historical development. However, there are currently disputes over the regeneration of urban villages. This is mainly due to the negative and positive impacts of urban villages on urban and population development. Therefore, they cannot be demolished in a very single manner. First, the negative impact of the urban village is mainly manifested in the following aspects:

(1) Low efficiency of land use. As a part of the city, the urban villages are distributed in the built-up areas of the city, occupying valuable urban construction land. Superior location and the surrounding sound urban facilities of the village land has great appreciation potential and the development value, but most of the villagers of village land for homestead land for development or collective enterprises basically exclusive single-family and “Handshake Building”, the land use efficiency is low, and the land value is

not fully reflected (L. H. Li et al., 2014). China's per capita land resources are scarce, and urban land is particularly scarce. Economic development and urbanization require a large amount of construction land. The further development of many cities has been affected by the bottleneck of land elements. Therefore, non-intensive land use exists in urban villages. The status quo is a waste of resources. The waste of land resources in the village is serious. On the one hand, due to obvious location advantages and loose population management in urban villages, and the low construction cost of farmers for their own homesteads, the real estate rental market in urban villages has become increasingly prosperous. Many villagers in urban villages only rely on renting apartments. On the other hand, although villagers can earn personal income by renting their apartments, the extensive leasing market in urban villages has a very low land utilization rate and a serious waste of land resources (Ying Liu, van Oort, Geertman, & Lin, 2014).

(2) Complex population structure and poor living environment. The population structure of the urban villages is mainly composed of two groups of people: one is the aboriginal villagers of the urban villages. These aboriginal villagers refer to farmers who have lived here before the formation of urban villages. Many of them have already handed in agricultural land in their hands to obtain rental income by renting out covered apartments (yani, 2014). The second is the floating population. Low rents in urban villages can satisfy their demand for low-cost housing, so urban villages have also become concentrated residences of migrants. The poor living environment is mainly due to three reasons: First, the apartments in the urban villages are mostly illegally built by the indigenous villagers in the village. The spatial structure of the apartments and the living comfort of the tenants are not considered at all, and the apartments built are mostly dense. Second, due to the lack of unified planning and unified management for the regeneration of urban villages, and the non-synchronization of the regeneration time, urban villages have become a huge construction site. Construction waste is everywhere, noise is constant, and the sanitary environment in the village is extremely poor, which

is easy to breed public health emergencies (Xue, 2014). Third, due to the complex composition of the population in the urban villages, different lifestyles and cultural exchanges, coupled with the imperfect administrative management system of the urban villages, and the lack of management, the social security situation in the urban villages is severe, and the living environment of the villagers, especially the social environmental condition is extremely poor.

(3) Incomplete transportation infrastructure. Since the vast majority of apartments in the urban village are private illegal construction, not only the poor quality of housing and with the support of the infrastructure is not perfect, mainly in the four side surfaces (Zhou, 2014). First of all, due to the chaotic layout of apartments in urban villages, the public roads in urban villages are much narrower than in cities, and the roads are uneven and severely curved. Generally speaking, motor vehicle lanes and fire-fighting passages in cities require smooth and wide roads, but the road conditions in urban villages simply cannot meet the minimum standards for establishment of these public facilities. When there are fires, explosions, and patient emergency treatment in urban villages, In the event of a situation, fire trucks and ambulances simply could not reach the designated disaster relief and rescue sites, and the results were disastrous. Second, many roads in urban villages have broken ends, and the road network system is incomplete. Also, there are structural problems, and the traffic microcirculation capacity is insufficient. Third, the internal residential land and freight storage land in the urban village are mixed, resulting in a disordered mix of passenger traffic and freight traffic. Fourth, most of the urban villages have insufficient parking facilities and roadside parking phenomena is popular with is harmful to the road traffic.

However, the positive role of the urban village is mainly manifested in the following aspects:

(1) It unburdened the government in terms of accommodating large amount of migrant workers in large cities (Kochan, 2015). On the one hand, with the rapid development

of the urban economy, the demand for labor in cities has continued to increase; on the other hand, scientific and technological progress has accelerated the process of agricultural modernization. A large number of surplus rural laborers have poured into cities from rural areas, and the supply of labor has continued to increase. The result of the combined effect of the above is that the number of migrants entering the city has increased substantially. Most of these migrants entering the city have only received a junior high school education. Due to their limited knowledge and labor skills, most of them are engaged in the dirtiest jobs in the cities, although they have made contributions to urban construction and urban development. But their income is relatively low, and the low rents in urban villages can just meet their most basic needs for housing, and urban villages have become a relatively concentrated residential area for migrants. From this point of view, urban Nakamura absorbs a large number of migrants, and to a certain extent shares the burden of resettling these migrants by the city and the government.

(2) It provided social security and economic supplements for land-lost farmers (El-Geneidy et al., 2016). The rapid development of urbanization will inevitably be accompanied by the expansion of urban scale. For a long time, land has been the only source of income for farmers. For villagers in urban villages, after their cultivated land is requisitioned, the only thing they can rely on is the collective land of the homesteads. The superior geographical location of urban villages can enable farmers owning urban villages to obtain substantial land rent. They can obtain considerable personal income by renting out converted apartments on their homesteads to migrant workers. It can be seen that the existence of urban villages can provide good fortune for land-lost farmers.

(3) The low cost of living provides a shelter for low-income groups. At present, the government has not been able to build enough affordable housing and low-rent housing to solve the housing problem of low-income groups (H. Song, Pan, & Chen, 2016).

Therefore, the low rent of urban villages can provide these city builders with low housing rent. In the urban housing system, there should be three levels of housing supply: high, medium, and low. However, in order to maximize profits, real estate developers in most cities tend to prefer the supply of high-level housing, and relatively little supply of middle-level housing and low-level housing, but the existence of urban villages can fill this gap. The existence of urban villages meets the needs of low-income groups for low-level housing, and urban villages have become the best housing choice for low-income people.

(4) From the aspect of urban transport, the separation of home and work in the city has been alleviated. As urban villages accommodate a large number of newly-increased urban employment populations and emigrants from areas with high housing costs, these populations choose to live in urban villages in consideration of closeness to employment. The high concentrated population has eased the trend of separation of employment and housing to a certain extent. Therefore, from the macro perspective of the city, the wide distributed urban villages in big cities provide more living location options for the urban employed population, and plays a certain role in alleviating urban transport jam. This reduces traffic congestion and helps reduce the total costs of the entire city.

To conduct regeneration strategies, several characteristics of urban villages should be considered, including the land use situation, the geographical location, the current functional income sources， the degree of agglomeration of the migrant population, resource conditions, major problems, construction levels, facility environment, public security conditions, market conditions, land value, development intensity, and industrial development orientation, etc. (Hao, Sliuzas, & Geertman, 2011; F. Wu, Zhang, & Webster, 2012). This research studied mainly for residential villages. Basically, there are two types of regeneration strategies.

The first regeneration type is *Demolition*. Urban villages belonging to this type usually are distributed in the built-up area of the city center areas. These villages have been completely surrounded by the city, and they are completely different from the surrounding cities in terms of landscape and material space. These communities still retain and implement rural collective ownership, but because the development of the city has expropriated their original agricultural land, the villagers no longer have land to engage in agricultural production. Due to the good location and the high economic value of land and real estate, most of the collective land is developed disorderly, and homesteads are built seriously, and the building density is high.

The second regeneration type is *Upgradation*, which is also called comprehensive regeneration of urban villages are mainly distributed in the current built-up area of the main city and the planned built-up area in urban fringe. These villages are located in the suburban area and still have a small amount of agricultural land, but most of them are located in the key construction areas of the city. These kind of villages are very different from the urban landscape, the physical space of the villages is relatively chaotic, public facilities are lacking, and a large number of urban floating population gather in such urban villages, some even exceed the local villagers by several times, and diverse cultures blend here. The villagers are basically not engaged in agricultural production, and most of them rely on rent as their main source of living. However, due to the large amount of urban villages have undertaken the role of city's low-rent housing, it is not feasible to completely demolish and rebuild the urban villages in the short term. Therefore, it is more realistic to carry out comprehensive upgradation of such urban villages and promote partial or overall renovation in batches in a planned manner. The method of upgradation is mainly to improve the appearance of the building, partially demolish it, which includes renovating the road in the village, and increasing public service facilities. In addition, the establishment of cultural squares and the addition of supporting cultural and sports facilities are also important aspects for the upgradation of urban villages.

Figure 4 An example of upgradation: Shui Wai International Talent Apartment Project in Shenzhen, China

1.3.2 Travel behaviour

Travel behaviour refers to the movement of people with certain purpose. Under normal circumstances, travel behaviour includes the following characteristics: ① Travel rate, that is, the number of trips made by an individual in a certain period of time (usually a day), ② Travel purpose , ③ Travel mode , ④ Travel distance , ⑤ Travel time , ⑥ others (departure / arrival time, the origin and destination, etc.).

Travel demand is an individual's need to participate in various activities that are discretely distributed spatiotemporally. Travel demand is the derived demand of daily activities. On this basis, the activity-based travel behaviour analysis model has received widespread attention. The decision-making process involves multiple dimensions of travel behaviour. In the long term the commuting distance has to be decided; in the medium term, the car ownership and travel modes have to be decides; in the short term, the daily travel distance has to be decided. The activity demand mentioned in the research review of this research will interfere with the judgment of the relationship between the built environment and travel behaviour, so it is necessary to distinguish the types of travel activities.

The city gathers high-density population and social and economic activities. It is a complex, dynamic and giant system. Residents complete work, housework, entertainment, shopping and other activities in different places in the city, as well as spatial movement between places. As a dynamic connection within the urban activity system, travel behaviour is actually a set of activities derived from people's daily activities, reflecting the time and space participation of residents in the city. The emergence of the activity analysis method connects residents' activities with travel and movement, and believes that travel is a derived demand of activities. Activities and travel are related in terms of time, space and participants. At the same time, they occur under limited resource constraints and space-time constraints.

Generally, when classifying the types of travel activities, travel trips are divided into ①work trips , ②school trips , ③business trips , ④shopping trips , ⑤living trips , ⑥recreation trips , ⑦return trips, etc. According to the purpose of travel, it can be subdivided into: ①work-based travel, ②home-based school travel, ③home-based shopping travel, ④home-based other travel.

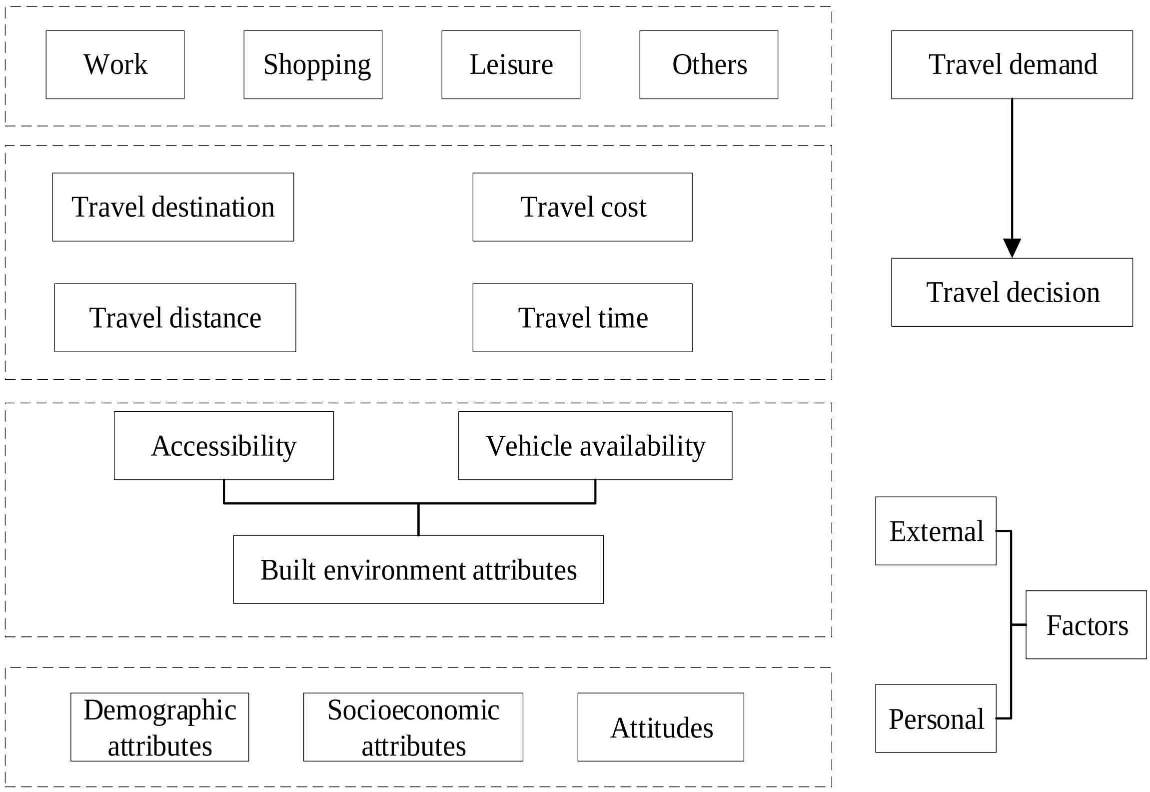


Figure 5 Influential factors for activity-based travel behaviour

The activity-based analysis method believes that travel demand stems from people's needs for social and economic activities, and the purpose of travel is to participate in different activities at different times and in different places. Therefore, activities are the foundation of travel demand analysis. It is the activity demand that triggers travel demand and affects important decisions such as travel mode and destination choice. The research focuses on the selection of activities and travel opportunities, methods, time and location, as well as the activities needs, preferences and habits of travelers and their families, community culture, social norms, transportation service levels, work and living environment and other factors constitute the research and the behavioural basis of the method (L. Liu, 2017). The activity-based method is conducive to characterize the mutual influence and restriction of each trip in terms of practice, space, and mode attributes.

In view of the demand attributes of travel activities mentioned in the research review, it will interfere with the judgment of the relationship between the built environment and travel behaviour. It is necessary to classify travel behaviour according to the purpose of the activity. At the same time, combined with the background of this research, nearly 80% of the travel activities of residents in urban villages are commuting trips based on home, and the remaining about 20% of non-commuting trips are not distinguished by obvious characteristics. Therefore, according to the research background and research needs of this research, trips of urban village residents are divided into commuting trips and non-commuting trips.

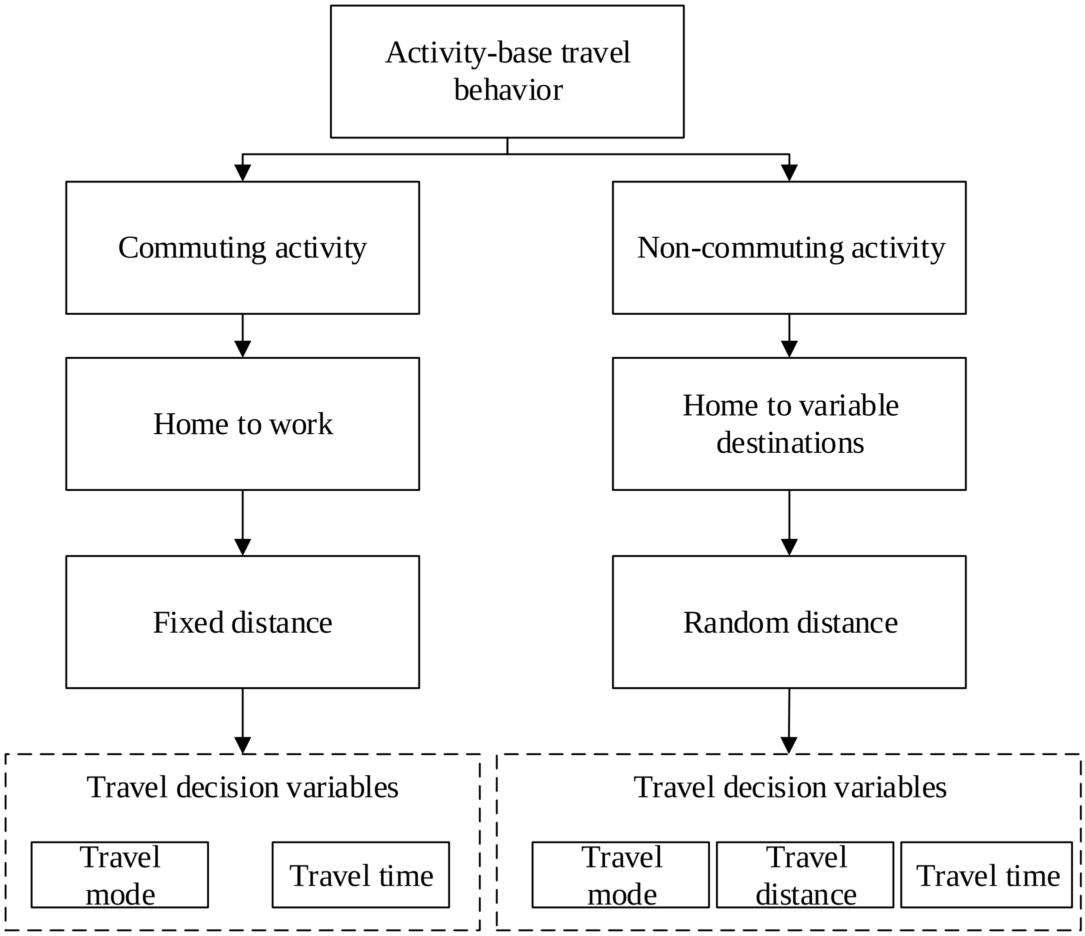


Figure 6 Travel decision variables classified by activity-based travel behaviour

In addition, travel mode is an important characteristic variable in travel behaviour analysis. The choice of travel mode in urban transport is closely related to travel distance.

Generally, in urban transport, the choice of travel mode is closely related to travel distance. The schematic diagram is shown in the Figure 7.

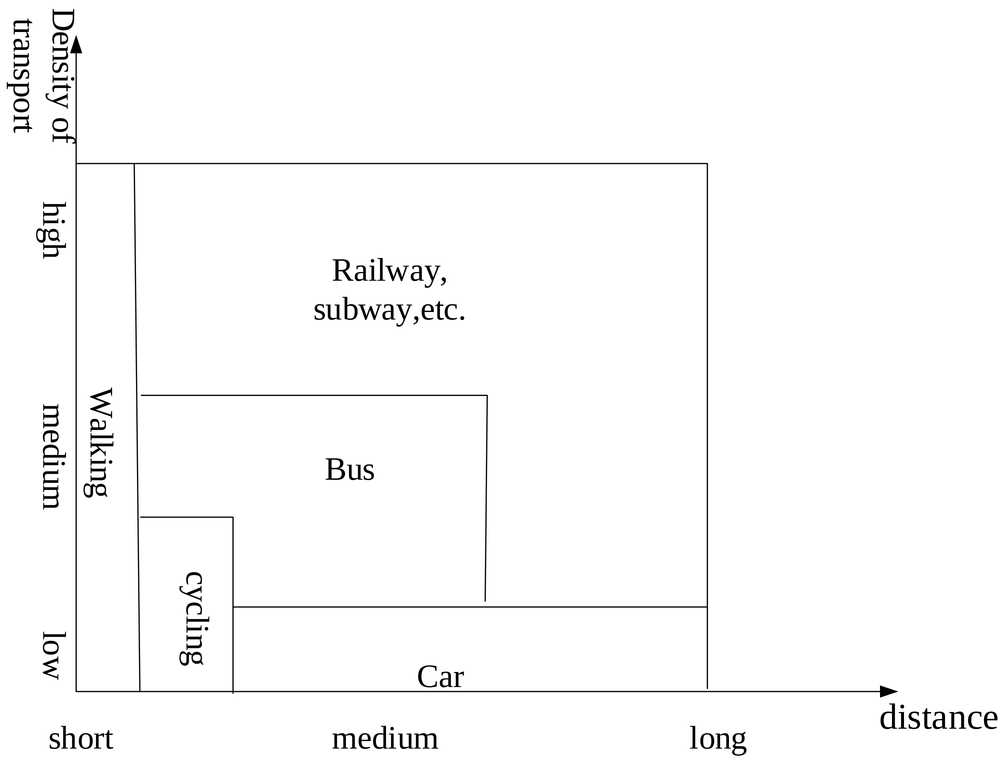


Figure 7 Characteristics of urban transportation modes

Travel behaviour is a conscious and purposeful social activity of a person, a product of the interaction between man and the environment, and a process of achieving a predetermined purpose through a series of actions. When studying the impact of the built environment on travel behaviour, because it is from the perspective of travel individuals, although the urban built environment forms the physical space environment for travel, it has a deep-rooted long-term impact on the daily travel of urban residents. However, the influence of personal and family factors on travel behaviour cannot be ignored, such as household income, car ownership, living habits and personal preferences.

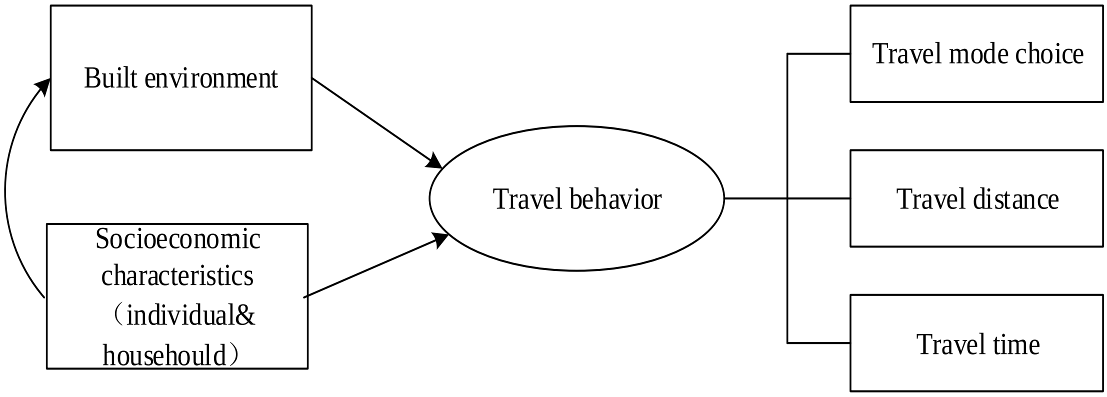


Figure 8 General research framework of the impact of built environment on travel behaviour

(1) Individual socioeconomic attributes are effective tools for identifying travelers and describing them objectively. Personal attributes that affect residents' choice of travel mode include gender, occupation, age, and education level, etc. Women are found to be more inclined to choose public transportation mode, walking or bicycle for commuting trips, while men are more inclined to choose driving for commuting trips (Elias, Benjamin, & Shiftan, 2015; Lee, 2014); men’s commuting distance and time are longer than women’s, the reason is that women also undertake daily housework. Company employees, managers, and other hired persons have a higher probability of choosing a car when traveling (Sharma & Chandrasekhar, 2016). Young people use more motorized travel, while the elderly have a higher proportion of walking trips, and older travelers (greater than 65 years old) are found to have lower levels of family car ownership and are more inclined to choose public transportation and carpooling Travel (J. Feng, 2017). Residents with a high level of education are more likely to choose a car to travel, and their commuting distance are longer; however, in high-density urban centers or places where rail transit is accessible, groups with high levels of education are found to also prefer to choose traveling by public transport (Ding, Wang, Tang, Mishra, & Liu, 2016).

(2) In terms of the household characteristics, the household car-ownership has a significant impact on individual travel mode choice behaviour. Families with higher incomes are more inclined to choose cars when traveling, and families with children use private transportation more (S. Yang, Fan, Deng, & Cheng, 2017). When the level of ownership of a certain vehicle in the family is higher, the corresponding frequency of use is also higher. For example, when the family has a large number of cars, residents tend to use cars for travel; when the family has a large number of bicycles, residents tend to use bicycles for travel (K. Choi & Zhang, 2017). Generally speaking, the results of research on travel choice behaviours different from family travel are more consistent.

1.3.3 Built environment

The subject of this research is the impact of the built environment on travel behaviour, so clarifying the elements of the urban built environment is also one of the key points. From the literature research, it can be found that there are many types of elements involved in the urban built environment, whether all of them need to be adopted, which elements must be included, and how to measure the built environment element indicators is one of the key issues that need to be fully considered (Cervero, 2002; Clark, Scott, & Yiannakoulias, 2014; J.-J. Lin & Yu, 2011). The built environment the product of human civilization. The land use patterns and transport systems are crucial compositions of the built environments. On the one hand, the built environment shapes people’s activity spaces, restricting people's behavior and activities through specific factors such as the accessibility of various facilities and the connectivity of the road system. On the other hand, the group regularity of individual behavior and performance also reflects people's needs for the built environment, which can promote the optimization and transformation of the existing built environment by the urban planning.

The built environment is composed of various buildings and places that are constructed and transformed by humans, especially those environments that can be changed through policies and human behaviour, including the site selection and design of residences, commerce, offices, schools and other items, as well as walking paths, bicycle lanes, green islands and roads. In the field of transportation and travel behaviour, the research elements of the built environment mainly refer to land use patterns, transportation systems, and a series of elements related to urban design that affect the behaviour of residents. The elements of the built environment has developed from “3D” to “5D” as Figure 9 shows.

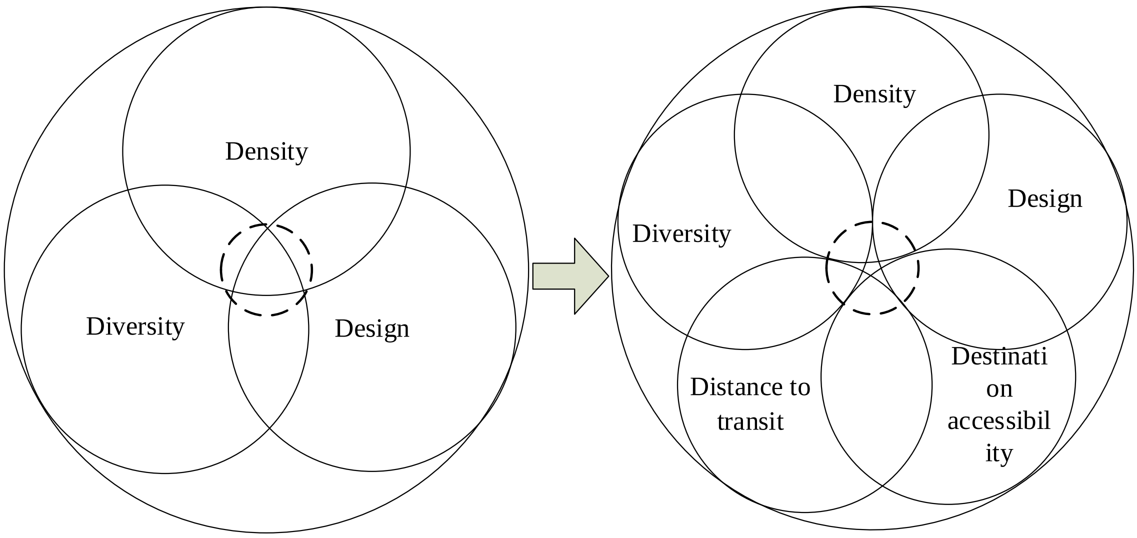


Figure 9 Elements extension from “3D” to “5D” of urban built environment

Density is mainly used to measure the intensity of the distribution of activities in the built environment of a city. It is often characterized by population density and job density.

Diversity is used to measure the types various activities and how the activities distribute in the urban built environment. The entropy index is often used to express the degree of mixed land use. Usually, the land use in the specified area is divided into k meter * k meter grids, and the proportions of various types of land use are calculated in each grid, as shown in the formula as following.

$$MixedLanduse = -\sum_{i=1}^{n} \frac{P_i * \ln P_i}{\ln(n)} \tag{1}$$

P_i is the proportion of the i-th type of all land use types in the current grid, and n is the total number of land use types in the current grid. The calculated *MixedLanduse* values from 0 to 1. The smaller the value, the lower of the diversity is and vice versa. When the value is 0, it means there is only a single type of land use in the grid. The higher the value is, the more diverse the land use is.

Design mainly refers to the design of the street network in the urban built environment. In the study of travel behaviour, road design indicators are often used, such as the width of motor lanes, the proportion of sidewalks, and the proportion of bus lanes.

Distance to public transportation stations is mainly used to measure the convenience of neighborhood-scale public transportation service facilities. It is often characterized by the distance to nearest public transportation stations or the distance to subway stations.

Destination accessibility is mainly measured from the perspective of the accessibility of job opportunities or the distance to a public CBD. It is often characterized by car and public transportation accessibility.

Table 1 General “5D”attributes for Built environment

“5D”attributes for Built environment	General indicators
Density	Population density, building density, residential/ employment density.
Diversity	Mixed land use， variety of POI
Design	Design of urban road network， including width of road, % of sidewalks, etc.
Destination accessibility	Distance to destination or CBD

Distance to transit	Convenience of transit, including number of bus stops within certain limits, distance to transit stations, etc.

From the viewpoint of geographic unit, when measuring the built environment to interpreting travel behaviour, the geographic unit can be divided into three levels like macro, medium and micro. The macro level focuses on the entire city, focusing on the impact of urban expansion and infrastructure layout on the operation of the urban transportation system; the medium level involves the composition of one or more regions, mainly focusing on density, mixed land use, and street connectivity; the micro level mainly focuses on the impact of the building and its location, including the impact of site design, street size, distance of public facilities, on individual travel behaviour.

Although the distance from the city center is not an adjustable built environment attribute of the urban village in the regeneration, it can reflect the location characteristics of the urban villages. At the same time, this index is also an indispensable dimension in the “5D” of the built environment, so it also needed to be incorporated as a built environment indicator. In summary, the built environment indicators selected in this thesis include the following aspects, as shown in the Figure 10.

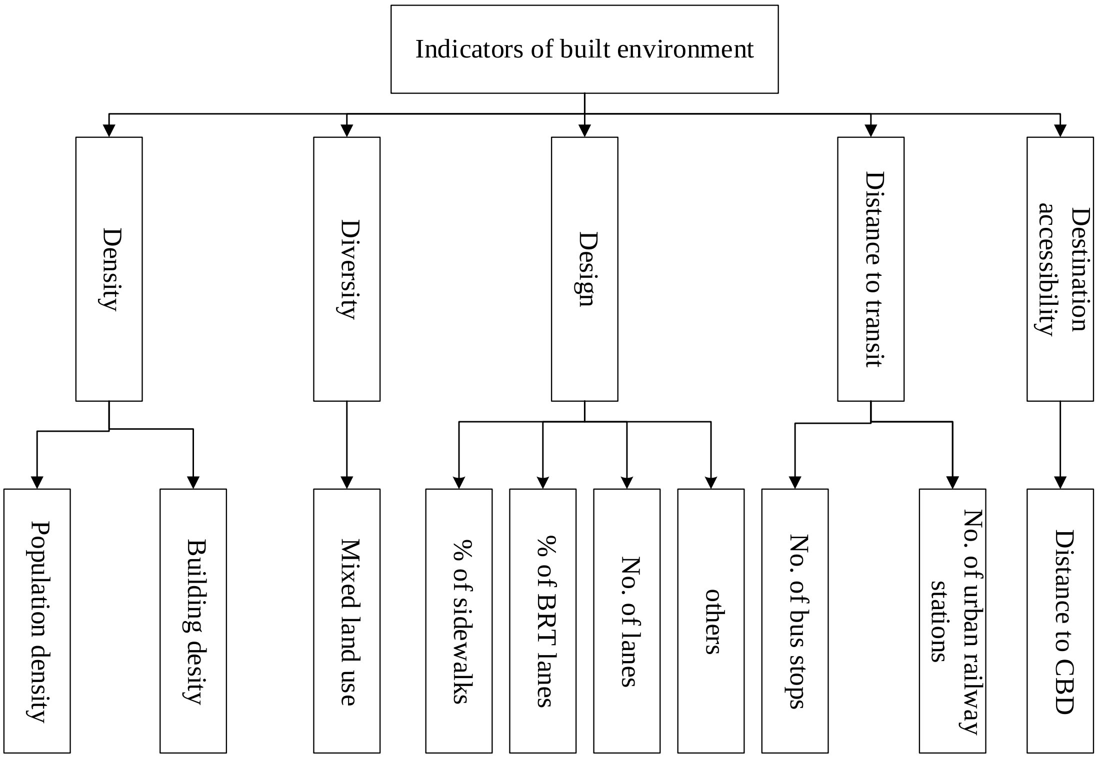


Figure 10 Indicators of built environment for urban villages in this research

1.4 The interaction between urban village renewal and transportation system

1.4.1 The interaction between urban land use and urban transport

The interaction mechanism between land use and travel is the basic theory to investigate how the built environment affecting travel behaviour. There is a complex interactive relationship between urban transport and land use, which is manifested as a “source-flow” relationship on a macro level (Xu & Yang, 2019). Land is the carrier of urban social and economic activities. The spatial separation of various types of land causes traffic flow, and the traffic flow between various types of land forms a complex urban transportation network (Siming Li & Liu, 2017). On the one hand, land use is the source of urban transport, which determines the occurrence, attraction and mode of urban transport, and regulates the urban transport demand and its structural pattern from a macro perspective. On the other hand, traffic changes the accessibility of urban areas which plays a decisive role in the attributes, structure and form of land use. The spatial separation of different land uses in cities is the source of traffic demand. The distribution and intensity of urban land use directly affect the travel frequency, travel distance and travel modes (Reisi, Aye, Rajabifard, & Ngo, 2016; Soria-Lara, Aguilera-Benavente, & Arranz-López, 2016). The urban transportation system, in turn, is an important factor affecting land use.

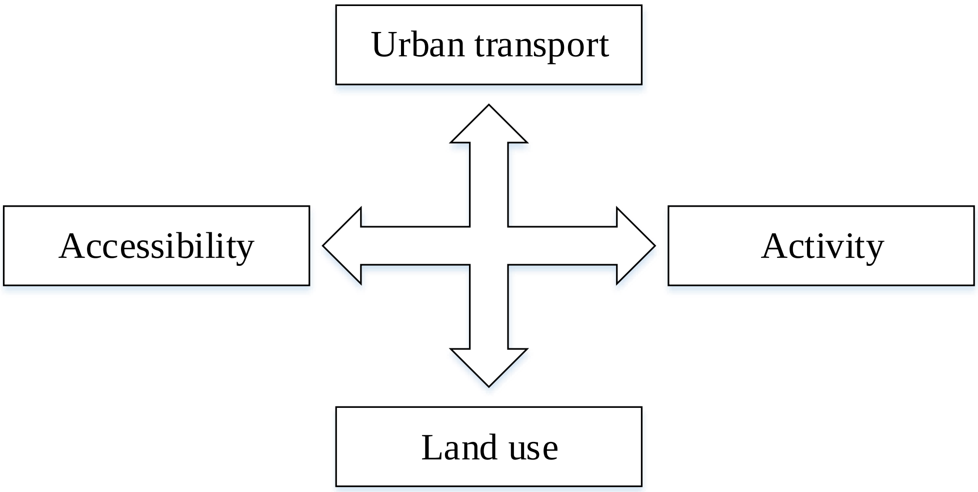


Figure 11 Interaction between land use and urban transport

It can be seen from the "source-flow" relationship between urban transport and land use that urban land use patterns are the basis for the formation of urban transport patterns, and specific urban land use patterns will lead to certain corresponding urban transport patterns; In turn, specific urban transport patterns also require corresponding land use patterns. Urban land use is the carrier of urban social and economic activities (Siming Li & Liu, 2017). The different spatial nature and types of land use trigger the generation transport demand, so land use is the source of traffic demand. Different types and intensities of land use also trigger different travel purposes and mode choices (W. Liu & Qin, 2016). The spatial distribution of land use determines the spatial distribution of various activities, as well as the temporal and spatial distribution of transport. At the same time, the supply of the transport system provides the possibility and way to realize the transport demand. Traffic demand affects land use and its activities. If the transport facilities are provided, and the transport demand can be realized (Ignaccolo, Inturri, Le Pira, Caprì, & Mancuso, 2016). Areas with well-developed transportation facilities have high accessibility and greater attractiveness, attracting more travel, thereby increasing the value of land use which includes land use type and intensity.

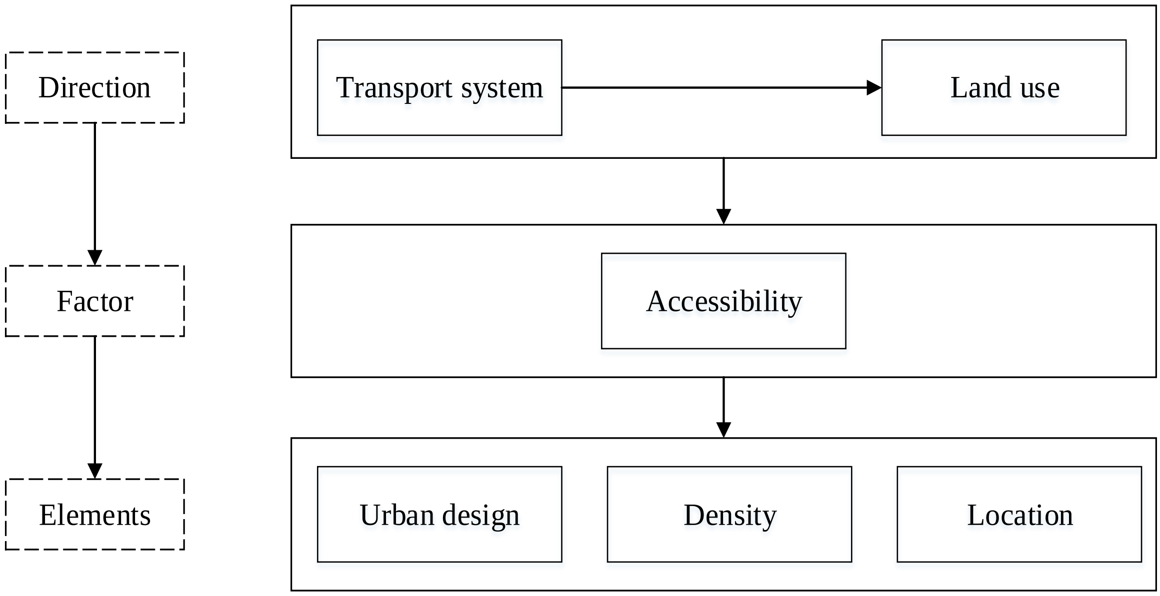


Figure 12 The influence of transport system on land use

As to the influence of land use on transport system, changes in land use elements such as the nature of land use, land use intensity, land use structure, land use scale, and the population density and employment density it carries, will induce the transformation of the number of trips, travel modes and patterns and temporal and spatial distribution. As a result, the total conditions of the transport system's facility structure, layout, and services are required to make adjustments to adapt to the new transport demand; otherwise land use changes will have a negative impact on the transport system. Specifically, from the perspective of microscopic travel behaviour, changes in land use intensity will cause changes in travel volume. The higher the intensity of land use, the greater the travel volume is. Under the condition of unchanged transport facilities, the service level of transport facilities will decrease. If the increase in land use intensity is large, the increase in travel volume will exceed the capacity of transport facilities, so that the transport system needs to be reformed.

To prevent intensified traffic congestion, it needs to provide transport facilities with larger capacity which will improve the transport system to adapt to changes in land use. In this process, there may also be changes in the choice of travel modes. When the intensity of land use increases leading to more travel and road congestion, if good public transport service facilities are provided, some residents may turn to choose public transport instead of using private car. The impact of this change on the transport system is positive, but if the transport system does not make corresponding changes, various traffic problems will arise.

Changes in the nature of land use will cause changes in travel distances and travel modes. When the diversity of land use increases, people will travel shorter and less choose private cars. While the travel distance is shortened, it will also affect the choice of travel mode. Short-distance travel is conducive to promoting the development of public transport and non-motorized modes. However, if the supply of public transit and non-motorized facilities are not considered enough when the nature of land use changes, it will cause a deeper dependence on private cars, which will aggravate the regional traffic congestion. Based on the classic interactive feedback mechanism of land use and urban transport, it can be seen that the impact of the urban built environment on travel has deep-seated reasons.

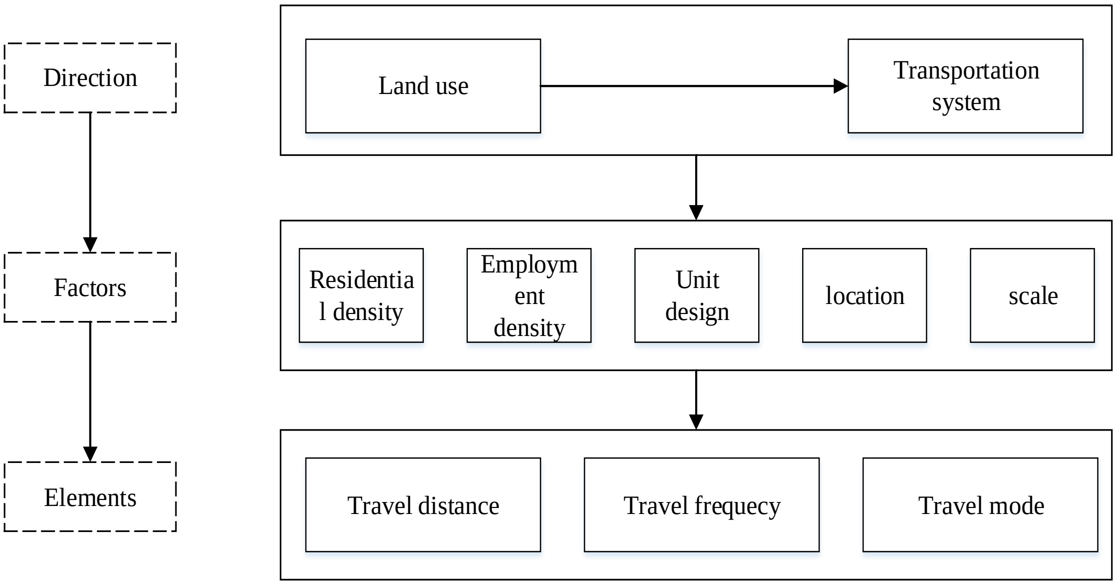


Figure 13 The influence of land use on transport system

On the one hand, land use change requires the adaptation of transport system; on the other hand, the transport system will generates demand and for land use change. Every time the transport mode is improved, the construction of the transport network will promote the evolution of the urban spatial patterns and promote the adjustment of the land use layout. The improvement of transport patterns and the construction of the transport network have saved travel time, changed the accessibility of various urban destinations, and caused the re-selection of the location of various industries and living activities, which was directly reflected in land use. It also causes changes in land price, location, spatial distribution and other characteristics (H. Su et al., 2014).

1.4.2 The interaction between urban renewal and urban transport

For a long period, the urban master planning has paid more attention to the urban fabric and structure planning, the layout of land use, public service facilities planning, etc. When implementing urban macro-planning, the transport system has not been thoroughly and comprehensively evaluated. In recent years, with the shortage of resources, the restrictive factors of population based on the comprehensive tolerance of resources have been put forward. It is proposed that population development cannot exceed the tolerance of resources, but it faces traffic bottlenecks, whether it is the development and forecast of population size or land. The using scale of forecasts does not take traffic tolerance as a reference indicator. In an over-developed city, on the one hand, there is a failure in the transport supply, that is, increasing transport facilities cannot effectively solve the urban transport problem (Börjesson et al., 2014). On the other hand, there will be no unlimited supply of transport facilities. Therefore, to following the demand of coordinated development of transport and land use, the tolerance of transport resources should be regarded as one of the limiting factors for the scale development of cities or regions (D. Lin, Allan, & Cui, 2015).

The major problems of current urban renewal major problems are existing in two aspects. First, less land can be used in the built-up areas for new facilities, because land values and property values are high, the demolition of old buildings is difficult so that it is difficult to use built-up area to update the overall regional areas, and the road form and layout of urban areas are difficult to change significantly. Second, the central areas of most cities are faced with very prominent problems such as partial lack of functions, partial old buildings, insufficient environment, high population density, traffic congestion and parking problems (Rye, Green, Young, & Ison, 2011). With the development of high urban transport mobility, the problems of traffic congestion and parking difficulties have become the crucial problem waiting for effective solutions, and also have become a tough problem to be faced in the process of urban renewal. In the process of urbanization in China, the traditional planning system is not suitable for high-speed urbanization and marketization (Bravo et al., 2010). The planning strategies and implements have been out of control and led to traffic congestion, the chaos of urban-rural junctions, and the loss of traditional urban features. The increase in motor vehicles is much faster than that of roads and other transport facilities, and the unreasonable layout of urban road networks leads to more traffic jams (Batarce & Ivaldi, 2014).

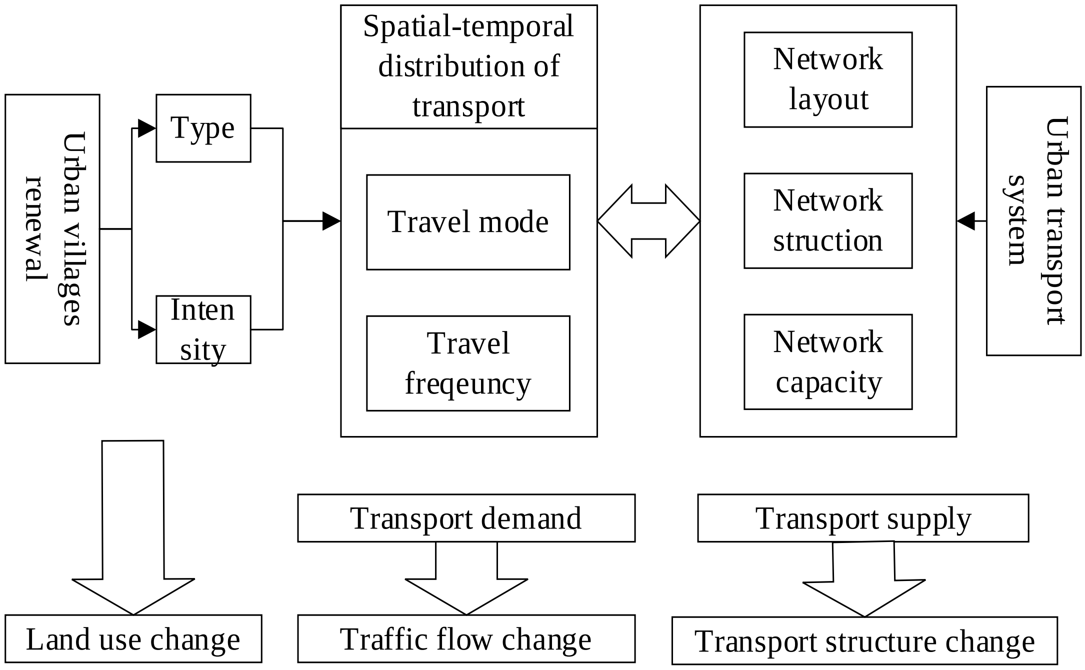


Figure 14 The interactive relationship between urban village renewal and transport system

As one of the main forms of urban renewal, the regeneration of urban villages is the basic goal of transforming a low-density single residential area to a medium or high-density composite functional residential area. The regeneration of urban villages can lead to major changes in the area's land function, development intensity, and functional organization of the plot. However, at the same time, this kind of regeneration will lead to a negative effect on urban transport because of transport not adapted to changes in land use. Some scholars have pointed out that in the recent urban renewal planning and implementation process, the original plot was simply adjusted and the original road network continued to be used to organize the living because the road network layout was not adjusted according to the changes in land use functions. The spatial layout of the district has caused the spatial form not adapted to the requirements of the new residential area, and new traffic problems have arisen as a consequence. In the process of urban renewal, if the original road network was not improved synchronously, it would be difficult to bear the high-density development and the high-intensity and decentralized travel demand with characteristics of new travel behavior in new residential areas.

The interactive relationship between urban village reconstruction and transport system is shown in the Figure 14.

With the advancement of urbanization and urban renewal, the regeneration of urban villages has taken an especially increasingly important position in urban development. The regeneration of urban villages is not only an important means to improve the physical environment, promote urban development, and excavate urban land use, but also a key opportunity to improve urban traffic conditions and guide the city to a green and sustainable development .

1.5 Significance of this study

(1) From the perspective of theoretical significance, the impact of the built environment on travel behaviour is a hot issue in the fields of urban planning, transport planning, and geographical science research. As a unique city spatial form in China, there lacks in-depth research on the characteristics of the built environment, the characteristics of travel behaviour, and the relationship and evolution between the two in the special context of urban villages. Therefore, the development of this research is helpful to enhance a scientific understanding of the development law of urban built environment and its relationship with travel demand under the background of urbanization and urban renewal in China. The connection between this built environment and travel behavior has important theoretical value. This research tracks the latest achievements in related disciplines such as urban and rural planning, transport science, behaviour science, and system science, and captures the travel characteristics and the differences in travel behaviour caused by the difference in the urban built environment, so as to analyse the internal influential mechanism of built environment-travel behaviour. In addition, this research takes the interference of residential self-selection effects into account, which is an important bias interfering the relationship between built environment and travel behaviour. A joint analysis model was established to measure the true impact of the

built environment, which enriches and perfects the key technology of correlation mechanism, and provides theoretical and methodological support on a more accurate comprehensive interpretation of the influence mechanism of travel behaviour. Finally, by incorporating the spatial dependence effect into the model system, the thesis provides a theoretical basis for the division of urban village renewal units, and enriches the knowledge system of built environment-travel behavior research.

(2) From the perspective of practical needs, although urban villages have relatively prominent social problems, it must be noted that urban villages have accommodated a large number of newly-increased urban employment populations and migrants from areas with high housing costs in the city. The population concentration has eased the trend of separation of work and residence to a certain extent, which is conducive to reducing the operating costs of the entire city. Therefore, in the context of differentiated renewal, it is also of great significance to carry out research on the impact of the built environment of urban villages on travel behaviour. On the one hand, by studying the impact mechanism of the built environment and travel behavior of urban villages, it helps city governors to correctly understand the status and role of urban villages in different stages of urban development, and rationally allocate social resources through differentiation and diversification of urban renewal strategies. The renewal strategy of urban villages can be promoted organically, orderly and effectively as a consequence, which also is helpful to promote urban spatial transformation and optimization. On the other hand, considering the impact of spatial morphology changes and the adjustment of population occupational structure on travel behaviour, reasonably predicting the temporal and spatial distribution of traffic demand, through urban villages differentiated update strategies and transport improvement measures to resolve possible traffic and social problems synchronously.

1.6 Dissertation Structure

The analysis frameworks used in this study are mainly correlation analysis framework and comparative analysis framework. The correlation analysis framework refers to the use of mathematical methods to reveal the influence of the urban built environment on residents' travel behaviour in urban villages, and to conduct statistical tests of significance. The comparative analysis framework mainly refers to the comparative analysis of the differences between urban villages and formal residence in the impact of the built environment on travel behaviour. The structure of this dissertation is shown in Figure 15.

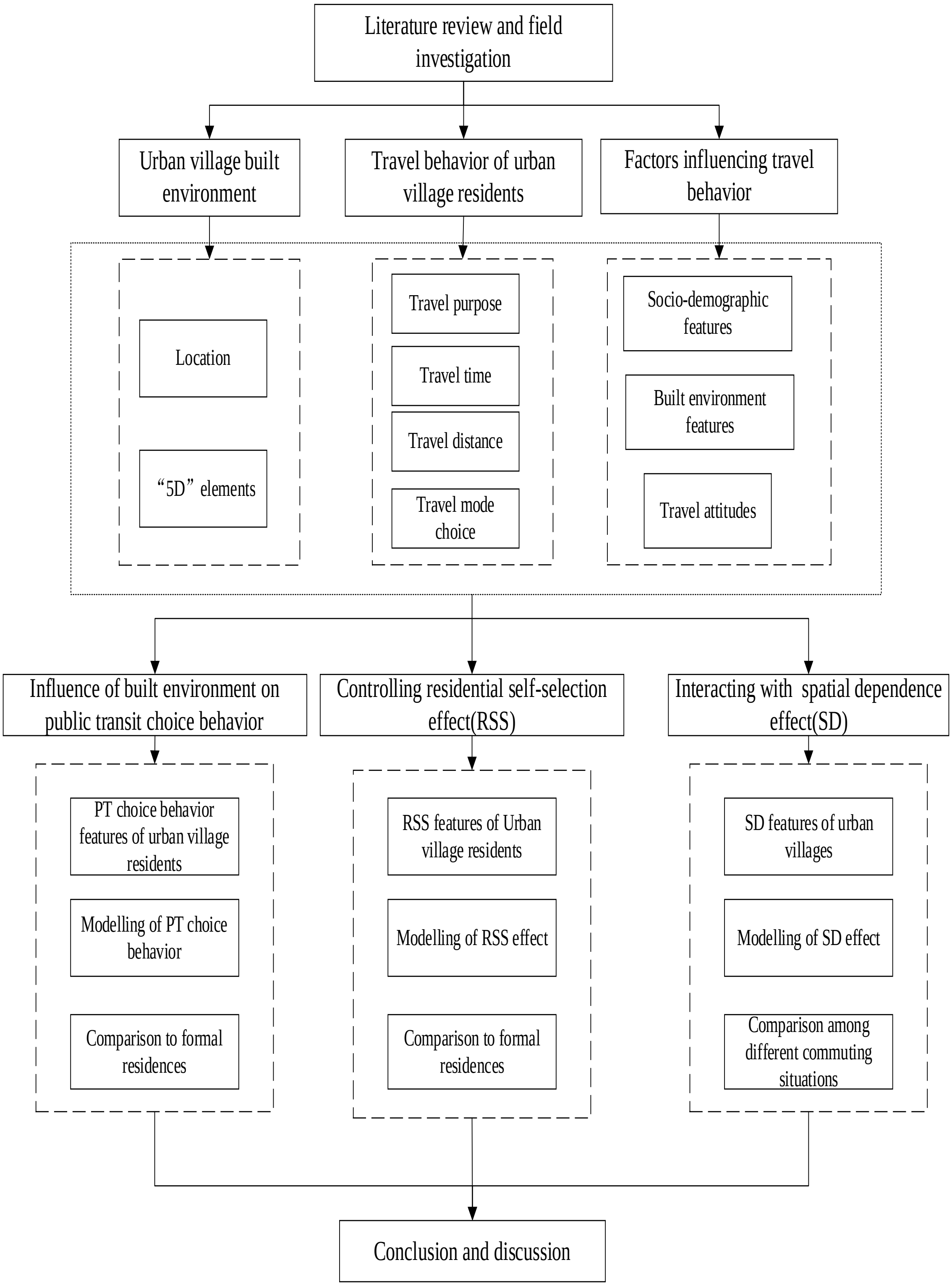


Figure 15 Research framework

2. Literature review and theoretical context

2.1 The relationship between the built environment and travel behavior

After the Industrial Revolution, as the population increased and there was a greater demand for housing, cities in Western countries entered a period of large-scale suburbanization. In the process of suburbanization, the urban built environment has gradually changed, and the disorderly expansion of the city has brought about many urban problems, such as traffic jams, environmental pollution, and the hollowing of the city center. To solve these tough problems in big cities, many planning scholars believe that a green transport-oriented built environment, that is, mixed land use, high-density development, pleasant walking environment, and convenient public transportation system can effectively reduce dependence on private cars and low-carbon transport. Non-motorized travel mode is an effective means to achieve ideal transportation goals.

In the 1980s, the drawbacks brought about by the construction of highways in the United States gradually emerged. Excessive reliance on private cars, climate change, and the effects of obesity on the health of the population has become increasingly prominent. The traditional transport prediction model is gradually unable to meet the needs of transport demand management. Planners began to think about the feasibility of implementing integrated transport and land use policies as a means of government intervention. If the government adopts urban planning measures to shorten the distance between the place of residence and travel destination, could people reduce the distance traveled by cars (Boarnet, 2011; Handy, Cao, & Mokhtarian, 2005)? Since then, the research on the relationship between the built environment and travel behaviour has gradually evolved to explore the mechanism of their causal relationship. Further, adjusting the built environment has been considered to be potential to moderate travel demand, acting as a basis tool for the formulation of public policies.

In fact, as early as in 1920, the research origin is the location theory from classical economics focusing on the interaction between urban transport and spatial form. Under the framework of location theory, it is claimed that investors choose the location of lowest cost including land use cost and transport cost (Srinivasan, 2002). Since 1980, with the intensification of transport and environmental problems in large cities in developed countries, the urban built environment, which has a broader meaning than land use, has been introduced to transport research frontiers. Meanwhile, some new urban planning concepts like new urbanism and compact city were put forward, expecting to moderate the travel demand through changing the built environment (M. B. R. Crane, 2001). With the rapid growth of related research, the relationship between the built environment and travel behaviour has been investigated in different regions. A variety of methods have been adopted to measure the built environment and travel behaviour variables (R. Crane, 2000). Although the results are not identical, there are some commonalities. The compact, highly mixed land use and the high accessibility to public transport can significantly change the way that people choose a travel mode (Sun, Ermagun, & Dan, 2017). Diversified land use and a public transportation-oriented built environment are conducive to reducing travel distances and promoting sustainable urban development.

Different from the natural environment, the built environment is the product of human civilization. It usually consists of three components: land use pattern, urban design and transport system (Ewing & Cervero, 2010). In transport research frontiers, the built environment is usually described from five aspects, called “5Ds” elements: density, diversity, design, distance to transit and destination accessibility (Cervero, 2003). Travel behaviour refers to a change in people's spatial displacement and how the people use transport facilities. It usually includes travel purpose, travel rate, travel distance, travel time and travel mode choice. Generally, the impact of the “5Ds” on travel behaviour are identified and discussed in the following aspects.

2.1.1 Density

Density is usually measured by population density or residential density. With the increase of spatial density, the residential location becomes closer to employment, thus the travel distance is shortened, and residents will be more likely to use public transit and non-motorized mode to work (Cai, Jia, Chiu, Hu, & Xu, 2014; Xinyu Cao & Fan, 2012; Xinyu Cao et al., 2009; Chatman, 2008; C. Chen, Gong, & Paaswell, 2007; Hui & Yu, 2013; J. Yang, Chen, Le, & Zhang, 2016), while Etminani (2016) from Iran argued that density had a significant impact on non-motorized travel in a home-based work and non-work trip but minimal impact on motorized travel (Etminani-Ghasrodashti & Ardeshiri, 2016). Severe transport congestion, well-developed public transport, and limited and expensive parking in dense areas also discourage commuting by car (Limtanakool, Dijst, & Schwanen, 2006). On the other hand, provision of public transit facilities in dense areas is always more abundant than that of sprawl areas. The parking space is relatively less in turn, thus these factors also lead to a reduction in the possibility of car travel (Clifton, Singleton, Muhs, & Schneider, 2016; J. Feng, Dijst, Wissink, & Prillwitz, 2017; S.-N. Kim, Choo, & Mokhtarian, 2015). However, a study of New York found that due to the heterogeneity of occupations, there are differences in the conclusions about the impact of density on travel mode choices (Salon, 2009). Some believe that for travel behaviour, there is weak or even no association between density and whether residents choosing a way to travel by car (C. R. Bhat & Eluru, 2009), but residents' travel attitudes and lifestyle substantially make a difference (Kroesen, Handy, & Chorus, 2017).

Although different scholars have differences in the measurement of density, most studies believe that there is a close relationship between spatial density and travel behaviour (Xinyu Cao & Fan, 2012; J. Yang et al., 2016) . With the increase of spatial density, more residents use public transport and non-motorized transport to go to work, thereby reducing the use of cars (J. Kim & Brownstone, 2013). The high-density-oriented development can better enable the unemployed to find jobs that match them locally, and help reduce the demand for long-distance transport (Xinyu Cao, Næss, & Wolday, 2019). In terms of travel mode choice, the increase in residential density tends to reduce the choice of private cars, while the increase in employment density will shorten the commuting distance (Ao, Yang, Chen, & Wang, 2019). A home-based study on work and non-work travel behavior suggested that residential density has a great influence on non-motorized travel, but has minimal impact on motorized travel (C. Chen et al., 2007). In addition, under normal circumstances, traffic congestion in high-density areas is serious, public transport services are complete, and parking fees are expensive. These factors also reduce the possibility of car travel (De Vos, Derudder, Van Acker, & Witlox, 2012). However, due to the heterogeneity of occupations, the conclusions on the influence of density on travel mode choice will also be different. Several other studies have pointed out that the relationship between whether residents choose to travel by car and the density of residential areas is weak or even non-existent, while psychological factors such as residents' travel attitudes and lifestyles have a greater impact (Kamruzzaman, Shatu, Hine, & Turrell, 2015).

As to researches focusing on classified population, a study found that minorities and low-income groups living in high-density areas consume less commuting energy (J. Kim & Brownstone, 2013). Another study in Quebec, Canada found that respondents living in the suburbs and urban fringe regions with lower population densities generally travelled, respectively 27% and 70% longer than those living in the central area (Maoh & Tang, 2012). But at the same time, they also pointed out that increasing the population density in the suburbs of cities may not be able to reduce travel distance significantly, unless a new urban center is built in the suburbs. However, Song et al. (2016) surveyed 11037 trips in Massachusetts, USA, and believed that the new built environment characterized by high density is conducive to reducing residents' travel (S. Song, Diao, & Feng, 2016).

However, some studies have found that there is a non-linear relationship between residential population density and travel behaviour. When the population density reaches a certain level, the effect of continuing to increase its density on reducing traffic will not be significant (Ding, Chen, & Jiao, 2018). In addition, Brand's study (2013) in the UK showed that the impact of residential population density on travel is not significant. Ding et al. (2015) taking Washington of the United States as an example, found that the population density of the workplace is more important than the population density of the residence in reducing the mileage of motor vehicles and their energy consumption and greenhouse gas emissions (Ding, Ma, Wang, & Wang, 2015). In addition, residential density (building density) is also negatively related to low-carbon transport. A study conducted in the Putje Bay area of the United States found that increasing residential density can significantly reduce traffic (its elasticity coefficient is -0.15%) (Hong, Shen, & Zhang, 2013). The study taking Jinan as an example showed that the average transport energy consumption of residents in the communities with the highest residential density is much higher than that of other types of communities (Jiang, Deng, & Seto, 2012). They pointed out that a high-density urban built environment is not an effective model for reducing traffic energy consumption under the context of China.

2.1.2 Diversity

Diversity is also called mixed land use, and it measures the diversity of different types of land uses that pertain to a given area and the degree to which they are represented in land area (Robert Cervero, 1997). Diversity is usually calculated by entropy, wherein low entropy indicating single-use and high entropy indicating more varied land uses (Chuan Ding et al., 2016; N. Wu, Zhao, & Zhang, 2016). The related research has been paying close attention to two aspects: one aspect is focusing on the value of non-residential land in the vicinity of residential land, especially land for retail use; the other is focusing on the issue of job-housing balance, of which the geographic scale of this type of research is relatively larger, and its potential purpose is to reduce traffic congestion during rush hours and improve air quality.

It is generally believed that when service facilities, housing, and employment sites are adjacent to each other, that is, when there is high mixed land use or high diversity, the travel distance can be reduced and non-motorized travel can be promoted (Handy, Boarnet, Ewing, & Killingsworth, 2002). On the one hand, mixed land use can increase the chances of residents working nearby and reduce the need for car commuting (De Vos, 2015; Limtanakool et al., 2006). Also, mixed land use may make other travel needs of residents satisfied on or near the commuter route, reducing the need for traveling by private cars (L. Yang, Shen, & Li, 2016). Meanwhile, in business traveling activities, it has been proved that integrated land use has a strong negative correlation with travel distance as well (Siming Li & Liu, 2016).

However, some researchers claim that the impact of mixed land use on travel modes choice is not as significant as expected (Frank, Bradley, Kavage, Chapman, & Lawton, 2007; Gehrke & Clifton, 2017). Some scholars even have found that mixed land use has no significant impact on travel mode choice (Xiaoshu Cao & Yang, 2017; L. Cheng et al., 2019; Ding et al., 2017; Haybatollahi, Czepkiewicz, Laatikainen, & Kyttä, 2015). In these research cases, the diversity of land use is much unimportant than other features of built environment.

2.1.3 Design

Design refers to street network characteristics within an area. Road networks vary from dense urban grids of highly interconnected, straight streets to sparse suburban networks of curving streets forming loops (Clauss & Döppe, 2016; J.-J. Lin & Yu, 2011; Zhong & Bushell, 2017). It usually measures road density, number of intersections per square mile, the proportion of BRT lines, and other features of road networks. In general, less parking space, continuous sidewalks, grid-like road systems, and agreeable walking environments like TOD-designed community induce residents to adopt green transport modes (Hong et al., 2013; D. Kim, Park, & Hong, 2017). For example, when using the ratio of the length of the sidewalk to the length of the road center line to measure the urban walking environment, the better the walking environment, the lower possibility of residents driving alone (Zailani, Iranmanesh, Masron, & Chan, 2016). Besides, the increasing road connectivity is conducive to inducing residents to choose non-motorized modes of travel (Mitra & Buliung, 2014; H. Su et al., 2014). The better the walking environment is, the less likely it is for residents to drive a car alone (Manaugh & El Geneidy, 2015). Small-scale and small-grid blocks are conducive to reducing the energy consumption of residents' travel (Y. Zhang, Wu, Li, Liu, & Li, 2014).

Nevertheless, another study claim that increasing the density of main roads would improve the possibility of commuting by private car and public transit simultaneously (Ma, Mitchell, & Heppenstall, 2014). In addition, a study conducted in Shanghai by Gang et al. (2013) does not find a significant effect of road network design on commuting mode choice (Gang, Guande, Zhaohui, Daqing, & Shijian, 2013).

2.1.4 Destination accessibility

Destination accessibility refers to the distance from residence to urban employment and various infrastructures, including destination accessibility, community accessibility, and accessibility to certain modes of transport infrastructure (Papa, Silva, Te Brömmelstroet, & Hull, 2015). Destination accessibility is measured by the number of jobs or other attractions reachable within a given area with a method of gravity model (Chudyk et al., 2015; Clifton et al., 2016). The distance from the city center directly determines the accessibility of urban residents to public facilities and services. The closer you are to the city center, the better the destination accessibility is; the more destinations you can reach within the same distance, the less the use of cars, and the higher the possibility of green transport people will choose (Vojnovic et al., 2016; Xu & Yang, 2019).

Especially, compared with other types of travel behaviour, commuting is more likely to be affected by distance between the place of residence and the place of employment (Chatman, 2008; Ma, Liu, & Chai, 2015). Taking Beijing as an example, the spatial mismatch between residence and employment, as well as lack of public service facilities increased the use of private cars; residents living close to their work locations tend to travel shorter distances (Ma et al., 2015). It is also believed that the distance between the residence and the city center has a significant positive overall effect on commuting. Therefore, the disordered expansion of the city should be controlled and the multi-center development should be promoted to reach a job-housing balance (Xiaoshu Cao & Yang, 2017).

2.1.5 Distance to Transit

Distance to transit is usually measured as an average of the shortest routes from the residences or workplaces in an area to the nearest rail station or bus stop (Cervero, 2007; C. Chen, Varley, & Chen, 2010; Hahm, Yoon, Jung, & Kwon, 2017). Alternatively, it may be measured as transit route density, the distance between transit stops, or the number of stations per unit area (Kwan & Weber, 2008). Public transport supply level or bus proximity also has a large impact on travel behaviour. Despite the continuous urban sprawl, major commercial activities and transport infrastructure are still concentrated in urban centers (Vale, 2015). Thus, the location or distance to city centers determines the accessibility to attractions. The better the accessibility, the less the travel distance and the less the car is used, resulting in a higher probability of green transport modes (Hahm et al., 2017; Tribby, Miller, Brown, Werner, & Smith, 2016; D. Wang & Zhou, 2017). For example, Limtanakool (2006) found that in the area with comprehensive public transit service in Dutch, people were more inclined to choose public transit instead of using cars in the medium and long-distance trips (≥ 50km) (Limtanakool et al., 2006). Another study using Seattle residents' travel behaviour survey data also confirmed that the farther away from the bus or subway station, the possibility that residents choose to travel by car and travel time would both increase (Hughes & MacKenzie, 2016). Research in Australia believes that there is a negative correlation between the proportion of public transport trips and transport energy consumption (Brownstone & Golob, 2009).

Studies based on Chinese context almost consistently show that the supply of subway services can effectively reduce traveling by private cars (Xiaoshu Cao & Yang, 2017; S. Yang et al., 2017; Y. Yang, Xu, Rodriguez, Michael, & Zhang, 2018), but the role of conventional public transport is not significant (R. Liu & Wong, 2018). Some scholars even found that it has a positive effect on car traveling in empirical studies in Beijing and Guangzhou (Xiaojing Xia, 2014).

Although variables regarding the built environment are roughly classified and divided by ambiguous and unsettled boundaries with intersected variables in each category that may change in the future, it is still typically found useful to use the "D" variables to organize the empirical literature and provide order-of-magnitude insights for travel behaviour research.

2.2 Neighborhood type and residential self-selection

However, empirical studies on the relationship between built environment and travel behavior usually display inconsistent results regarding influential factors and magnitude. As the understanding of this research topic continues to deepen, general analysis on the associations between travel behaviour and the built environment are no longer enough for increasingly sophisticated demand of individual travel and urban development in large cities where various urbanites with different socio-economic backgrounds are living in diversified neighbourhoods. A specific question has arisen as to whether the neighborhood type makes a difference to the dissonance (Xinyu Cao, 2015; T. Schwanen & Mokhtarian, 2005)? Neighborhood type is always associated with geographical location (urban or suburban), income distribution (the low-income or the high-income), residential environment (advanced or decayed), thus it is necessary and effective to investigate the relationship between the built environment and travel behaviour focusing on one specific neighborhood type because these spatial and socio-economic characteristics play significant roles in disturbing the impacts of the built environment on travel behaviour.

Considering the great cost and promised benefit of implementing land use policies, it is critical to understand the underlying causal relationship between the built environment and travel behaviour rather than to only observe an empirical association. Although a considerable number of studies have been conducted to test their correlations, only few of them have shed light on the direction of the causality between what type of residential neighborhood one chooses and what travel behaviour one produces (Xinyu Cao, 2009, 2015; Manaugh & El Geneidy, 2015; T. Schwanen & Mokhtarian, 2005). For example, Schwanen & Mokhtarian (2005) randomly selected households of three neighborhoods in the San Francisco Bay Area and assessed the impact of residential neighborhood type dissonance on distance traveled overall as well as by transport mode (T. Schwanen & Mokhtarian, 2005). The results suggested the weekly distance traveled overall and the distance by private vehicle are shortest among true urbanites and longest among consonant and dissonant suburban travelers pooled, with mismatched urban dwellers falling in between these extremes and the level of neighborhood type mismatch affect distance traveled overall as well as by rail and bus (T. Schwanen & Mokhtarian, 2005). Cao (2015) examined the influences of neighborhood type, travel attitudes, and their interaction terms on commute mode choice and concluded that urban neighborhood is positively associated with transit commute and has a negative association with solo-driving commuting (Xinyu Cao, 2015).

Actually, the principle of the effects of neighborhood type choice is residential self-selection which confounds the relationships between the built environment and travel behaviour. Residential self-selection is commonly defined as the process by which households choose their residential location based on their desired and expected travel behaviour (Sinniah, Shah, Vigar, & Aditjandra, 2016; Ming Zhang & Zhang, 2018). An ongoing debate regarding how to interpret the research findings of the built environment and travel behaviour focuses on the phenomenon of residential self-selection to carry implications for the efficacy of land-use policies in influencing travel behaviour (De Vos et al., 2012; Olaru, Smith, & Taplin, 2011; D. Wang & Lin, 2017; Ming Zhang & Zhang, 2018). The influence of the built environment on travel behaviour of residents may be overestimated because of residential self-selection effects, because these studies rely on observational rather than experimental data, they tend to substantiate only that there is a statistical association between travel and the built environment (Tran, Zhang, Chikaraishi, & Fujiwara, 2016). These biases on the influence of the built environment may mislead policymakers. Even when controlling for observable demographic factors, there may be unobserved heterogeneous travel preferences that are correlated with neighborhood environments, confusing the analysis (Hong et al., 2013). For example, research has yet to establish the extent to which people living in walkable neighborhoods walk more because the built environment itself 'causes' them to do so, because people who like to walk choose to live in residential neighborhoods where they can walk, or due to some combination of the two considerations (C. R. Bhat & Eluru, 2009; Heres-Del-Valle & Niemeier, 2011). Others have argued that such results imply that the built environment actually enables alternative travel behaviour by allowing households to self-selection (Næss, 2013), and that this self-selection may provide a non-trivial contribution to driving reduction in addition to any causal effect of the built environment (Krizek, 2003).

The theory of self-selection is relatively simple. People's choices are based on (1) variables included in a model (including interactions between the variables); (2) variables not included in the model ('omitted variables') (including their mutual interactions); and (3) interactions between the variables from (1) and (2). A problem is that (3) can exist: the unobserved variables can be correlated with the observed variables

(Humphreys & Ahern, 2017). In this case, the estimated effects attributed to the observed variables might in fact be partly or completely due to the unobserved variables with which they are correlated. To understand the impact, we might include the characteristics of the built environment (e.g. densities, mixed land use, distance to railway stations), socio-demographic variables (such as age, sex, income), but fail to measure the preferences to certain travel modes (Ming Zhang & Zhang, 2018). However, the preferences for modes may be correlated to residential choice: people with a preference for travelling by bus will, on average, live closer to bus stops (Sinniah et al., 2016). Ignoring this preference leads to an overestimation of the impact of the distance to railway stations on travel behaviour. As a consequence, preferences for residential locations and attitudes toward travel modes will systematically differ between different geographical settings, and explain at least part of the observed differences in travel behaviour between locations (Acheampong, 2018; Ibrahim, 2017; T. Lin, Wang, & Guan, 2017; D. Wang & Lin, 2017). Jinhyun Hong (2013) examines the effect of residential density on CO_2 equivalent from automobile using more specific emission factors based on vehicle and trip characteristics, and by addressing problems of residential self-selection (Hong & Shen, 2013). Drawing on the 2006 Puget Sound Regional Council Household Activity Survey data, the 2005 parcel and building database, the 2000 US Census data, and emission factors estimated using the Motor Vehicle Emission Simulator, the influence of residential density on road-based transport emissions was analyzed. In addition, a Bayesian multilevel model with spatial random effects and instrumental variables is employed to control for self-selection. The results indicate that the effect of residential density on transport emissions is influenced by residential self-selection. Results still show, however, that increasing residential density leads to a significant reduction in transport emissions (Hong & Shen, 2013).

In turn, to study effects of residential self-selection is a necessity for predicting the residential relocation choice in relation with travel behaviour. When measuring residential location preferences, the location attributes are considered from several aspects, including the built environment of the residential community, socioeconomic and demographic attributes of the individual, commuting considerations and the cost-related attributes of the residential unit (Schirmer, Van Eggermond, & Axhausen, 2014). Therefore, to understand the relations among residential self-selection, the built environment and travel behaviour is the foundation to predict how residents in urban villages will relocate the new residential community.

The reason for the initial concern about residential self-selection is that researchers found that different residential communities often have different research conclusions. The relationship between the built environment and travel behaviour of similar types of residential communities shows similar characteristics, while the built environment and travel behaviour of different types of residential communities There are obvious differences in behavioural relationship characteristics (T. Lin et al., 2017; Næss, Peters, Stefansdottir, & Strand, 2018). Therefore, the researchers put forward a reasonable hypothesis based on this phenomenon. Residents' autonomous choice of settlements, that is, residential self-selection of residence, affects residents' travel behaviour, and this influence will cause a deviation in the understanding of the relationship between the built environment and travel behaviour (Kroesen, 2019). For example, some residents themselves are very inclined to use public transport rather than cars to travel, so they tend to choose residential areas with good public transport services. In other words, these residents' own attitudes towards different transport modes make them choose residential areas that are more convenient for public transport and less motorized vehicles; it is difficult to define the extent to which the built environment reduces car travel. Therefore, ignoring the residential self-selection can easily lead to a deviation in the estimation of the impact of the built environment on traffic. Some studies incorporate many socio-economic factors into the regression model to solve the self-selection problem of residence, but after controlling for the self-selection effect, the impact of certain built environment factors on travel becomes insignificant (Guan & Wang, 2019).

2.3 Spatial dependence effect

A large number of studies have confirmed that a variety of built environment factors have significant relationship with travel mode choice, and some results also support the development of new urbanism, which is to change residents' travel behaviour by developing a more compact and mixed-use built environment, thereby reducing the negative impact of massive use of motor vehicles. (Chaix, Merlo, Subramanian, Lynch, & Chauvin, 2005; Ding, Wang, Yang, Liu, & Lin, 2016; Sun et al., 2017). However, the existing empirical results of the relationship between the built environment and travel behavior are still controversial. For example, a study in Beijing found a significant relationship between land use and travel speed and travel distance (Zhao, 2013), but in a similar study in Los Angeles, however, no similar results were found (De Grange, Boyce, González, & Ortúzar, 2013). Given inconsistent empirical results, it is necessary to study the causes of such differences. The understanding of the relationship between the built environment and travel behaviour still requires more in-depth research. The differences in some research conclusions may be the by-products of different methods, data and empirical case cities or regions. In addition, a number of more complex methodological problems, also resulted in the different empirical conclusions (X. Feng, Zhang, & Fujiwara, 2009).

Spatial dependence (spatial autocorrelation) is a main methodological problem which results in the differentiation among the empirical results. Spatial dependence refers to the correlation between sample observations in one area and observations in other areas (C. R. Bhat, Pinjari, Dubey, & Hamdi, 2016). Due to the location and diffusion of elements among regions, interaction and mutual influence are formed in geographic space, resulting in that samples are not independent in space. The correlation strength of the variable will be affected by the relative position and absolute position between regions, indicating that there will be spatial interactions between the economic and geographic behaviours (Jian, Hossein Rashidi, Wijayaratna, & Dixit, 2016). Spatial correlation is mainly reflected in the lag term of the dependent variable and error term in the spatial regression model. The two basic spatial econometric models are the spatial lag model and the spatial error model (Ding et al., 2018). Besides, spatial dependence (spatial auto autocorrelation) occurs when observations at nearby locations tend to have similar characteristics (Sener, Pendyala, & Bhat, 2011). Spatial autocorrelation is a common problem in geographic analysis, and it presents a major challenge to applications of statistical methods.

Several approaches have been developed to resolve spatial autocorrelation with spatial econometrics methods. For example, one can construct a spatial contiguity matrix to represent how different locations get in touch with each other geographically (Castro, Paleti, & Bhat, 2012). By adding the matrix in the linear regression model, the influence of spatial dependence can be controlled. In addition, distance between neighborhoods is often incorporated with different functions to represent the more complex spatial relationships. The multilevel or hierarchical modeling framework has been applied to spatial analysis by many researchers (Duncan and Jones 2000; Bhat and Zhao 2002; Bottai et al. 2006; Antipova et al. 2011; Chaix et al. 2005). Most spatial data are grouped into geographic levels such as census tract, Travel Analysis Zone (TAZ), and zip code district. Also, residents and workers can be grouped into neighborhoods and workplaces, respectively. In addition, heterogeneities among geographic units can be explicitly modeled by employing multilevel models (C. Bhat & Zhao, 2002; Duncan & Jones, 2010). Specifically, multilevel models set two different levels of variances between individuals and groups, and these variances can be expressed by predictor variables with different functions to relieve the homoscedastic assumption. This allows researchers to differentiate heterogeneity existing both among individuals and among groups.

As an application of the multilevel approach, Bottai et al. (2006) examined the effects of gender and age of travelers on travel distance and trip generation while modeling the variances of families, geographical areas, and travelers (Bottai, Salvati, & Orsini, 2006). They conducted likelihood ratio tests to identify homogeneity of the people living in the family and same area, and concluded that people from the same family and area tend to have similar travel distance. Families living in the same area have a small, albeit statistically significant, similarity in the measured travel outcomes. In another example, Bhat (2000) introduced an algebra form of the multilevel cross classified model considering the clustering influence of residential area and workplace area and analyzed mode choice using commuting data. By comparing the result from a multinomial logit model to that from a multilevel logit model, he concluded that spatial clustering of individuals into both the residential and work places should be considered to achieve more accurate results (C. R. Bhat, 2000). The multilevel model has also been employed in land use-travel analysis. Schwanen et al. (2016) examined the influence of urban form on auto travel time in the Netherlands (T. Schwanen, Dijst, & Dieleman, 2016).

2.4 Urban villages related topics

China's rapid urbanization, characterized by large-scale "rural to urban" migration and radial expansion of urban built-up areas, produces a new type of urban neighborhood, namely the urban village. The urban village is considered as a community of interest for urbanized villagers, a migrant settlement with low-rent housing, and an urban self-organized grassroots unit, respectively related to the ambiguous property rights, an informal rental market, and the vacuum of state regulation (Yuting Liu et al., 2010).

It is noticeable that China's urban village is quite unique derived from the context of China's urbanization process and quite different from the western planning concept of the "urban village", which refers to a village style neighborhood in the urban context of western countries. The Urban Villagers Forum developed the "urban village" in London as a concept of an urban settlement which is small and of neighborhood size, combines residential with work, retail and leisure units, aims to be self-sustaining, mixes different social and economic groups, has efficient transport, and is well designed and managed (Aldous, 1995). Meanwhile, although China's urban village is one type of informal housing neighborhoods, it is unlike the slum in some other developing countries. First, residents in urban villages are tenants (immigrant workers), but the owners of urban villages are the original villagers. However, the slums are self-constructed and self-resided areas. Second, urban villages are communities of social life, combined by deep social relationship like consanguinity, geographical relationship, or village regulation and agreement, but slums are temporary, casual and the location is changeable according to relocation by government. Thirdly, urban villages have developed into an effectively united socioeconomic system to meet the market demands.

Due to their crowded and cluttered material landscape, unhealthy living environment, and the resulting security and social problems, urban villages in Chinese cities are widely condemned by the media, the government and even academia (Yuting Liu & Wu, 2006; F. Wu et al., 2012; W. Wu, 2004). They are usually associated with unsuitable land use, poor housing construction, and severe infrastructure deficiencies, intensified social disorder and deteriorated urban environment (Landman, 2003; Yuting Liu & Wu, 2006; F. Wu et al., 2012; W. Wu, 2004). In fact, however, the urban village also plays a positive role in China's rapid urban development. A few studies have started to pay attention to the positive effects of the urban village. For instance, Zhang et al. (2003) signify the important role that the urban village has played in housing the temporary population from the perspective of self-help housing strategy in Guangzhou and Dongguan (L. Zhang, 2003). Lin et al. (2014) further argues that the urban village not only provides cheap accommodation for low-income migrants to live in cities, but also puts less pressure on the government to develop a costly program to house migrant laborers during the rural to urban regeneration (Yanliu Lin et al., 2014). The vacuum of state regulation in the urban village provides a means of subsistence for landless villagers and low-cost housing for migrants. Therefore, the regeneration of the urban village under state regulation would be complicated.

To look for appropriate ways for urban villages regeneration, many studies have proposed their viewpoints based on empirical studies in terms of the informality and inequality of urban villages. The redevelopment and integration of urbanized villages into the urban fabric poses one of the most difficult challenges urban planners are facing today, leading to a tendency to concede the informality of urban villages (Schoon & Altrock, 2014). On the one hand, urban villages facing regeneration in China offer a unique institutional environment which combine both market-oriented transition and official socialist principle of equality. For example, drawing on a household survey of 32 villages in Guangzhou, Zhang et al. (2016) analysed the housing inequality among indigenous villagers between and within villages, and concluded that the state fails to respond to the growing difference between urban villages caused by rapid urbanization, and to the incremental stratification within villages caused by economic and political inequality (L. Zhang, Ye, & Chen, 2016). One the other hand, local authorities are encouraged to explore suitable regeneration strategies for themselves. By a detailed case study of Liede Village in Guangzhou, Lin et al. (2014) found that local authorities in China are willing to explore neoliberal approach in coordinating with market forces in the process of regeneration (L. H. Li et al., 2014).

Although urban villages are unique in China, they are similar to some self-help housing settlements in terms of external manifestation. Therefore, notwithstanding there have not seen any study emphasizing the relationship between travel behaviour and the built environment regarding urban villages, other comparative studies related to urban sprawl, and slums have achieved some interesting results, which have certain enlightening significance for the study of Chinese urban villages. Anantharajan (1981) studied the travel behaviour of Madras slums in India and found that the employment market in the region is large and has high employment accessibility. 78% of the residents walked to work, 5% of the residents went to work by bicycle, and more than 50% of the commuters did not travel more than 3km, so it can be seen that high employment accessibility can encourage more non-motorized travel (Anantharajan, 1981). Luo (2005) studied relationship between the development of urban fringe areas and the supply of transport services, conducting a comparative study of private car travel and bus travel. The results showed urban transport development has greatly changed with the urban fringe. The lack of public transit facilities made commuters unwilling to live in marginal communities, which led to increased congestion in urban centers (Luo, 2005). Inbakaran (2010) conducted a study on the travel choices of the urban fringe communities in Melbourne, Australia, and found that the shortcomings of the bus system in urban fringe community did not bother residents' travel mode choice, and more trouble came from the increase in travel distance (Inbakaran, 2010).

2.5 Utility theory and travel behaviour modeling

2.5.1 Aggregate analysis VS. Disaggregate analysis

Aggregate analysis usually uses traffic analysis zones (TAZs), communities, or even cities as basic geographic units to analyse the relationship between built environment and travel behaviour. That is to say, the variables of the built environment and travel behaviour describe an area rather than the individual characteristics. Even if the data for travel behaviour comes from household surveys, researchers will aggregate individual travel behaviour into a certain area, such as the average car ownership and average travel distance of the travel zone. Then the relationship between the built environment and the travel trip is tested by correlation analysis and regression analysis. For example, Holtzclaw et al. (2002) analysed the impact of built environmental factors in Chicago, Los Angeles and San Francisco on vehicle ownership and vehicle use based on TAZ (Holtzclaw, Clear, Dittmar, Goldstein, & Haas, 2002), and they found that the average car ownership and car travel distance in the travel zone were negatively related to the household density (Holtzclaw et al., 2002). A typical shortcoming behind this method is the human ecological fallacy, or in another word, overgeneralization, which means that when the results obtained from the aggregate statistics are directly applied to individuals within the group, the heterogeneity between individuals and groups could be ignored. Therefore, disaggregate analysis was developed to solve this problem.

Disaggregate analysis uses an individual or a household as the basic research unit to analyse the relationship between the built environment and travel behaviour (Xiaoshu Cao & Yang, 2017; P. Chen & Zhou, 2016; C. Wang & Chen, 2017; Mengzhu Zhang & Zhao, 2017; Zhao, 2013). Most data on individual travel behaviour come from large-scale household travel surveys conducted by municipal departments every five years. The built environmental variables are usually measured in units of certain geographic areas. The disaggregated analysis has tended to narrow down the area of the units as much as possible instead of using TAZs. Recent research has applied individual-centred unit such as residential communities. In the context of disaggregate analysis, individual travel behaviour is often expressed as a function of built environmental variables and socioeconomic attributes, providing an important empirical basis for investigating the influence of built environment on travel behavior. Disaggregate analysis has become the mainstream in the domain of travel behaviour analysis.

2.5.2 Utility theory

The disaggregate models emphasize the heterogeneity among individuals, and they are also named individual choice models or discrete choice models, explaining and predicting choices between two or more discrete alternatives, such as choosing among travel modes. When it comes to travel mode choice behaviour, utility maximization hypothesis acts as the theoretical basis and necessary premise. It hypothesizes that decision makers would always choose the alternative with maximum utility for himself or herself from the set of all alternatives.

$$U_{in} = V_{in} + \varepsilon_{in} \tag{2}$$

U_{in} is the actual utility when individual n choose the alternative i; V_{in} is the observed utility of individual n choosing alternative i; ε_{in} is unobservable probability of utility. That is, the utility function consists the confirmed and random value regarding utility. If C_n is the set of all alternatives for individual n, then when $U_{in}>U_{ij}, \forall j \neq i \in S_n$, the individual will choose the alternative i.

$$V_{ni} = \mathbf{x}'_{ni}\boldsymbol{\beta} + k_i \tag{3}$$

Among them, $\mathbf{x}_{ni}$ is the dimensional attribute vector of the scheme i; $\boldsymbol{\beta}$ is the corresponding dimensional parameter vector; k_i is the inherent constant corresponding to the scheme i, which describes the average value of the overall effect of all model explanatory variables on the utility. Different assumptions on the distribution function of the utility random term ε_{ni} ultimately determine the structure of the selected model. The models represented by the logit model and the hierarchical logit model are the most widely used in the field of travel behaviour analysis.

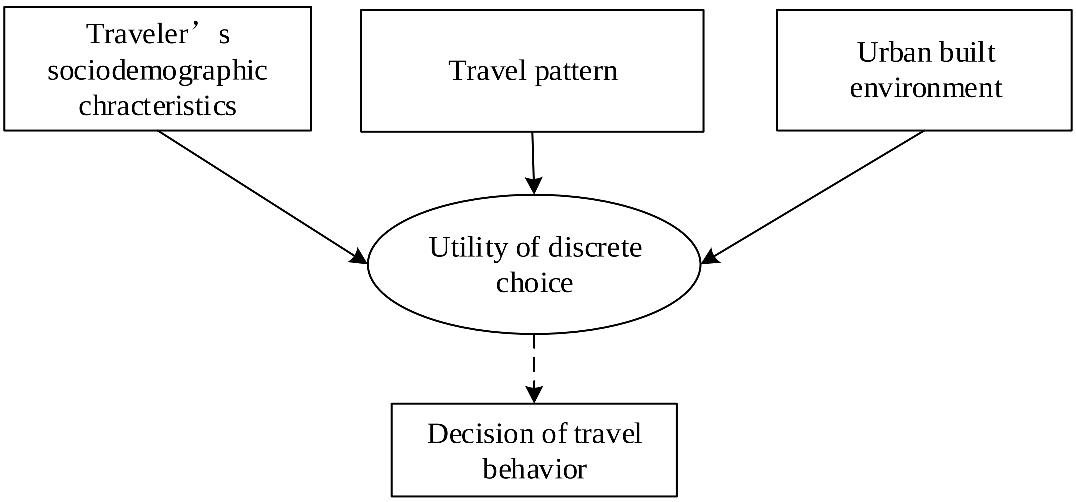


Figure 16 Conceptual framework of travel behaviour decision based on utility theory

Activity-based travel behaviour analysis model was developed based on utility maximization theory, assuming that individual consumers to choose their travel mode based on behavioural economics and utility maximization theory. Discrete choice model

(DCM) based on stochastic utility theory is widely used to explain traveler's choice decision-making behaviour. These explained choice decision-making behaviours include travel mode choice, travel destination, departure time, etc. A complete choice and decision-making behaviour framework generally includes five elements. The first element is the behaviour decision-maker, which can be either an individual or a family. When the decision-maker is a family member, the choices of family members are regarded as a whole choice. The second element is alternatives which can be discrete variable choices, such as travel mode choices. The third element is the social economic characteristics of decision-makers, such as the gender, age and income. These personal attributes will involve the preference of individual choice. The fourth element is the characteristics of alternative options, such as the travel time of different travel modes. The fifth element is behaviour decision-making rules, such as the principle of maximum utility or principle of minimum regret. Therefore, based on the above five analysis elements, a framework for the impact of the built environment on travel behaviour can be constructed as shown in the Figure 16.

2.5.3 Travel behaviour modelling

Discrete choice model is the main method used by many scholars to study the influence of urban built environment on travellers' decision-making behaviour. This theoretical model is derived from microeconomics theory. It is based on the assumption that travel decision makers are all rational actors. It believes that travellers follow the principle of maximum utility when making travel decisions. It is assumed that the decision-making behaviour of travel individuals is affected by a series of internal and external factors. In the utility model, the stochastic utility consists of a deterministic part and a random part. The deterministic part considers the influence of the average tendency of travel decision-making behaviour, while the random part is the unobservable decision-making information.

When it comes to the impact of the urban built environment on travel behavior based on the theory of random utility, it is believed that as long as there are certain characteristics of the urban built environment (such as land use diversity, road network structure, accessibility, etc.) and the utility of travel behaviour are relevant, that is, different urban built environments can affect the "utility" of travel behaviour for a certain travel mode or route, and the changes in travel behaviour that may be caused by changes in the urban built environment can be predicted and judged.

Based on the utility theory, a series of Logit models were developed regarding disaggregate analysis. The Logit model is a regression method where the log-odds of the probability of an event is a linear combination of independent or predictor variables and this model was first proposed by Cox (Cox, 1958). The basic Logit models include Binary Logit Model (BL) and Multinomial Logit Model (MNL), applied for questions with two available travel mode choice alternatives and multiple alternatives respectively. These standard logit model assume the variables should be independent, which is called irrelevant alternatives (IIA) characteristics among variables.

(1) Binary Logit Model

Binary Logit Model is the simplest type of mode choice models, comparing the travel choices between two modes. For example, say C_{ij}^{m} is the generalized cost of travel between zone 'i' and 'j' using a mode m, then

If $C_{ij}^{2} - C_{ij}^{1}$ =-ve, then mode 1 would be chosen;

If $C_{ij}^{2} - C_{ij}^{1}$ = + ve, then mode 2 would be chosen;

If $C_{ij}^{2} - C_{ij}^{1}$= 0, then both two modes have been equal probability of being chosen.

The probability of choosing mode for a trip between zone 'i' and 'j' is given by-

$$P_{ij}^1 = \frac{T_{ij}}{\sum T_{ij}} = -\frac{e^{-\alpha C_{ij}^1}}{e^{-\alpha C_{ij}^1} + e^{-\alpha C_{ij}^2}} \tag{4}$$

$$P_{ij}^2 = -\frac{e^{-\alpha C_{ij}^2}}{e^{-\alpha C_{ij}^1} + e^{-\alpha C_{ij}^2}} \tag{5}$$

When it comes to multiple choices, the Binary Logit Model is not applicable any more, then the Multinomial Logit Model is employed to settle with three options and above.

(1) Multinomial Logit Model

Assume that the independent and identical distribution in the formula is in the Gumbel distribution with parameters (0, 1), that is

$$f(\varepsilon_{ni}) = e^{-\varepsilon_{ni}} e^{-e^{-\varepsilon_{ni}}} \tag{6}$$

Then the utility random item obeys the Logistic distribution, and the probability of the decision maker n choosing option i can be expressed as the following multinomial Logit model:

$$P_{ni} = \frac{e^{V_{ni}}}{\sum_j e^{V_{nj}}} = \frac{e^{\mathbf{x}'_{ni}\boldsymbol{\beta} + k_i}}{\sum_j e^{\mathbf{x}'_{nj}\boldsymbol{\beta} + k_j}} \tag{7}$$

Multinomial logit models have the characteristics of independence from irrelevant alternatives (IIA). Any two options and only depends on the program, the ratio of its option probability and utility to determine, and not by other utility programs to determine the impact of items, namely:

$$\frac{P_{ni}}{P_{nj}} = \frac{e^{V_{ni}} / \sum_k e^{V_{nk}}}{e^{V_{nj}} / \sum_k e^{V_{nk}}} = \frac{e^{V_{ni}}}{e^{V_{nj}}} = e^{V_{ni} - V_{nj}} \tag{8}$$

With the increasingly deep understanding into travel behaviour, more socio-demographic and built environmental variables are introduced into the models, so standard logit models are not always suitable, since alternatives might correlate to each other in some ways. A number of advanced logit models have been proposed to allow correlation over alternatives and more general substitution patterns. Nested Logit Model is proposed to capture correlations between alternatives by partitioning the choice set into 'nests', but the independence between nests are forces (Train, 1998). Nested logit models have been presented as an alternative to multinomial logistic models for multiple-choice test items and possess a mathematical structure that naturally lends itself to evaluating the incremental information (Suh & Bolt, 2010).

(3) Hierarchical logit model

The IIA feature of the Logit model limits its application to the option problem where the utility random term has a significant correlation (Long, Lin, & Proussaloglou, 2010). If the options set can be divided into several levels according to the degree of similarity of the option plan C_n, the hierarchical Logit model can be used to solve the limitations brought by the IIA feature. Assume that the set of options $S_1, S_2, \cdots, S_M$ can be divided into non-overlapping subsets, namely

$$C_n = S_1 \cup S_2 \cdots \cup S_M \tag{9}$$

If the vector composed of random utility terms $\boldsymbol{\varepsilon}_n = < \varepsilon_{n1}, \cdots, \varepsilon_{n1J} >$ has the following distribution function

$$\exp\left[-\sum_{m} \left(\sum_{i \in S_m} e^{-\varepsilon_{ni}/\lambda_m} \right)^{\lambda_m} \right] \tag{10}$$

Among them, the parameter λ_m is the scale parameter, which represents the degree of mutual independence between the utility random items of the schemes belonging to the same layer m. It can be seen that in the hierarchical Logit model, the ratio of the option probability of the two schemes $i \in S_m$ and $j \in S_n$. The relative size of the utility of each plan option $S_d (d \neq m, d \neq n)$, and has nothing to do with the choices in other strata (independence from irrelevant nest, IIA), that is

$$\frac{P_{ni}}{P_{nj}} = \frac{e^{V_{ni}/\lambda_m} / (\sum_{l \in S_m} e^{V_{nl}/\lambda_m})^{\lambda_m - 1}}{e^{V_{nj}/\lambda_n} / (\sum_{l \in S_n} e^{V_{nk}/\lambda_n})^{\lambda_n - 1}} \tag{11}$$

Nested logit (NL) model is the most commonly used hierarchical choice model structure in travel behaviour analysis. However, the NL model requires that the hierarchical structure of the option problem be accurately set in advance, and it is assumed that the correlation only exists between the option schemes in the same hierarchy. For the C dimension combination choice behaviour, the NL model can at most simultaneously describe the interaction between the selected dimensions.

The Cross-nested logit (CNL) model based on the generalized pole model is another model structure that analyzes joint choice behaviour. This model retains the analytical form of option probability and can flexibly describe the multi-dimensional choice behaviour between different dimensional choices.

Suppose the decision-maker n from a selected set A_n of a program element option regimen utility is $U_{ni}(i = 1, 2, \cdots, I)$, which may be expressed as the sum of a fixed term V_{ni} and stochastic term ε_{ni}. The GEV model assumes that the joint distribution of random items $\varepsilon_n < \varepsilon_{n1}, \varepsilon_{n2}, \cdots, \varepsilon_{nI} >$ in all alternatives is a general extreme value distribution:

$$F_{\varepsilon_{n1}, \varepsilon_{ni}, \cdots \varepsilon_{nI}}(y_{n1,} y_{ni}, \cdots y_{nI}) = e^{-G(e^{-y_{n1}}, e^{-y_{n2}}, \cdots, e^{-y_{nI}})} \tag{12}$$

Where $G(\cdot)$ is the generating function, which has the following form:

$$G(y_{n1,}y_{ni},\cdots y_{nI}) = \sum_{k=1}^{K}\left[\sum_{i\in B_k}(\alpha_{jk}y_{nk})^{1/\mu_k}\right]^{\mu_k} \tag{13}$$

In the formula, K is the number of layers of options; B_k is the set of all options that belong to the k layer. According to the theory of the GEV model, the option probability P_i in the CNL model (to simplify the notation, the letter representing the decision maker is omitted from the back) can be expressed as:

$$P_i = \sum_{k=1}^{K} P_{i|k}P_k \tag{14}$$

Wherein: P_k is the probability that the option is located on the k layer, $P_{i|k}$ is the probability that the option locating on the k layer is selected.

$$P_{i|k} = \frac{(\alpha_{ik}e^{V_i})^{1/\mu_k}}{\sum_{j\in B_k}(\alpha_{jk}e^{V_j})^{1/\mu_k}} \tag{15}$$

In the formula, α_{ik} is the allocation parameter, which determines the relative size of the plan belonging to each layer ($(0 \le \alpha_{ik} \le 1, \forall i$ and $k, \text{and} \sum_{k} \alpha_{ik} = 1, \forall i)$). The heterogeneity parameter $\mu_k(0 \le \mu_k \le 1)$ is a measure of the degree of correlation between the schemes in the k layer. The larger the value, the more independent and the lower the correlation between the schemes is.

A hierarchical logit model is applied to quantify variability in commuters' mode choice in the Chicago metropolitan area and the contextual effects are found to modify the marginal utility of mode choice (Long et al., 2010). Furthermore, random variation is present even after both contextual and individual traits are controlled for, suggesting intrinsic randomness in individual mode choice (Long et al., 2010).

In recent years, there have been important developments in the joint analysis of the travel behaviour based on discrete choice models as well as in the formulation of increasingly flexible closed-form models belonging to the generalized extreme value class. The objective of this work is to describe the simultaneous choice of shopping destination and travel-to-shop mode in downtown area by making use of the cross-nested logit (CNL) structure that allows for potential spatial correlation. The analysis uses data collected in the downtown areas of Maryland-Washington, D.C. region for shopping trips, considering household, individual, land use, and travel-related characteristics. The estimation results show that the dissimilarity parameter in the CNL model is 0.37 and significant at the 95% level, indicating that the alternatives have high spatial correlation for the short shopping distance (C. Ding et al., 2016). The results of analysis reveal detailed significant influences on travel behaviour of joint choice shopping destination and travel mode. Moreover, a Monte Carlo simulation for a group of scenarios arising from transport policies and parking fees in downtown was undertaken to examine the impact of a change in car travel cost on the shopping destination and travel mode switching. These findings have important implications for transport demand management and urban planning (Yaoyu Lin et al., 2014).

(4) Probit Model and Mixed Logit ModeL

The Logit model has three limitations, namely, the inability to describe the randomness of decision-makers' preferences, the IIA attribute's restriction on alternative alternative modes, and the inability to describe the temporal correlation of unobservable influencing factors in panel data. Probit Model and Mixed Logit Model can solve the above three problems at the same time (DANIEL MCFADDEN 2000).

The Probit Model assumes that the random vector $\varepsilon_{ni}(i=1,2,\cdots,J)$ composed in the formula obeys a normal distribution $\boldsymbol{\varepsilon}'_n = <\varepsilon_{n1},\cdots,\varepsilon_{n1J}>$ with a mean value of 0 and a covariance matrix of $\boldsymbol{\Omega}$, namely

$$\phi(\boldsymbol{\varepsilon}_n)=\frac{\exp(-\frac{1}{2}\boldsymbol{\varepsilon}'_n\,\boldsymbol{\Omega}^{-1}\boldsymbol{\varepsilon}_n)}{(2\pi)^{\frac{J}{2}}\,|\boldsymbol{\Omega}|^{\frac{1}{2}}} \tag{16}$$

Then the option probability can be obtained by

$$\begin{aligned} P_{ni} &= P(V_{ni}+\varepsilon_{ni}>V_{nj}+\varepsilon_{nj},\forall j\neq i) \\ &= \int_{\{\boldsymbol{\varepsilon}_n s.t. V_{ni}+\varepsilon_{ni}>V_{nj}+\varepsilon_{nj},\forall j\neq i\}}\phi(\boldsymbol{\varepsilon}_n)\,\mathrm{d}\boldsymbol{\varepsilon}_n \end{aligned} \tag{17}$$

Where the probability density function is a normal distribution. The formula is a double integral and there is no analytical expression, so the parameters of multiple Probit models need to be calibrated through simulation methods.

Mixed logit model structure is very flexible, to solve the logit limitations of three existing models, its usefulness is not limited to the normal distribution of random items, parameter calibration party more convenient for Mixed logit model definition is based on the probability of option, any Mixed Logit Model has the following option probabilities

$$P_{ni}=\int L_{ni}(\boldsymbol{\beta})\,f(\boldsymbol{\beta})\,\mathrm{d}\boldsymbol{\beta} \tag{18}$$

Where $f(\boldsymbol{\beta})$ is the probability density function and the model option probability at the parameter vector $\boldsymbol{\beta}$, namely

$$L_{ni}(\boldsymbol{\beta})=\frac{e^{V_{ni}(\boldsymbol{\beta})}}{\sum_j e^{V_{nj}(\boldsymbol{\beta})}} \tag{19}$$

If assuming that the utility term is a linear function:

$$P_{ni}=\int\frac{e^{V_{ni}(\boldsymbol{\beta})}}{\sum_j e^{V_{nj}(\boldsymbol{\beta})}}\,f(\boldsymbol{\beta})\,\mathrm{d}\boldsymbol{\beta} \tag{20}$$

It can be seen from the formula that the Mixed Logit Model option probability is the weighted average of the logit formula at different values, the weight is given by the probability density, and the Mixed Logit Model parameter calibration also needs to be obtained through simulation methods.

2.6 Research gaps

The research on the relationship between the built environment and travel behaviour has been developed in the developed countries for nearly 40 years. It has a rich theoretical system and empirical basis. Although the research methods in the field of research on the relationship between the built environment and travel behaviour have been greatly developed, how the empirical results of empirical research are applied to the background of Chinese urban development, especially the research on the background of urban renewal in China has not yet been carried out. As far as current research is concerned, the empirical conclusions of Chinese cities are not consistent with Western cities, and there are differences between Chinese cities. In general, the impacts of built environment on residents' travel behaviour and its mechanism have not yet reached a consistent research conclusion. However, Chinese cities face different ways of urban expansion. Many large cities have problems such as excessive density, highly mixed land use, and insufficient road infrastructure. In the context of Chinese cities, how to measure and evaluate "5D" and other built environment indicators is the difficulty and key of related research. Different from the cities of Western countries, Chinese cities are in a stage of rapid development, the community built environment, both spatial and temporal behaviour of its inhabitants links between all happening faster and greater change. Empirical research from Chinese cities can enrich local empirical research and applications in China. At the same time, whether the built environment factors that affect the travel behaviour of Chinese residents have different characteristics or even different typologies from those in the West. Therefore, it is urgent to explore and summarize transport research theories with Chinese characteristics in the background of Chinese cities.

Nowadays, the regeneration of urban villages in China provides opportunities to simultaneously improve the built environment and traffic problems, but how to effectively use the opportunity of urban village regeneration to improve the transport structure while providing suitable and sustainable regeneration strategies for urban villages? The urban village is a unique phenomenon in the rapid urbanization of Chinese society, and it is relatively rare in the urbanization process of other countries. Although foreign research on the relationship between urban built environment and transport is relatively early, from the initial proposal of the concept of neighborhood unit, which emphasized the organization of pedestrian transport with life service facilities such as schools as the center of the community, to the promotion of traditional neighborhood design in new urbanism, Public transport-oriented development to deal with urban transport congestion, and then to explore effective ways to reduce motorized traffic from the perspective of urban built environment. However, in comparison, the domestic research on the relationship between the urban built environment and transport has been carried out late, and systematic and comprehensive results have not yet been formed. At the same time, due to the big differences in travel attitude preferences, lifestyles and social norms of Chinese urban residents from Western countries, Chinese cities are very different from Western cities in terms of spatial structure, land use patterns, and transport systems. Transport energy consumption and related proportions are generally smaller than those of European countries and the United States, also the existing Western research conclusions is not fit for China. More attention has been paid to the research on the impact of travel at the macro-aggregate level, and less attention has been paid to the research on the impact of the urban built environment on the micro-individual travel behaviour, especially the lack of research results on key technologies such as the modeling of the two linkage mechanisms. The current research gaps and the lack of in-depth research can be summarized in the following points:

(1) Although researchers have conducted some research on the built environment characteristics of self-help residential areas and fringe communities, the research on the built environment of urban villages is rarely involved, especially lack of theoretical research. The research on urban villages is mostly limited and they are rarely regarded as part of the organic whole of the city and conduct joint research with traffic problems. Urban villages are a unique spatial form that appears in China, and due to differences in geographic location, spatial form, and traffic conditions, the travel behaviours of residents in urban villages reflect differentiated characteristics, but less attention has been paid to the current characteristics and impact on the travel of residents in urban villages, especially the travel characteristics and influencing factors of residents in different types of urban villages. Due to the differences in the development stages of Chinese and Western societies and the lifestyles of residents, for example, domestic residents' dependence on public transport is much higher than that of western cities. Compared with other built environment factors, the degree of accessibility to public transport stations is more important for residents' travel behavior. The impact of behaviour may be higher than in Western cities. Therefore, it is necessary to study the built environment related to travel in the context of Chinese cities, especially the urban villages in large cities.

(2) The research on residential self-selection effect under special background needs to be supplemented. An important premise of the theory of residents' self-selection is that residents can freely choose their living environment according to their own preferences. However, in the context of China's existing housing system and structure, residents may consider more built environment factors such as surrounding education when they choose a certain formal residence. Especially for residents in urban villages, almost all of the households are tenants, and their choice of residence is more affected by rental prices and employment commuting. This may be quite different from the self-selection

effect of other groups. Different housing types can provide a comparative reference for the study on the influence of built environment on residents' activity and travel behaviour. At present, domestic travel research still seldom considers the influence of residential self-selection of residence. If the confounding effect of residential self-selection of residence is not eliminated, the impact of the built environment on travel is likely to be incorrectly estimated, which may mislead the formulation of relevant transport and land use policies.

(3) The spatial dependence effect needs to be tested in the context of urban villages. The result of the spatial dependence effect is that the behaviour of travelers in a certain area may be affected by the behaviour of travelers in adjacent or related areas, and may also be affected by the built environment of adjacent or related areas. This effect may be spatial overflow or spatial competition effect. If the impact of dependence is ignored, the impact of the built environment on the travel behaviour of the area may be incorrectly estimated, resulting in the failure of the built environment to guide travel behaviour during the regeneration of urban villages and even aggravate the traffic problems in the surrounding area.

3. Research data

3.1 Case study-Urban villages in Shenzhen, China

To date, urban villages have proliferated in almost every Chinese city, especially wide-spread in large cities. This study intends to select Shenzhen as the case city because the condition in Shenzhen is very typical and could act as a demonstration for other cities across the world. According to a recent survey conducted by the Shenzhen Municipal Bureau of Housing, there are a totally of 1,782 urban villages currently, covering almost 60% of the built-up areas of the whole city (see Figure 17), providing 70% of the city's total housing, and accommodating a population of about 9.4 million surpassing half of the city's gross population. As one of the most prosperous cities, also a Special Economic Zone in China, Shenzhen is a typical dual-structured city with informal urban villages and formal commodity housing co-existing for more than thirty years. Shenzhen has experienced significant growth in population from 0.31 million since its establishment in 1979 to 12 million in 2016 (Bureau, 2017), and about 7 million of the population live in urban villages most because of the low rent and thus generating large travel demand for commuting and non-commuting activities.

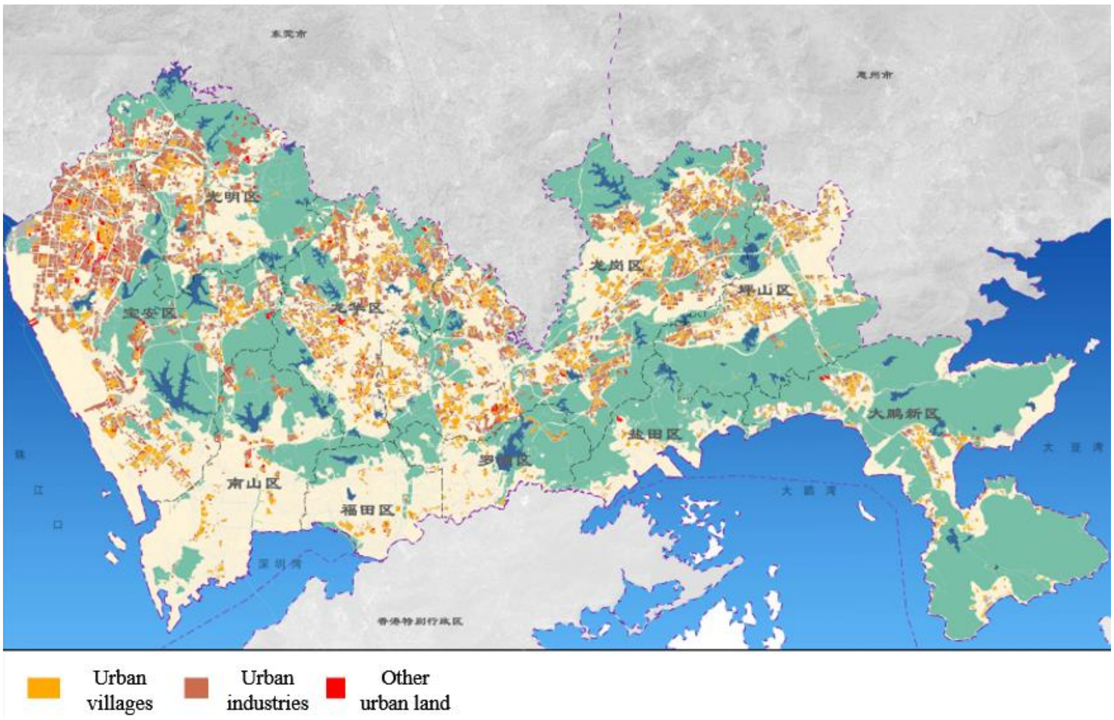


Figure 17 Distribution of urban villages in Shenzhen*
*Source: The Thirteenth Five-Year Plan of Urban Renewal in Shenzhen

Shenzhen is one of the top four most developed cities in China (the other three are Beijing, Shanghai and Guangzhou). Before the establishment of the Shenzhen Special Economic Zone in 1980, Shenzhen was a small town dominated by agriculture. In 1979, the built-up area of the city was only 3 square kilometres. After its establishment, Shenzhen's economy began to soar rapidly, and urban land continued to expand. In 2017, the built-up area of Shenzhen has reached 923 square kilometres. In the process of rapid expansion, Shenzhen government chose to bypass village housing for urban construction to reduce cost of land acquisition, so the original villages for residential use were preserved. Corresponding to economic development, Shenzhen's population is growing rapidly, especially for migrant population. At the beginning of the establishment of Shenzhen in 1980, the total population was 330.2 thousand, of which the temporary population was 12.2 thousand. By the end of 2017, Shenzhen had a population of 12.5 million, of which the temporary population reached 8.2 million, and the urbanization rate was 100%. As the number of migrants increases, so does the demand for low-rent housing. The Shenzhen Municipal Government did not provide a large number of low-rent housing for low-income groups in time, and the urban villages with relatively low living costs just took on the responsibility of low-rent housing to meet the needs of these new population. According to the statistics of Shenzhen Urban Management Bureau, there are currently 1,877 urban villages in Shenzhen, accommodating a population of more than 8 million. Figure 17 demonstrates the extensive distribution of urban villages in Shenzhen, covering almost 60% of the built-up areas of the whole city. Taking account of these characteristics, Shenzhen is selected as the case study area.

3.1.1 The generality of Shenzhen case

Among the problems of urban villages across China, the Pearl River Delta region is the most prominent area where urban villages are ubiquitous, and among these cities in this region, Shenzhen is the most representative city. The number of urban villages in Shenzhen has always been the highest in the Pearl River Delta. There are 277 urban villages in Guangzhou and 275 urban villages in Foshan. There are currently 336 administrative villages and 1044 natural villages in Shenzhen, with a total land scale of about 321 square kilometers, of which 286 square kilometers are currently used for construction, accounting for 1/3 of the city's current total construction land. Moreover, compared with other cities, Shenzhen has the largest urban built-up area, and the urban core area is relatively the most extensive, and because the city has a small land area, Shenzhen has the highest urban village density. Whether it is the speed of urbanization, economic development, and population inflow, Shenzhen has always been the highest in the country. Therefore, the evolution of Shenzhen's urban villages has become more intense and the problems more representative. Therefore, further exploration of the renewal of urban villages in Shenzhen will inevitably provide guidance and demonstration for the current or future urban village renewal problems encountered by other cities.

Figure 18 Urban villages in Shenzhen in the 1980s

Figure 19 Urban villages in Shenzhen in the 1980s

In terms of the strategy of renewal and regeneration of urban villages, Shenzhen's approach also plays a guiding and exemplary role. First, Shenzhen’s urban renewal experience may become a typical model for national implementation, and it is necessary to study Shenzhen’s renewal experiment. Shenzhen Urban Renewal began to explore the regeneration of urban villages and industrial areas in 2004. At present, the implementation of its renewal policy has achieved good results. The “Shenzhen Model” of urban renewal has been awarded by the Guangdong Provincial Government for five consecutive years. It has been recognized by the Ministry of Land and Resources as a reform result and is a national plan. The reform and innovation of the land management system provides practical experience, and its model research is conducive to updating and popularizing in accordance with local conditions nationwide. Recently, Shenzhen designated 56% of the city’s urban village residential land as a comprehensive remediation zone. The comprehensive remediation area will not be allowed in the next seven years. Differentiated and diversified urban village renewal strategy will help alleviate the problems of traffic congestion, fuel dependence and environmental pollution in the development of urbanization.

3.1.2 The specificity of Shenzhen case

In terms of commonality, the exploration of Shenzhen's urban village renewal has a certain leading role, but in terms of individuality, Shenzhen's urban village problem has its own characteristics. Shenzhen is a specimen of rapid urbanization in China. In 2004, Shenzhen achieved full urbanization and became the first city in China without a rural area. However, due to the incomplete conversion of urbanized land, a large number of urban villages emerged. In addition, Shenzhen is also a typical immigrant city, and the rapid growth of the migrant population has led to a strong housing demand. Inspired by rental income, villagers in urban villages continue to add and rebuild, which promotes the development of informal housing in urban villages. Therefore, taking Shenzhen as the research object is typical.

First of all, from the time of development, Shenzhen Special Economic Zone as the first since the establishment of China's reform and opening, within a short period of time from a more than thirty years only two small fishing village developed into more than the population now exceeds 1600 million inhabitants. The development speed is far ahead. While the economy is booming, Shenzhen's land resources are also rapidly depleted. The total land area of Shenzhen is 976 square kilometers, but the actual urban construction land has reached 942 square kilometres in 2018. In this context, Shenzhen's development increasingly relies on urban renewal to provide it with stock land.

Second, in terms of spatial distribution of urban villages, the distribution of urban villages in Shenzhen is wider and more scattered. Big cities such as Beijing, Shanghai, Guangzhou, and Xi'an have a long history of urban construction, and there will be an old city center. Although multiple urban sub-centers will be formed during the rapid development process, most of these sub-centers also have traces of urban construction. However, the overall urban spatial structure development is still centered on the old city and gradually expands to the outer circle. Urban villages are also formed in this process. Therefore, in these large cities, there are very few urban villages near the city center, especially in the old city center, and there are almost no urban villages. Most of the urban villages are located in the marginal area or the interval between the central areas. However, Shenzhen is different. After the reform and opening up, the Shenzhen Special Economic Zone was established and the construction was carried out in Luohu, Yantian, and Shekou respectively. These urban central areas did not originally have an urban construction base. In the development process, either Rise on the ground beside the village. Therefore, Shenzhen belongs to multiple centers and develops simultaneously with the nearby villages. Although the urban villages are demolished in the process of urban development, the overall spatial layout characteristics have not essentially changed. Therefore, the research on the renewal strategy of urban villages in Shenzhen can not only serve as a reference for other cities, but also renew and explore the unique phenomenon of urban villages in Shenzhen.

As far as Shenzhen is concerned, the local government recently released the "Shenzhen Urban Village Comprehensive Regeneration Master Plan (2019-2025). It clearly stated that the target of the comprehensive renovation is the residential land of urban villages in Shenzhen, with a total land scale of about 99 square kilometers. During the 2019-

2025 planning period, the city's comprehensive remediation zone has a land scale of 55 square kilometers. The Plan proposes that it is necessary to orderly guide all regions to carry out the renewal of urban village in the comprehensive renovation zone, which focuses on comprehensive renovation, and integrates the addition and construction of auxiliary facilities, functional changes, and partial demolition and construction. Through micro-renovation, increase the necessary public space and supporting facilities in the urban village, improve the quality of space, improve the living environment, and strengthen housing security.

3.2 Data Source

3.2.1 Data Source 1

To investigate the impact of built environment on travel behaviour and the residential self-selection effect, travel survey data with The integrated dataset in this research included not only the 2014 Shenzhen Household Travel Survey, which recorded the individual, household, and travel information, but also the 2014 Shenzhen Land Use data and 2014 Shenzhen Construction Census as well, from which could be extracted the built environment information. The data was collected from various paths as shown in Figure 20. The information was related to each other as shown in Figure 21.

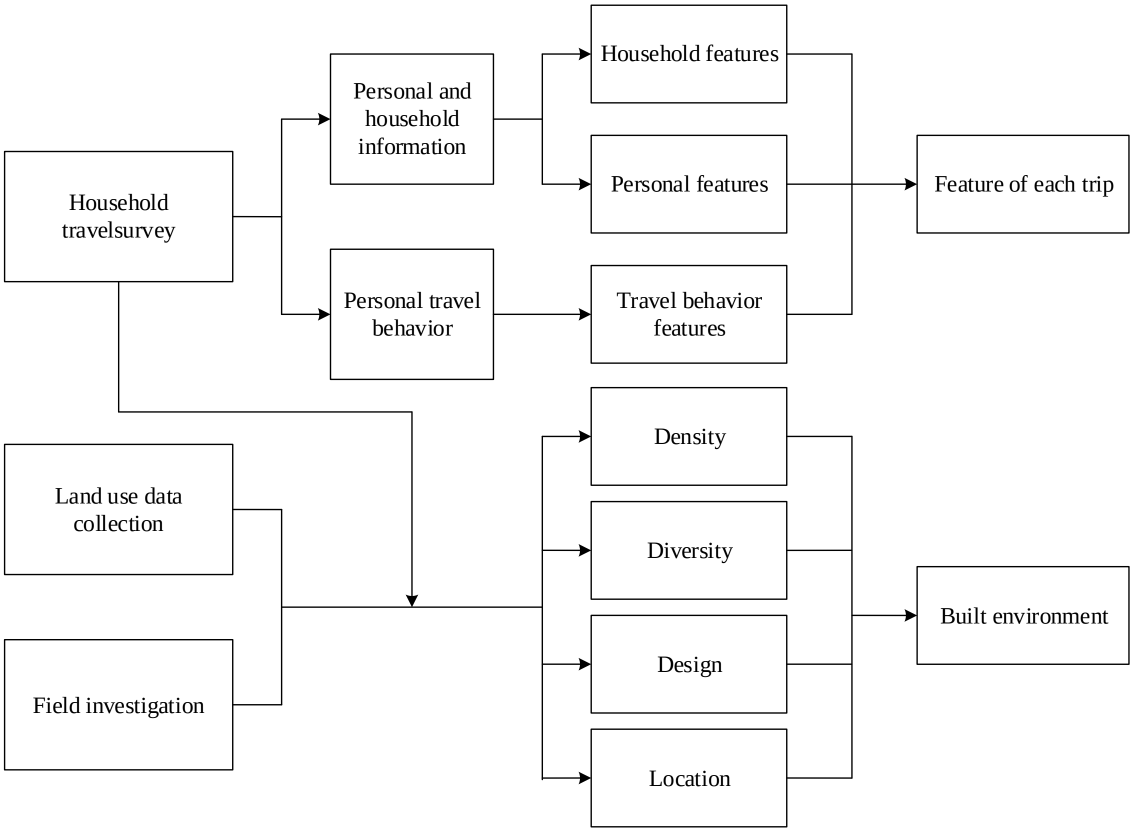


Figure 20 Data source of each trip and built environment

In this research, the raw data came from a large-scale household travel survey in Shenzhen, conducted by a public sector body named Shenzhen Urban Planning and Land Resource Research Centre (UPLR) in 2014. The survey mainly investigated four areas in the city centre and fringe where urban villages are compactly located, namely Shangxiasha (SXS), Longhua centre (LHC), HW tech centre (HWT) and Tianbei community (TBC), including 8309 respondents in total. As part of the agreement with UPLR, I were eligible to select one of the four areas for this research use because the survey contained some information not public. I picked SXS as our study area because it is located in the city centre called Futian district and is one of the largest urban village localities in Shenzhen (see Figure 22). More than 100 thousand people are living in SXS area, covering an area of 1.41 square kilometres and substantially 70% of the residents living in urban villages. Commodity housing are also considered as a contrast.

The selected SXS area covers six urban villages and five commodity housing (residential communities) (see Figure 3). As shown in Figure 22, urban villages seem to be more compact than commodity housing, but in fact, the residential density is just the opposite, because the plot ratio of urban villages is much lower than that of commodity housing. The survey in this area contains 249 households with 565 trips in urban villages and 263 households with 985 trips in commodity housing. Also, according to our survey, there are 46 bus stops and one metro station within 500 metres of the area.

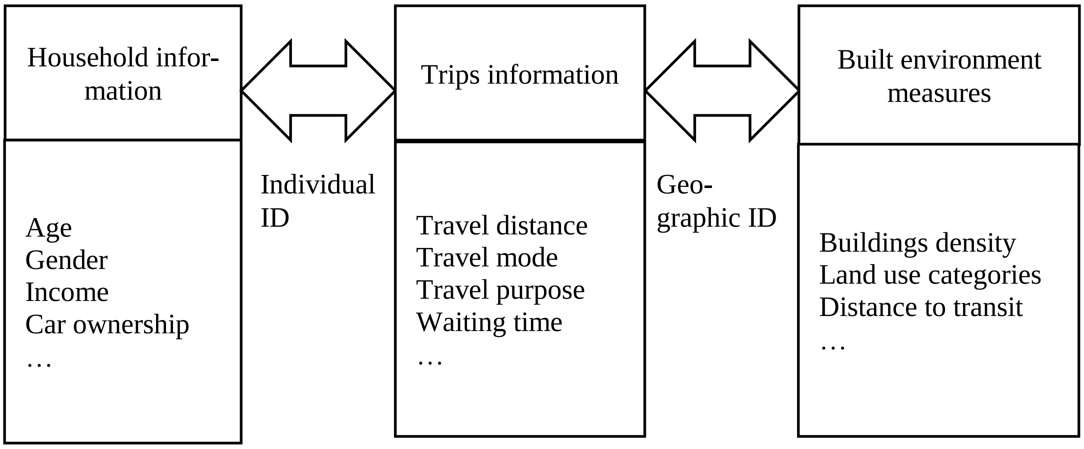


Figure 21 Integrated database for research

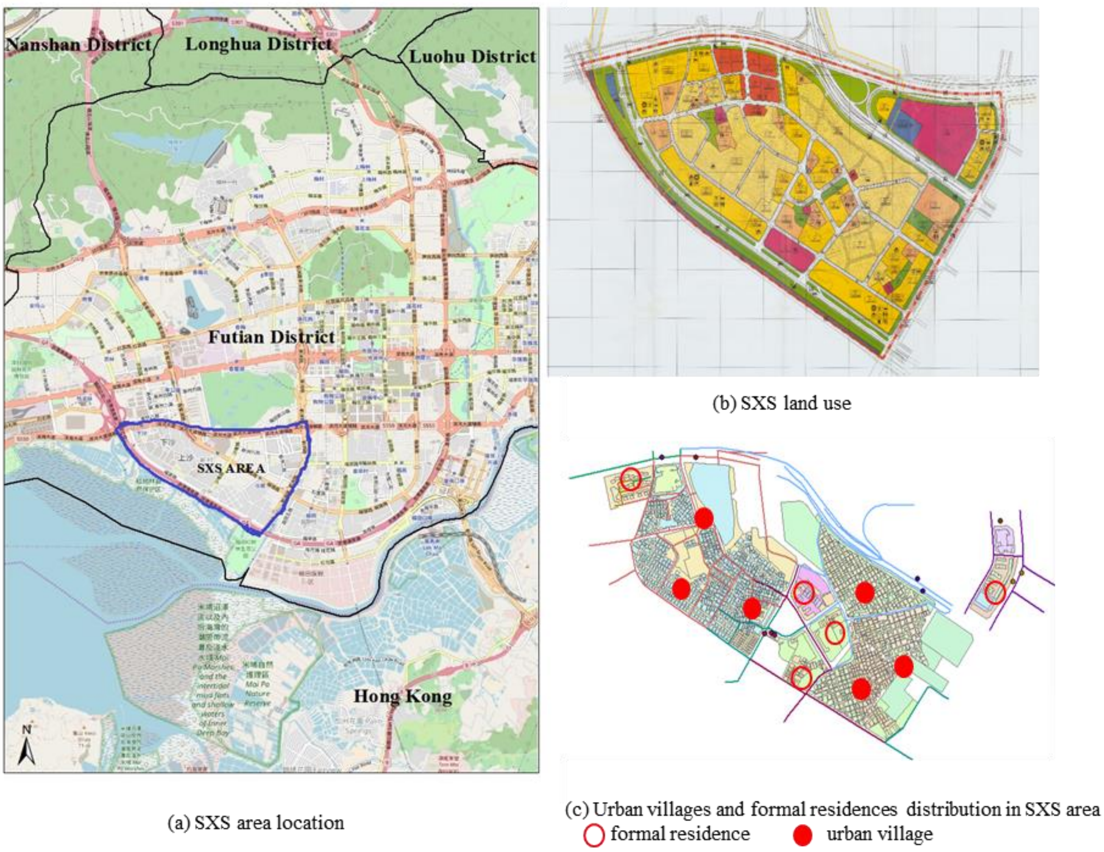


Figure 22 Illustration of SXS area

The integrated dataset included not only the 2014 Shenzhen Household Travel Survey recorded the individual, household, and travel information, but also the 2014 Shenzhen Land Use data, and 2014 Shenzhen Construction Census as well which could be extracted of the built environment information.

3.2.2 Data Source 2

Another data set comes from DiDi Chuxing Company (a ride-souring service company), Shenzhen branch. In terms of online car-hailing market share, DiDi Chuxing is the world's largest one-stop diversified travel platform, with nearly 300 million users in more than 400 cities in China at the end of 2017. According to various online data, DiDi covers more than 87% of China's online ride-souring market and more than 99% of the online taxi market. Therefore, to study the problem of online car-hailing travel from a macro perspective of the city, the data of the DiDi travel platform used in this research is highly representative.

This research has obtained a total of 253,370 items of DiDi trips data records in Shenzhen during the five working days (Monday-Friday) from July 4, 2016 to July 8, 2016. The DiDi Travel platform has defined travel time as three peak types, where “1” represents the morning peak and is defined as 7:00-10:00, “3” represents the evening peak and is defined as 17:00-20:00, and “2” is the normal period defined as 10:00-17:00. This research focuses on commuting travel of urban villages, so it extracts travel records with origin type as “urban villages” and arrival type as “commercial building” in morning peak hours, and travel records with departure type as “commercial building” and arrival area as “ urban villages” in evening peak hours. After data cleaning to eliminate the abnormal latitude and longitude of the departure and arrival locations, the effective record of morning peak commute trips was 23,622, and the effective record of evening peak commute trips was 13,083. Below is an example of DiDi travel record as Tabel 2 shows.

Table 2 Description of DiDi commuting trips of urban villages

Data	ID	Origin longitude	Origin latitude	Destination longitude	Destination latitude	Departure time	Peak type	Origin type	Destination type	…
2016/7/1	2798439385	113.9832	22.75048	114.0681	22.62849	09:19	1	Urban village	Commercial buildings	…
2016/7/1	2949340043	113.9351	22.54093	113.9609	22.56938	19:43	3	Commercial buildings	Urban village	…
…	…	…	…	…	…	…	…	…	…	

4. The influence of built environment on public transit choice behaviour

4.1 Introduction

For decades, public transit (PT) has gained increasing attention due to its significance in addressing environmental problems, limited urban land resources, job-housing unbalance issues as well as the demand for equity and equality of various classes of population in society with the advancing urbanisation process (Abenoza, Cats, & Susilo, 2017; Zailani et al., 2016). Generally, PT is regarded as a sustainable travel mode, beneficial to both individuals and the society. To individuals, it is an effective motorised mode, meeting the needs of medium and long distance urban trips, with a low level of cost and acceptable time consumption. To the society at large, PT acts as an alternative to private cars that alleviates urban congestion and air pollution, especially in dense urban areas (C. Chen et al., 2010; Haywood, Koning, & Monchambert, 2017; Zhu, Wang, & Ding, 2016).

Considering PT's positive and significant functions, governments have implemented supportive measures and invested substantial funds to construct PT infrastructure and enhance PT services to attract more PT travel demand, while the sharing of PT has not undergone a breakthrough. For instance, in China, the fixed investment into PT grew from 66 billion yuan in 2004 to 368 billion yuan in 2014, accounting for the total investment in road transport going up from 8.96% in 2004 to 19.45% in 2014, but the share of PT passenger volume did not increase significantly, only growing from 16.3% in 2004 to 18.2% in 2014. Only a few studies have investigated the reasons for this situation, claiming that the PT travel demand was not paid as much attention as the supply of PT infrastructure (Abenoza et al., 2017; Serulle & Cirillo, 2016). To be specific, transport planners attached more importance to adding bus lines or bus stops, but ignored the features of the travel demand, such as what types of groups would prefer

PT travel and how to satisfy their PT travel demand, or neglected to encourage more people to choose PT for daily trips. In fact, various groups of the population or different urban forms would generate distinct patterns of travel behaviour, so it would be more effective and significant to probe into a particular demand segment rather than the overall demand. Therefore, the study reported in this chapter chose a segment with large demand for PT but a lack of attention to certain characteristics of population and urban form, so as to provide specific policy suggestions for PT encouragement.

In China, an urban village area is such a segment that importance needs to be attached to regarding PT travel. Urban villages are unique informal housing accommodating large amounts of migrant workers in mega-cities, especially in China. They are derived from rapid urbanisation when villagers still kept their dwelling spaces while their cultivating lands in original villages were requisitioned and surrounded by built-up areas in the city, either in urban centres or peri-urban areas in the process of urban regeneration (L. Zhang et al., 2016). This phenomenon is especially popular in high-speed developing metropolises in China, such as Beijing, Shanghai, Guangzhou and Shenzhen, where great job opportunities attract much external labour. In this context, for profit, the indigenous villagers or aborigines reconstructed their original cottages into multilayer buildings (under poor quality and arbitrarily without authorisation from governments) and then leased their village apartments to migrant workers at a relatively low rent compared to commodity housing. A *Formal Residence* is defined as a type of residence approved by the government within the scope of legal urban planning and which conforms to the procedures and rules stipulated by the government. It serves as a comparison to the urban village which is a typical *Informal Residence*. Spontaneously, urban village areas assembled a large number of low-income workers and generated a large volume of PT commuting demand. Therefore, to meet the PT demand or in other words, to avoid the probability of car use increasing due to unsatisfied PT demand, this trend has been prompting states and localities to turn to land planning and urban design to encourage car users to switch to PT (Ewing & Cervero, 2010). Urban villages are results of urbanisation and China is still undergoing an unprecedented surge of urbanisation and motorisation, with a rapidly expanding urban population and the rapid increase of private car ownership. Chinese cities are mimicking the suburbanisation trends and patterns of the US during the Post-World-War-Two period, which is the world's most car-dependent nation (Cervero, 2007). In order to prevent an auto-dependent tendency, China's urbanisation should follow the transit-oriented development, with the integration of land use and transport to attract more citizens to take public transit as their main trip mode choice. Besides, regeneration in urban villages is a demand for efficient land use. Therefore, it is vital to understand the relationship of the built environment with public transit behaviour in urban villages in China.

So far, there have been several, but not abundant, studies concerning PT choice. In general, previous studies have emphasised the relationship between PT and land use policies (C. Chen et al., 2010; Soria-Lara et al., 2016), giving rise to the trend of connecting the built environment and travel behaviour as a feasible way to switch mode choice behaviour. However, regarding to PT choice, previous studies have mainly focused on the general elements of the built environment without distinguishing its features under particular contexts of urban forms, especially in compact cities in developing countries (J. Feng, Dijst, Wissink, & Prillwitz, 2013). In the last four decades, Chinese cities have undergone rapid spatial transformation and expansion, and the regeneration process is still underway. New developments in Chinese cities, however, are generally being built according to the typical modernisation following the developed world (western) style, regardless of the compact city and population features in China (J. Feng, 2017). Particularly, the suitable built environment to meet PT demand is neglected because of the differences of transport structures between western countries and China. Subsequently, traffic problems have appeared in all directions due to the unsuitable built environments. But urban villages faced with undergoing or future renewal still have chances for better planned development if I find a more self-adapted method for urban regeneration in the aspect of built environments for sustainable transport. Also, the urban villages may face their future choice from the perspective of their transport role. Thus, urban villages play a significant role for PT development, and so PT choice behaviour in urban villages matters to sustainable urban transport.

Therefore, this chapter focus on the most important travel mode choice of urban village residents, which is public transit mode choice. This chapter will answer the question that how the unique urban form settings in China, interacting with other attributes, affect the public transit choices of residents living in urban villages in Shenzhen, China, compared to those in commodity housing

4.2 Public transit Choice Behaviour Characteristics

Figures 23 and 24 show the travel characteristics of residents in urban villages in SXS area in terms of travel mode choice and travel purpose. To provide the contrast, travel behaviour in commodity housing is also shown in the two figures. As indicated in Figure 23, PT is the most popular mode for both urban villages and commodity housing, while people in urban villages are more likely to travel by PT than those in their formal counterpart. Regarding travel purpose, I can see from Figure 24 that when travelling by PT, substantially 82% of people in commodity housing travel for commuting, while only about 50% of residents in urban villages travel for commuting. In other words, people in urban villages travel by PT for more varied purposes, whereas those in commodity housing travel by PT mainly for commuting purposes.

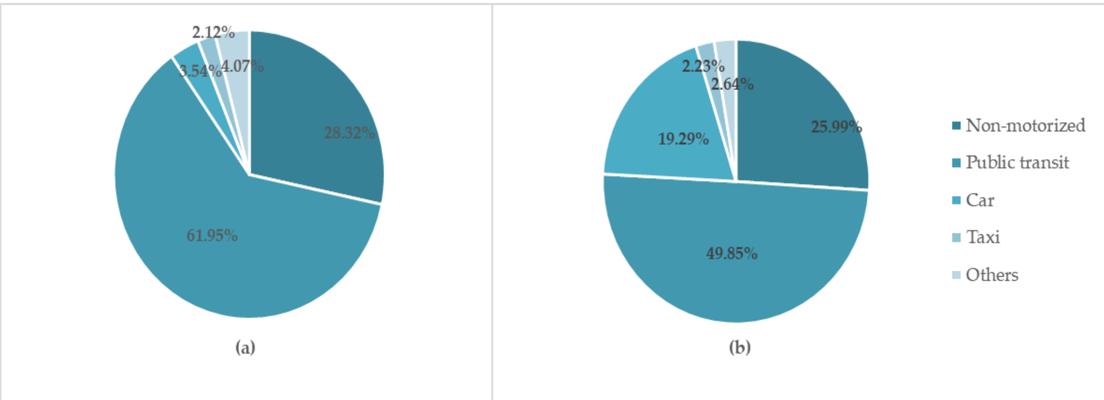


Figure 23 Travel mode choice in urban villages and commodity housing.

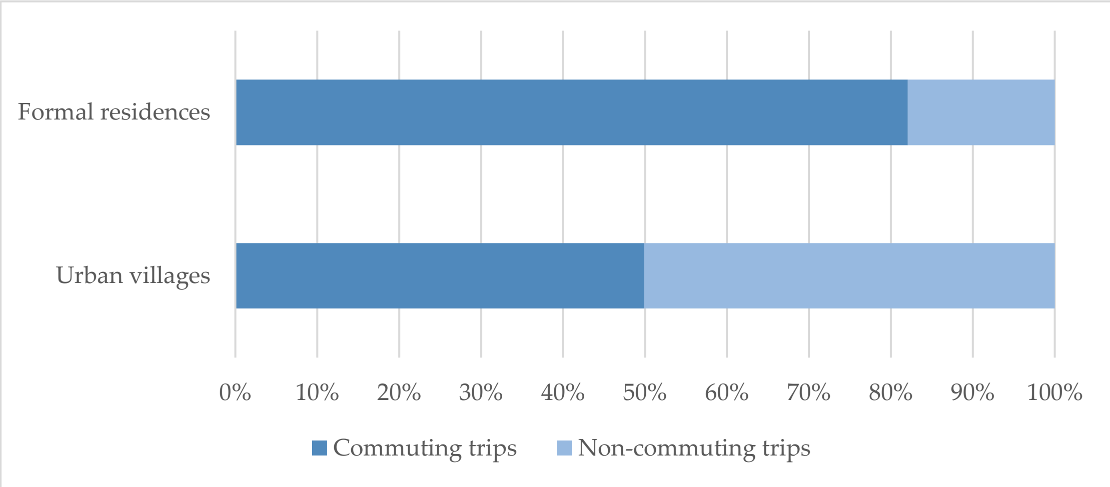


Figure 24 Travel purpose by PT.

In addition, other travel characteristics of urban villagers also indicate significant differences compared to those of formal residents as shown in Table 3.

Table 3 Travel behaviour characteristics comparison

Travel behaviour characteristics	Residence	Non-motorised	Public Transit	Car	Taxi	Others	Total
Travel purpose	Urban villages	28.32*	61.95*	3.54*	2.12	4.07	100
	Commodity housing	25.99*	49.85*	19.29*	2.23	2.64	100
Travel distance (km)	Urban villages	1.99*	14.77*	11.08	14.36*	16.85*	12.30*
	Commodity housing	2.17*	13.29*	13.40	5.85*	11.24*	9.87*
Travel rate[2]	Urban villages	0.30*	0.78*	0.04*	0.03	0.05	1.20*
	Commodity housing	0.37*	0.72*	0.28*	0.03	0.04	1.44*

* means $p \leq 0.05$, ANOVA and Chi-square test show significant differences of travel features between urban villages and commodity housing; [2] Travel rate means the average frequency of trips per day.

As can be seen from Table 1, PT features of urban villages exceed those of commodity housing in every aspect, that is travel distance and travel rate apart from mode choice. Beyond that, features of travelling by non-motorised mode and by car also show significant differences. As a result, non-motorised and car mode will be considered as reference dependents in the following regression model.

4.3 Descriptive analyses

A comprehensive set of variables collected and defined from four dimensions are incorporated in the model, comprising socio-demographic attributes, PT service attributes, daily travel features, and, most importantly, the built environment attributes. As mentioned in the literature review section, PT service attributes are particularly concerned in the PT choice study here. Table 4 and Table 5 display detailed statistical information of the variables. The final sample contains 565 respondents from urban villages and 985 respondents from commodity housings as a contrast. The built environment variables were measured in the scale of each residence area, which is smaller and more precise than those in previous studies that were measured in TAZ scale. Importantly, before applying data into the model, some diagnostic checks have been conducted to check the models. Firstly, the collinearity statistics show that the tolerance values are all larger than 0.1 and the VIF value is smaller than 10 (actually between 1 to 6) for both urban villages model and commodity housings model, suggesting that there is no collinearity in the data-set of the models. Secondly, when examining the goodness-of-fit, the significance values are all larger than 0.05, proving that the model meets the assumption. Finally, the Pseudo R-Square value for the urban villages model and commodity housings model are 0.634 and 0.659 respectively, which means that the model can explain most of the actual data.

Table 4 Socio-demographic variables profile

Variables	Order	Categories	Survey Data			
			Urban Villages (n = 565)		Commodity housing (n = 985)	
			Frequency	Percentage (%)	Frequency	Percentage (%)
Gender	0	Female	251	44.42	452	45.89
	1	Male	314	55.58	533	54.11
Age	1	<15	34	6.02	114	11.57
	2	15-35	433	76.64	687	69.75
	3	35-59	94	16.64	172	17.46
	4	>60	4	0.71	12	1.22
Income (thousand yuan/year)	1	<80	379	67.08	244	24.77
	2	80–150	170	30.09	681	69.14
	3	150–200	16	2.83	34	3.45
	4	>200	0	0	26	2.64
	0	No car	535	94.69	833	84.57

Car ownership	1	Have car	30	5.31	152	15.43
Occupation	1	Common labour	181	32.04	129	13.10
	2	High-skilled labour	90	15.93	487	49.44
	3	Self-employed	244	43.19	234	23.76
	4	Others	50	8.85	135	13.71

Table 5 Other variables profile

Dimension	Name	Description
Built environment variables	Residential density	Residential density of each residential unit
	Mixed land use	An entropy measured index[1]
	Distance to transit	Walking time from home to the nearest bus stop (min): 1. <5min; 2. 5–10min; 3. 10–20min; 4. >20min
	Bus stops	Number of bus stops within 500m
Public transit service variable	Frequency	Actual waiting time at bus stops (min): 1. <5min; 2. 5–10min; 3. 10–20min; 4. >20min
Daily travel features variables	Purpose	1. Commuting; 2. Non-commuting
	Travel distance	Distance from origin to destination (km)
	Travel time	Time spent during one trip (min)

[1] $\mathrm{E} = -\sum_j \frac{[P_j \cdot \ln (P_j)]}{\ln (n)}$, E refers to mixed land use (entropy); j refers to the type of land use (j=1,2,...n); P_j refers to the proportion of land use type j.

4.4 Model Specification

Random utility theory is the basic core to model choice behaviour and its determinants. Given j is one option from a set of M options (j=1, 2…, M), the utility derived from the jth option selected by the ith individual can be expressed as U_{ij}. Supposing this utility is a linear function of H factors (determinants). Of these H factors, assume that R of these factors are personal related but are irrelevant to option attributes, and S of these factors are option related but are irrelevant to individuals. Assume that X_{ir} represents the characteristics of ith individual with R attributes (r=1, 2…, R), and W_{js} represents the value of jth attributes (s=1,2,…S), so the utility functions can be written as the following equations (21) and (22):

$$U_{ij} = \sum\nolimits_{r=1}^{R} \beta_{jr} X_{ir} + \sum\nolimits_{s=1}^{S} \gamma_{is} W_{js} + \varepsilon_{ij} = Z_{ij} + \varepsilon_{ij} \tag{21}$$

$$Z_{ij} = \sum\nolimits_{r=1}^{R} \beta_{jr} X_{ir} + \sum\nolimits_{s=1}^{S} \gamma_{is} W_{js} \tag{22}$$

β_{jr} is the coefficient between the the jth option and the rth characteristic, and is the coefficient between the ith individual and the sth attribute. In addition, the relationship between the utility function and its determinant variables is not quite precise, with possibilities that some factors may be excluded or the measurement of some factors is inaccurate, so an error term is added to the equation to capture this uncertainty. Therefore, the utility function is called a stochastic utility model. Only if the mth option provides the highest utility of all available options, will a person choose j = m. In other words, if Y_i is a random variable, its value j (j $= 1,2, \dots,$ M) represents the choice made by the ith individual, the probability that the ith individual chooses the mth option is shown as the following equation (23):

$$P(Y_i = m) = P\left(U_{im} > U_{ij}\right), j = 1,2, \dots, M, j \neq m \tag{23}$$

To investigate the relationships between one dependent variable and independent variables, mainly when modelling the associations between a categorical (more than two categories) dependent and one or more predictor variables, a multinomial logistic regression model is widely employed in this domain (Abdul Hamid, Bee Wah, Xie, & Seng Huat, 2017). Multinomial logistic regression has been performed fitting results from the evidence of previous studies (C. R. Bhat, Astroza, Sidharthan, Alam, & Khushefati, 2014; Xinyu Cao & Fan, 2012). In our study, the observed numbers of mode choices made by individuals are classified into five categories as demonstrated in Table 1. Therefore, I will use multinomial logistic regression (MNL) to examine the impacts of several variables including built environments on PT choice behaviour.

In an MNL model, all Y_{is} = 0, and the individual specific model is represented as equation (24).

$$Z_{ij} = \sum_{r=1}^{R} \beta_{jr} X_{ir} \tag{24}$$

However, there are m equations in the MNL model but only m-1 independent unknowns. In order to standardise this problem, I set $\beta_{1r} = 0, r = 1, \ldots, R$ and $Z_{i1} = 0$, so the probabilities are shown in equations (25) and (26).

$$P(Y_i = 1) = \frac{1}{1+\sum_{j=2}^{M} exp\ (Z_{ij})} \tag{25}$$

$$P(Y_i = m) = \frac{exp\ (Z_{im})}{1+\sum_{j=2}^{M} exp\ (Z_{ij})} \tag{26}$$

A comprehensive set of variables collected and defined from four dimensions are incorporated in the model, comprising socio-demographic attributes, PT service attributes, daily travel features, and, most importantly, the built environment attributes. As mentioned in the literature review section, PT service attributes are particularly concerned in the PT choice study here. Table 2 and Table 3 display detailed statistical information of the variables. The final sample contains 565 respondents from urban villages and 985 respondents from commodity housing as a contrast. The built environment variables were measured in the scale of each residence area, which is smaller and more precise than those in previous studies that were measured in TAZ scale (Manoj & Verma, 2016; Munshi, 2016; D. Wang & Lin, 2013). Importantly, before applying data into the model, some diagnostic checks have been conducted to check the models. Firstly, the collinearity statistics show that the tolerance values are all larger than 0.1 and the VIF value is smaller than 10 (actually between 1 to 6) for both urban villages model and commodity housing model, suggesting that there is no collinearity in the data-set of the models. Secondly, when examining the goodness-of-fit, the significance values are all larger than 0.05, proving that the model meets the assumption. Finally, the Pseudo R-Square value for the urban villages model and commodity housing model are 0.634 and 0.659 respectively, which means that the model can explain most of the actual data.

4.5 Results

As shown above, there are five types of travel modes, including non-motorized, PT, car, taxi and others. When running the MNL model with one baseline, the relative advantage of the other four modes are resulted. However, to make the results easy to read and understand, travelling by non-motorized mode and car mode will act as reference dependents (a baseline) in the MNL model and I only tabulate the PT result. I omit “taxi” and “others”, because non-motorized, PT and car travelling are the main travel modes in urban villages and commodity housing, and I only want to know how advantageous PT is with respect to non-motorized and car mode. The data analysis procedure using the MNL model was run for four times referring to non-motorized mode in urban villages and commodity housing respectively, and then referring to car mode in urban villages and commodity housing respectively.

Table 6 demonstrates the regression results of the PT choice regression referring to non-motorized mode, with a comparison between urban villages and commodity housing. Among the built environment variables, after controlling variables of other dimensions, only residential density shows significant influence for both urban villages and commodity housing, respectively at the 90% and 95% confidence level. Also, the direction of the influence is consistent for both urban villages and commodity housing. Although urban villages and commodity housing are in urban centre area, the correlation in urban villages is less significant than that in commodity housing. This implies that people in urban villages are less affected by density to switch from PT mode to non-motorized mode for travel. Meanwhile, other built environmental variables did not show significant effect on travel mode. Therefore, it is not much helpful to alter built environments to attract PT travellers to shift to non-motorized travelling in urban villages.

Apart from the built environment, other variables also show significant influence. First, it is consistent with most previous studies that income affects travel mode choice behaviour remarkably (Khan, Maoh, Lee, & Anderson, 2014; Ureta, 2008). People in different income levels exert different modes of preference. Compared to non-motorized mode, people in urban villages with income below CNY80 thousand are less like to choose PT, while people in commodity housing with income above CNY200 thousand are more likely to choose PT. Secondly, travel distance is another significant factor encouraging people to choose PT instead of a non-motorized mode, but urban villages (an 16.1% increase) are less likely to be affected than commodity housing (an 33.9% increase) regarding this. In addition, more factors, like age, car ownership and travel time affect people to choose PT or non-motorized mode in commodity housing, but these variables do not show significant influence in urban villages. This could reflect that people in urban villages exhibit a more stable status than those in commodity housing when they have to decide to choose PT or a non-motorized mode.

Table 6 PT choice regression referring to non-motorized mode.

PT Choice Variables	Urban Villages		Commodity housing	
	Coef.	OR	Coef.	OR
Socio-demographic				
(Age=1)	–1.707	0.181	1.944	6.983
(Age=2)	1.869	6.480	3.690***	40.040
(Age=3)	1.740	5.696	2.529**	12.543
(Age=4)	0	-	0	-
(Gender=0)	0.167	1.182	0.119	1.126
(Gender=1)	0	-	0	-
(Occupation=1)	0.200	1.222	0.783	2.187
(Occupation=2)	–0.063	0.939	0.564	1.758
(Occupation=3)	0.658	1.931	–0.036	0.964
Occupation=4)	0	-	0	-
(Income=1)	–2.618***	0.073	-0.112	0.894
(Income=2)	–1.360	0.257	0.307	1.360
(Income=3)	0	-	1.985*	7.280
(Income=4)	-	-	0	-
(Car ownership=0)	1.021	2.777	0.547*	1.728
(Car ownership=1)	0	-	0	-
Public transit service				
(Frequency=1)	–0.183	0.833	0.677	1.968
(Frequency=2)	0.014	1.014	0.416	1.516
(Frequency=3)	0.244	1.276	0	-
(Frequency=4)	0	-	-	-
Daily travel features				
Travel distance	0.150**	1.161	0.292***	1.339

Travel time	0.080	1.084	0.304**	1.355
(Purpose=1)	0.794	2.213	0.571	1.770
(Purpose=2)	0	-	0	-
Built environment				
Bus stops	0.020	1.020	–0.175	0.840
Residential density	–0.352*	0.703	–0.454**	0.561
Mixed land use	–0.492	0.611	2.941	20.380
(Distance to transit=1)	0.498	1.646	–3.038	0.000
(Distance to transit=2)	0.432	1.540	–2.706	0.000
(Distance to transit=3)	–0.746	0.474	–2.955	0.000
(Distance to transit=4)	0	-	0	-
Intercept	–0.797	-	–33.839	-

*: significance<0.1; **: significance<0.05; ***: significance<0.01

Table 7 illustrates the regression results of PT choice regression referring to private car mode, with a comparison between urban villages and commodity housing. Regarding the built environment variables, it is found that most of the factors show a significant influence, which is a great disparity from the results in Table 6 where only residential density matters. This suggests that the built environment plays a more important role to switch people between PT and car than the shift between PT and non-motorized mode. Firstly, with the increase of bus stops within 500 metres, there will be a larger population with a 77.6% and 32.2% rise in urban villages and commodity housing respectively to choose PT rather than car at 95% and 99% significance confidence levels. This manifests that adding bus stops could encourage more PT choice and hinder car use effectively. Secondly, when residential density increases, people in urban villages will transfer from car use to PT choice which is also consistent with most previous studies (L. Zhang, Nasri, Hong, & Shen, 2012). Thirdly, people in urban villages show a more tolerant quality than those in commodity housing regarding the distance to transit. Even it takes 10 to 20 minutes to bus stops or metro stations, people in urban villages prefer to travel by PT than car. Specifically, mixed land use shows the distinctive influence on PT choice versus car use. In the case of people in commodity housing, the mixed land use shows a positive effect on their PT choice, which is in accord with most past research studies have claimed (Ewing & Cervero, 2010; Zailani et al., 2016; L. Zhang et al., 2012). However, the mixed land use influences urban villages in an opposite way. To clarify, increased mixed land use is in correlation with less traveling by PT mode, in fact, people almost give up PT mode in urban villages. This may be due to the fact that the higher mixed land use in urban villages means a great improvement of their living environment and that this would lead to higher rents in this region, which could make low-income residents have to leave this community, while those with a relatively higher income still living in this community would exert an increased proportion of car use.

In terms of other variables, females in urban villages tend to prefer to drive instead of taking the bus than males, while there is an opposite result in the case of commodity housing. Also, resident occupation demonstrates significant influence in urban villages but not in commodity housing. Regarding income, people earning 80–150 thousand yuan per year prefer PT than car. Although car ownership shows no significant influence in urban villages, people having no car in commodity housing would be more likely to choose PT. Concerning daily travel features, a longer distance is correlated with a higher probability of choosing car mode, even though it is not in direct proportion to travel time. The reason could be that the congestion context could not be neglected and maybe BRT (Bus Rapid Transit) plays an important role in reducing travel time by PT.

Table 7 PT choice regression referring to car mode.

PT Choice Variables	Urban Villages		Commodity housing	
	Coef.	OR	Coef.	OR
Socio-demographic				
(Age=1)	9.141	33.641	−30.728	0.000
(Age=2)	−16.224	0.000	−15.958	0.000
(Age=3)	−16.853	0.000	-15.911	0.000
(Age=4)	0	-	0	-
(Gender=0)	−3.278*	0.038	0.377*	1.458
(Gender=1)	0	-	0	-
(Occupation=1)	6.352**	15.514	−18.420	0.000
(Occupation=2)	5.085**	6.591	−17.365	0.000
(Occupation=3)	11.305***	8.012	−17.187	0.000
(Occupation=4)	0	-	0	-
(Income=1)	22.320	16.503	0.196	1.217
(Income=2)	4.176**	5.076	−0.049	0.952
(Income=3)	0	-	0.036	1.037
(Income=4)	-	-	0	-
(Car ownership=0)	1.078	2.938	2.211***	9.128

(Car ownership=1)	0	-	0	-
Public transit service				
(Frequency=1)	13.735	9.471	0.026	1.027
(Frequency=2)	−0.469	0.626	−0.183	0.833
(Frequency=3)	−1.639	0.194	0	-
(Frequency=4)	0	-	-	-
Daily travel features				
Travel distance	−0.115*	0.891	−0.025**	0.975
Travel time	6.717***	16.205	1.366***	3.922
(Purpose=1)	−15.983	0.000	0.759	2.137
(Purpose=2)	0	-	0	-
Built environment				
Bus stops	0.574**	1.776	0.279***	1.322
Residential density	2.278***	3.103	−0.016	0.984
Mixed land use	−12.556**	0.000	2.006*	9.593
(Distance to transit=1)	0.561	1.753	1.577*	4.842
(Distance to transit=2)	3.149	13.318	2.210**	9.119
(Distance to transit=3)	4.899*	14.156	1.616	5.032
(Distance to transit=4)	0	-	0	-
Intercept	26.806	-	7.293	-

*: significance<0.1; **: significance<0.05; ***: significance<0.01

Changing the built environment has little impact on the transfer between non-motorized travel and bus travel, but it has a significant impact on the transfer of bus travel and car travel in urban villages. Compared with residents in commercial housing communities, increasing the number of bus stops around the urban villages can promote the residents' public transport travel choices to a greater extent, and at the same time give up a greater proportion of car travel.

5. Controlling for the residential self-selection effect

5.1 Residential self-selection for urban villages

Residential self-selection effect mainly refers to the importance of emphasizing travel-related attitudes and preferences when residents choose their residences. Residents choose their place of residence based on their travel ability, travel demand and travel preferences (Mokhtarian & Cao, 2008). In another word, residential self-selection is not only a choice caused by personal preferences and attitudes, but also a restriction of abilities and demand defined by socio-demographic characteristics. In recent years, a series of studies on the relationship between travel attitudes and residential self-selection have verified the establishment of the residential self-selection hypothesis (C. R. Bhat & Eluru, 2009). Early empirical studies have proved that travel behaviour is related to the built environment, and living in a high-density, high-mixed area is related to reduce car travel. However, these studies only confirm the relationship between the built environment and travel behaviour, and cannot prove the causal relationship between them. In recent years, research has increasingly focused on a question: can the built environment determine travel behaviour? Or conversely, does travel behaviour determine the built environment? These research questions are waiting for answers from the perspective of residential self-selection.

Those residents who choose to live in a community with certain built environment characteristics according to their socio-economic attributes or attitude preferences, show certain travel characteristics. The influence of built environment on travel behaviour could be overestimated if the residential self-selection was ignored. Existing studies have examined the effects of residential self-selection and most suggested that the effects of built environment variables remained statistically significant, even after controlling for statistically significant effects of residential self-selection (C. Ding et al., 2016; Humphreys & Ahern, 2017; Jarass & Scheiner, 2018).

Most studies claimed that the residential self-selection is one of the significant influencing factors when investigating the relationship between built environment and travel behaviour. However, after controlling for the residential self-selection, built environment variables still have a significant impact on travel behaviour (Xinyu Cao, 2009). Some studies have separately quantified the impact of residential self-selection and built environment on travel behaviour, suggesting that the contribution of the built environment is around 51% -81% (C. R. Bhat & Eluru, 2009; Xinyu Cao, Xu, & Fan, 2010). Therefore, the built environment can explain travel behaviour better than residential self-selection. The two key points in the study of residential self-selection are how residential choices and travel-related preferences affect residential choices. Current research on the background of Chinese cities has revealed the representational relationship between the built environment and travel behaviour from some perspectives, but the extent to which this observable connection will be attributed to residential self-selection has not been definitively concluded. Wang and Lin (2014) pioneered the study on residential self-selection of residence in the context of Chinese cities, and put forward an important argument that China's unique real estate market has a significant impact on the residential self-selection of residence (D. Wang & Lin, 2014). The conclusions about attitude preferences are not completely applicable to the Chinese market. As to the China's housing situation, there are three main sources of housing for Chinese residents: housing allocated by the work unit, commodity housing and public housing. The availability of unit housing and travel tools limits individual housing choices, which means the effect of residential self-selection is limited.

Chinese cities need more attentions because they differ significantly from European and American cities in terms of travel behaviour and especially the transit preference. As one of the main sources of rental housing, urban village housing has its own unique residential self-selection attributes. First, compared with the residents who choose to live in higher-quality commodity housing communities, the first consideration of the residents who choose to rent houses in urban villages is cost, since most low-income population live in urban villages. Therefore, on the premise of cost and location, transport conditions around the urban villages should be taken into consideration. Location here refers to the spatial location, that is, the distance from the city center. Second, in the case of abundant housing resources in urban villages and sufficient and reasonable geographical location, convenient transport is the main consideration for urban village selection. Therefore, in the Chinese context, it should be emphasized of the particularity of the influence of residential self-selection in urban villages.

5.1.1 Preference for short-distance commuting

According to the previous explanation, the earliest housing-employment relationship in China originated from the unit welfare housing allocation. Under this housing market and system, housing and employment are located very close to each other. This historical origin also formed the characteristics of the original spatial structure and built environment of China's big cities, and at the same time formed a deep-rooted impression of residents' preference of proximity to employment and residence, which resulted to a natural preference for the short commuting distance.

Although the housing reform has broken this spatial pattern of housing-employment proximity in China, it has become a deep-rooted notion of the Chinese to commuting in short distance as far as possible. Coupled with the relatively low rate of car ownership, the consideration of the short distance between the location of work and residence is an important consideration in residential choice. The empirical evidence provided by Wu (2013) supports this argument. According to the travel survey data of 3481 families in Beijing, the research found that a family is more inclined to live in a community with high employment accessibility and short commuting time (J. Wu & Yang, 2013). Another survey of young office workers in Guangzhou found that in addition to the proximity of the public transport network, employment accessibility is an important determinant of residential choice. However, the research on western cities has different conclusions. The distance to the workplace is not an important determinant of people's choice of residence (Humphreys & Ahern, 2017). This has once again verified the necessity of research under the special background of Chinese cities.

This preference for short-distance commuting may have important explanatory significance for residential self-selection and travel behaviour. When an individual shows a non-motorized travel behavior, it may because he chooses to live in a community close to his work place, which leads to a short commute distance and further leads to the choice of non-motorized travel, rather than the good transit infrastructure in this community lead him to behave like that.

Furthermore, the impact of the built environment on travel behaviour observed (measured) may be the result of not only caused by the impact of the built environment, but also the result of travel preferences or residential self-selections. In order to test the influence of residential self-selection, a simple way is to explicitly ask the interviewee that whether short-distance commuting is an important consideration in the choice of residence.

5.1.2 Preference for bus proximity

Although car ownership has experienced rapid growth in the past decade in China, public transport (such as buses and subways) is still the main daily travel mode for most Chinese urban residents. According to the statistical data extracted from 2017 China Statistical Yearbook, even in the most developed cities, such as Beijing and Shanghai, the per capita car ownership rate is only 28.23 % and 21.08 %, which is much lower than that of 79.05% per capita car ownership in the United States (D. Kim et al., 2017). One of the main differences in travel modes choice behaviour between Chinese cities and the USA cities is that cars are the main mode of travel in North America but not in China. Therefore, good public transport accessibility is an important factor considered by Chinese urban residents in their residential choices.

Empirical studies based on major cities in China suggest that residential communities with better public transit accessibility are more popular. Although residents of Europe and North America may also prefer to choose communities with good public transport, this may be affected by the dual effects of economic constraints and travel attitudes, that is, even if they own a private car, due to factors such as environmental protection, it is also possible for them to prefer public transport and actively choose public transport. However, in China, this phenomenon is more likely to be caused by economic constraints, because most people do not own private cars. Therefore, in the research context of Chinese cities, the socio-economic background of residents rather than their attitudes toward public transport may better explain the residential self-selection related to public transport.

5.1.3 Preference for daily shopping proximity

Daily shopping activities traveling by walking or cycling is an important part of residents' daily activities in China. A study by Cao (2006) in Austin, Texas found that the preference for shops within walking distance has a profound impact on personal walking shopping trips. This impact is also a possible reason for the overestimation of the relationship between the built environment and walking. However, there are remarkable differences in shopping behaviour between the Chinese and the Americans. Most Americans conduct a large-scale shopping once a week, but the Chinese people's habit is to go shopping every day to buy fresh vegetables, meat, etc., because the Chinese believe that the freshness of food will affect its taste and health, so the Chinese travel demand of shopping is more frequent. In this context of cultural differences, Chinese people also pay attention to the proximity of large food shopping markets or daily necessities stores when choosing residences, or they have a higher degree of preference for daily shopping locations. This preference for proximity to food markets or commodities caused by the demand for fresh food is of unique and significant significance to the study of travel behaviour in the context of Chinese cities. When studying the impact of the built environment on daily shopping and travel behaviour, it is necessary to seriously consider whether and how the travel preferences and residential choices caused by this food culture will have an impact.

In a short summary, the residential self-selection features for urban villages is demonstrated in Figure 25.

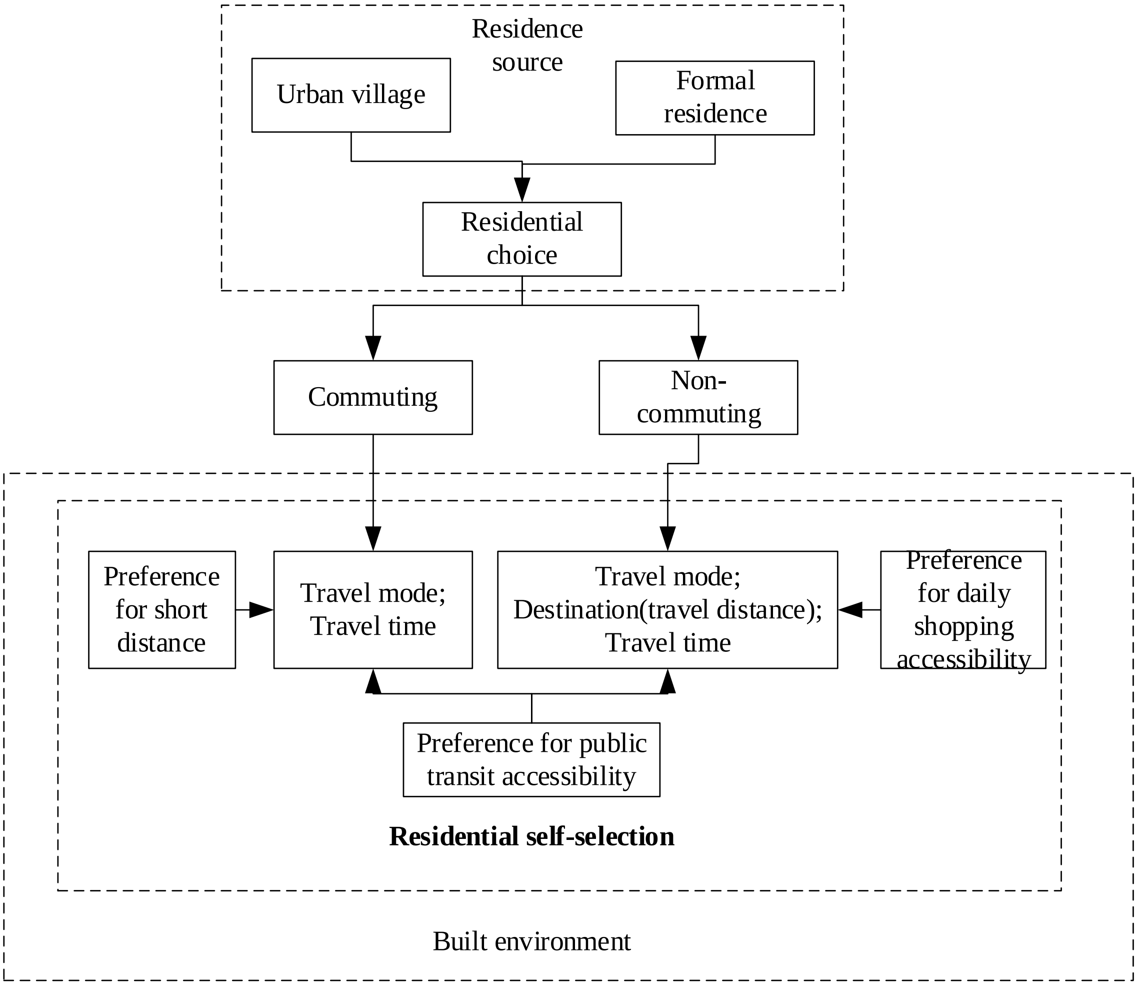


Figure 25 Residential self-selection features for urban villages

5.2 Model structure

5.2.1 Structural Equation Modelling

Existing studies that used the discrete choice model can only focus on testing the direct linkage of the built environment and travel mode choice but cannot explore how the built environment may indirectly affect travel mode choice through mediating factors. In recent years, Structural Equation Modelling (SEM) has been widely employed in transport research since it can handle the complex relationships among the endogenous and exogenous variables under a holistic framework while separately identifying direct and indirect effects (Brownstone & Golob, 2009; Ding et al., 2017; S. Song et al., 2016). The structural equation modelling combines multiple regression, path analysis, factor analysis, covariance analysis and other methods to clearly analyse the relationship between individual indicators. Using the SEM approach, the study conducted by Van Acker and Witlox (2010) showed that car ownership mediated the relationship between built environment and car mode choice. Ignoring the mediating effect of car ownership is more likely to generate an incorrect conclusion on the influence of built environment on travel mode choice (Van Acker & Witlox, 2010). Consequently, this will provide misguidance for urban planning strategies and policy-making process (Van Acker & Witlox, 2010). Silva (2012) addresses the relations between travel behaviour and land use patterns using SEM framework (de Abreu e Silva, Morency, & Goulias, 2012). The model estimation results indicated that the total effects between land use variables and the other endogenous variables are presented last (de Abreu e Silva et al., 2012). Jing Ma (2015) adopted Structural equation modeling to examine the relationship between urban form, travel behaviour, and CO_2 emission, while accounting for residential self-selection and socio-demographic attributes (Ma et al., 2015). Results show that residents living in neighborhoods with higher job density, proximity to an employment sub-center and greater subway accessibility tend to travel shorter distance, choose low-carbon travel modes, and emit less CO_2 from work related trips (Ma et al., 2015). Chuan

Ding (2017) explored the influence of built environment on travel mode choice considering the mediating effects of car ownership and travel distance using a framework of integrated structural equation model and discrete choice model and revealed the direct and indirect effects of built environment on travel mode choice (Ding et al., 2017).

There are seven steps of the main procedure to build a structural equation model, which are: related theoretical research, model hypothesis, establishment of structural equation model framework, model operation and identification, evaluation of whether the model meets the requirements of adaptation, modification of the model, and model interpretation and discussion. The basic procedure of structural equation model analysis is shown in Figure 26.

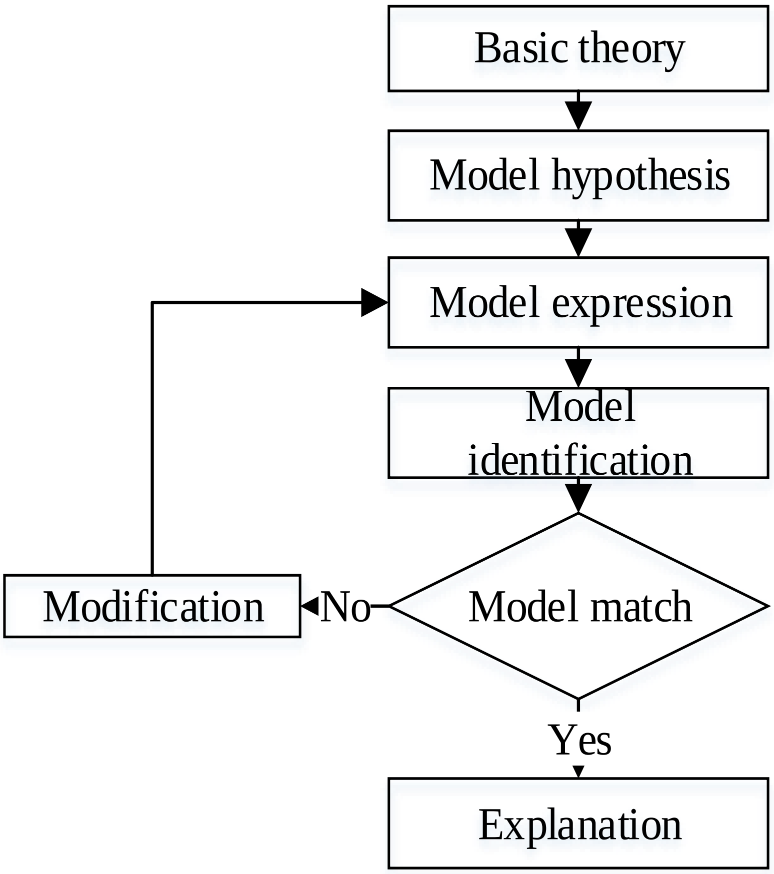


Figure 26 Procedure of SEM

In a SEM model, the endogenous variables can include not only discrete variable like travel mode choice, but also continuous variable like travel distance and time. Besides, to investigate the total effect of built environment on transit behaviour, direct effect and indirect are both examined in a SEM structure (Deutsch, Yoon, & Goulias, 2013; Etminani-Ghasrodashti & Ardeshiri, 2015; Tsao, Chang, & Ma, 2017).

This research employs SEM to investigate influential factors for public transport travel behaviour in the villages and residences separately and explores the impact mechanism of the built environment of two different residential communities on transit travel. Basic SEM is formulated like equations (27) and (28).

$$X = \wedge_X \xi + \delta \tag{27}$$

$$Y = \wedge_Y \eta + \varepsilon \tag{28}$$

$\wedge_X$ and $\wedge_Y$ are loadings for exogenous variables X and endogenous variables Y, δ and ε are measurement errors for exogenous latent variables ξ and endogenous latent variables η. Factors influencing public transport travel behaviour come from three aspects, involving Socio-demographic attributes, built environment attributes and transit service attributes. These abstract concepts are latent variables represented in the model and they are expressed by respective observed variables.

5.2.2 Model structure integrated with mixed logit model

Travel activities have complex multi-dimensional attributes, like travel mode choice, travel distance and car ownership, but most studies analysing models only incorporate on outcome variable. Among them, travel mode choice is the most cited outcome indicator. Under this circumstance, in a one-outcome variable model, other travel decision-making variables are regarded as exogenous variables, and the structural relationship between decisions is not considered. In recent years, scholars have begun to pay attention to the issue of joint travel decision-making models. Yang (2013) established a cross-nested Logit (CNL) model to analyze joint the decision-making research question of two outcome variables which are residential location decision and travel mode decision, and found that when external conditions change, decision makers tend to be the first to change the departure time, then travel mode, and finally the location of residence. Although this approach is convenient and easy from the perspective of modeling and estimation, it simply treats the making of multi-dimensional activity-travel decisions as a sequential process, ignoring that each decision behaviour may have simultaneously mutual relationship to some extent. When Islam (2012), etc. analyzed the relationship between travel activity chain structure and travel mode in detail, he found that in the working travel activity chain, the chain structure and travel mode were determined at the same time, which challenged the analysis method that travel mode choice is independent of other activity-travel decision. Existing studies have confirmed that each activity-based travel decision is not independent to each other, but there are very complex interactions among them, and they are not simply nested relationships. They need to be treated as one “Decision Bundle”, which takes into account of the complex interaction relationships among various decision variables into the model, and establishes a joint decision model for integrated analysis.

Based on the previous analysis and definition of travel behaviour in urban villages, combined with previous studies on travel behaviour outcome variables, this research intends to conduct a joint decision-making analysis on travel mode choice, travel distance, and travel time in travel behaviour decision-making modelling in urban villages. At the same time, the emergence of attitude indications variables should be considered. The outcome variables not only have direct visible structural influences, but are also assumed to be affected by common invisible factors, involving the complex dependency structure among the multi-dimensional attributes. The multi-type attributes and variables the research make the original single data type decision analysis model less applicable, so it is necessary to establish a joint decision model of mixed data types research. Therefore, the model structure accommodation multiple types of data is established as Figure 27 shows.

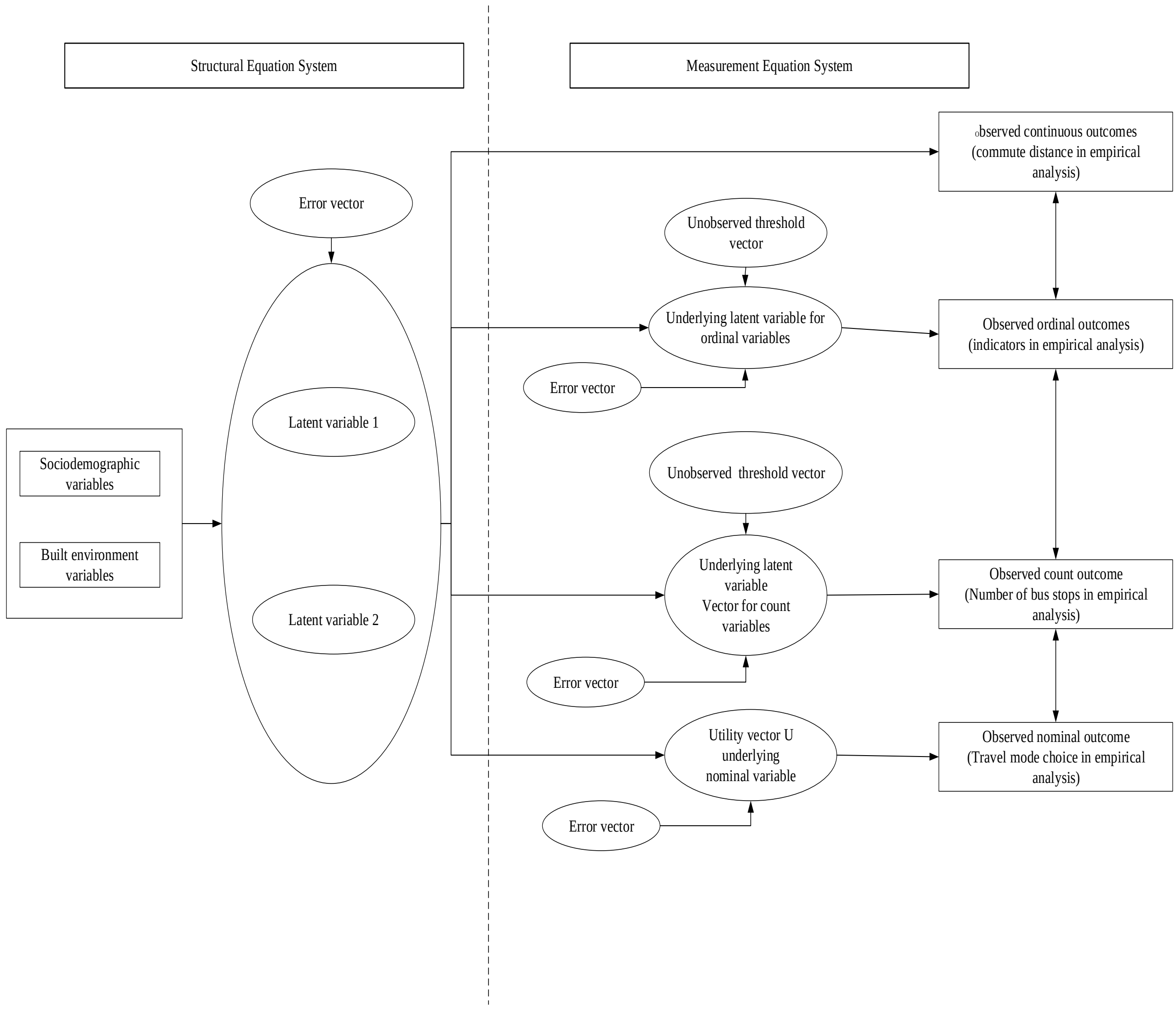


Figure 27 Latent variables accommodating multiple types of data

In the above structural model, the latent equation system part is SEM modelling, and the measurement equation system part is a mixed logit model.

Mixed logit model structure is much flexible that MNL model, and mixed logit model is also known as the random parameter Logit model, it has the following advantages: it does not have IIA characteristics, and takes into account of the repetitive selection of individuals; it can be assumed that the error term obeys an arbitrary distribution function, which breaks the double exponential distribution in other logit models and the probability model obeys normal distribution limit; the estimated parameter is a random number distribution, that is, the coefficient of the characteristic variable is random that obeys a certain distribution. Mixed logit model has the following choice probabilities

$$P_{ni} = \int L_{ni}(\boldsymbol{\beta}) f(\boldsymbol{\beta}) \mathrm{d}\boldsymbol{\beta} \tag{29}$$

Where L_{ni} is the probability density function and the model selection probability at the parameter vector, namely:

$$L_{ni}(\boldsymbol{\beta}) = \frac{e^{V_{ni}(\boldsymbol{\beta})}}{\sum_j e^{V_{nj}(\boldsymbol{\beta})}} \tag{30}$$

If assuming the utility term is a linear function, the P_{ni} is represented as following:

$$P_{ni} = \int \frac{e^{V_{ni}(\boldsymbol{\beta})}}{\sum_j e^{V_{nj}(\boldsymbol{\beta})}} f(\boldsymbol{\beta}) \mathrm{d}\boldsymbol{\beta} \tag{31}$$

It can be seen from the formula that the mixed logit model selection probability is the weighted average of the logit formula at different values, the weight is given by the probability density, and the mixed logit model parameter calibration also needs to be obtained through simulation methods.

(3) SEM-mixed logit joint model

The integrated model of SEM and Mixed logit can incorporate the influence of latent variables into the utility function of the individual discrete choice model, and increase the composition of the utility function from the traditional way which only consider the determination of the explicit variable to the combined effect of the explicit variable and the latent variable to realize the potential variables with significant variables. Also, the quantitative relationship between the latent variable and its corresponding observed variables are calculated, so logit consideration of latent variables in the model becomes possible. However, there are still some unresolved problems and challenges in the model, which are mainly reflected in: (1) quantitative measurement of latent variables; (2) description of the quantitative relationship between latent variables and other significant variables in the integrated model; (3) The derivation and fusion of the integrated theory of the latent variable and the traditional discrete choice model, rather than simple superposition; (4) The determination of the latent variable parameter value and the calculation of the integrated model result should be realized simultaneously through the algorithm.

The two important parts of the SEM-Mixed logit model are: (1) latent variable structural equation model, which is the essential part of SEM, and (2) latent variable measurement equation model, which employs mixed logit model. The framework of SEM-Mixed logit Discrete choice model shown in Figure 28.

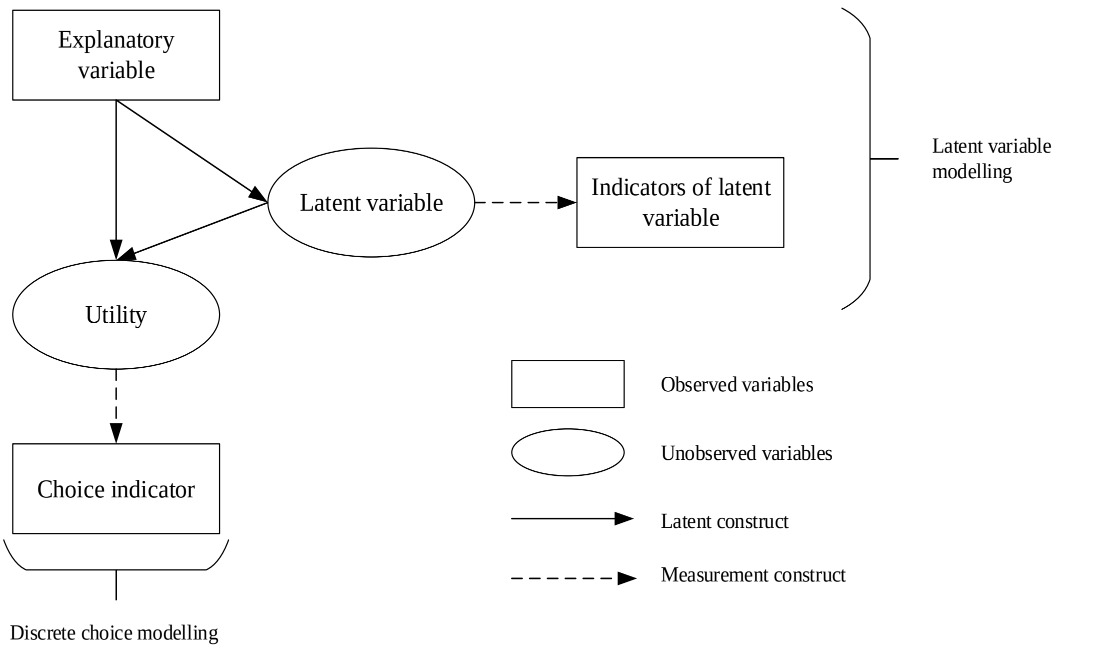


Figure 28 SEM-Mixed logit discrete choice model

Latent variables are introduced into the discrete choice model to realize the modelling and prediction of incorporating psychological variables into behavioural choices. The theoretical framework is the hybrid choice model (Hybrid. Choice. Model, HCM). In recent years, there have been many related modelled developed based on the application of mixed discrete choice models in the transport research frontiers. By incorporating the latent variables into the discrete choice analysis, a research studied the influence of individual characteristic information and attitudes on mode choice behaviour (Q. Wang, Feng, Liu, Wang, & Zhang, 2014); Based on the San Francisco Travel Survey in 1998, Schwanen et al. combined 16 latent variables such as behaviour attitude, lifestyle, personality characteristics and 10 socioeconomic information variables into the MNL model, and found that the latent variables analysed are all related to the choice of the type of vehicle used by the individual significantly (T. M. Schwanen, Patricia L., 1998). Temme et al. conducted a survey of 907 commuters in Germany and established a mixed choice model containing latent variables of traveller's emotion, status and attitude, and used the plus software package to estimate the model (Paulssen, Temme, Vij, & Walker, 2013). In Bhat's research, the choice of residence is expressed by density. His explanation is that density is closely related to other built environment attributes. Density is a most representative attribute of other built environment attributes. Therefore, the combination of dwelling density and commuting distance in the model can clearly describe dwelling choices, and at the same time, it can provide a convenient way to capture the impact of the built environment on travel and car ownership. Indeed, there has been a long history of using resident density as a synonym for land use elements in transport literature (C. R. Bhat & Eluru, 2009).

In a short summary, the mixed model incorporating multiple outcomes is necessary and applicable to this research. On the basis of the integrated SEM-mixed logit model, descriptive analysis and variables specification are conducted, and results are obtained based on the model and data.

5.3 Descriptive analysis

Features of transit trips are illustrated in following figures from Figure 29-31. Figure 29 indicates difference of travel mode choice between urban villages and commodity housing. Travellers in urban villages prefer public transit, and remarkably, travel much less by car than those in commodity housing.

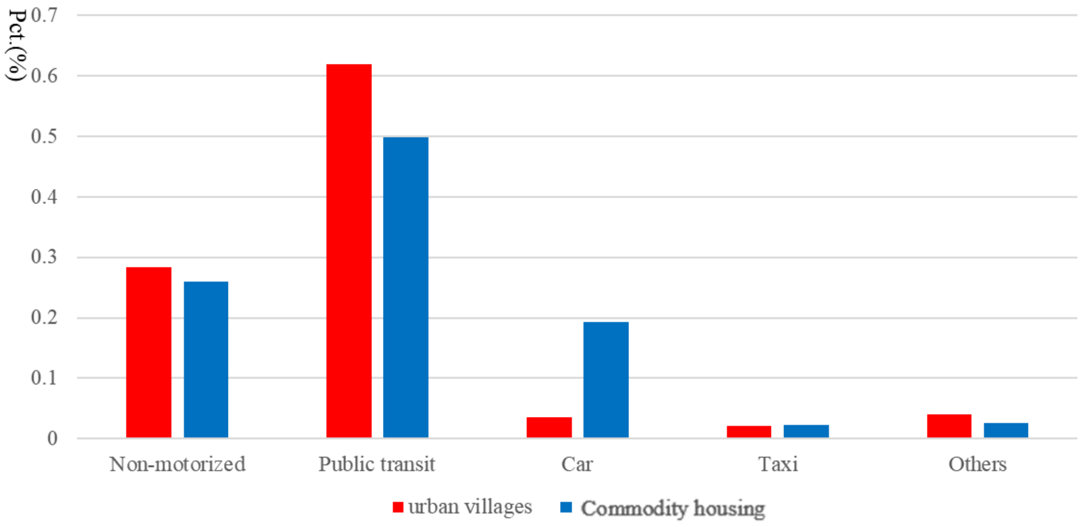


Figure 29 Travel mode choice

Figure 30 demonstrate the difference of travel distance by transit between urban villages and commodity housing by exhibiting trips percentage in every distance interval.

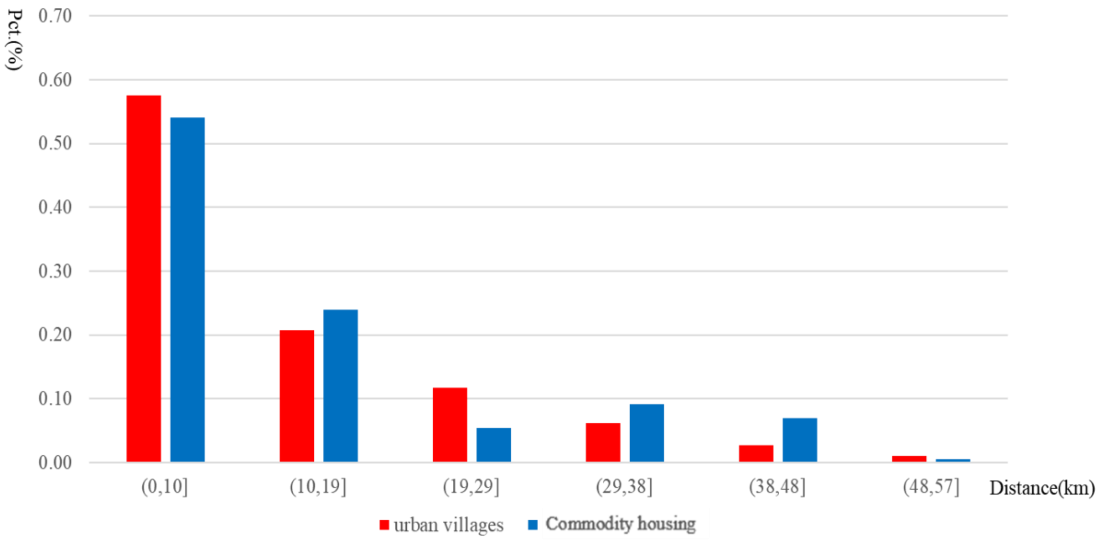


Figure 30 Travel distance by public transit

More than half of transit trips in both urban villages and commodity housing are short trips within distance less than 10km. However, in long distance travel (above 30 km), urban villages show less interest to travel by transit. Regarding travel purpose by transit shown in Figure 31, almost all trips of urban villages' travellers are commuting trips, but commodity housing travellers travel for more diverse purposes other than commuting.

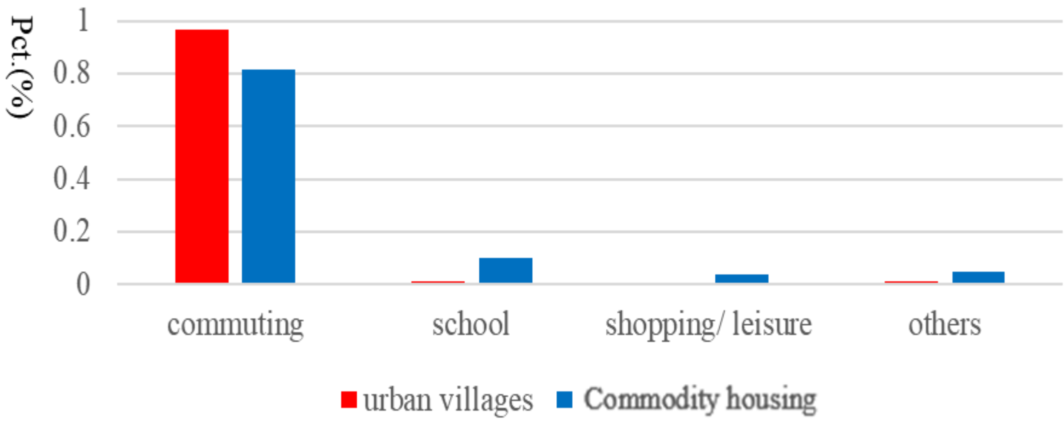


Figure 31 Travel purpose by transit

Table 8 demonstrates socio-demographic characteristics of respondents. Some features are very recognizable in the table 8. For instance, respondents' income of urban villages is much lower than that of commodity housing, and so does the car ownership.

Table 8 Description of Socio-demographic variables

Variable	Index	Category	Urban Villages (n = 565)		Commodity housing (n = 985)	
			Frequency	Percentage (%)	Frequency	Percentage (%)
Gender	0	Female	251	44.42	452	45.89
	1	Male	314	55.58	533	54.11
Age	1	<15	34	6.02	114	11.57
	2	15-35	433	76.64	687	69.75
	3	35-59	94	16.64	172	17.46
	4	>60	4	0.71	12	1.22
Income (thousand yuan/year)	1	<80	379	67.08	244	24.77
	2	80–150	170	30.09	681	69.14
	3	150–200	16	2.83	34	3.45
	4	>200	0	0	26	2.64
Education background	1	Junior high school and below	181	32.04	129	13.10
	2	Senior high school	244	43.19	234	23.76
	3	Undergraduate	90	15.93	487	49.44
	4	Graduate and above	50	8.85	135	13.71
Car ownership	0	No car	535	94.69	833	84.57
	1	Have car	30	5.31	152	15.43

Table 9 measured built environment in unit of residence. On the whole, land use in urban villages are less mixed use than that in commodity housing, and transit accessibility in urban villages is worse than that in commodity housing .

Table 9 Statistics of built environment variables

Residence type	Residence name	Sample size	Population density (people/m^2)	Mixed land use	Distance to transit*（km）	No. of bus stops within 500m
Urban village	LQV	17	0.09	0.352	2.44	15
	SDV	44	0.24	0.338	2.11	15
	JYV	21	0.12	0.565	2.01	7
	SQV	66	0.08	0.497	2.33	20
	TYV	29	0.12	0.412	2.62	19
	XSV	72	0.23	0.559	1.72	25
	HYC	110	0.29	0.845	1.62	18

Commodity housing	TRC	30	0.07	0.833	1.82	16
	YSC	30	0.13	0.896	1.54	14
	YHC	6	0.18	0.793	1.28	14
	YDC	87	0.43	0.842	1.67	13

*Distance to transit is self-reported, it is measured by walking time from home to the nearest bus stop (min), and the figure means: 1. <5min; 2. 5–10min; 3. 10–20min; 4. >20min. Other variables are measured according to geographic information.

5.4 Variables Specification

Correlation analysis framework is generally applied in this area based on empirical theories, which takes travel behaviour (TB) as explained variables, the built environment (BE) as explanatory variables, and the socioeconomic attributes (X) as control variables. To apply ε as random error, and their relations can be expressed as equation 1 and Figure 5 shows.

$$TB = f(BE, X) + \varepsilon \qquad (32)$$

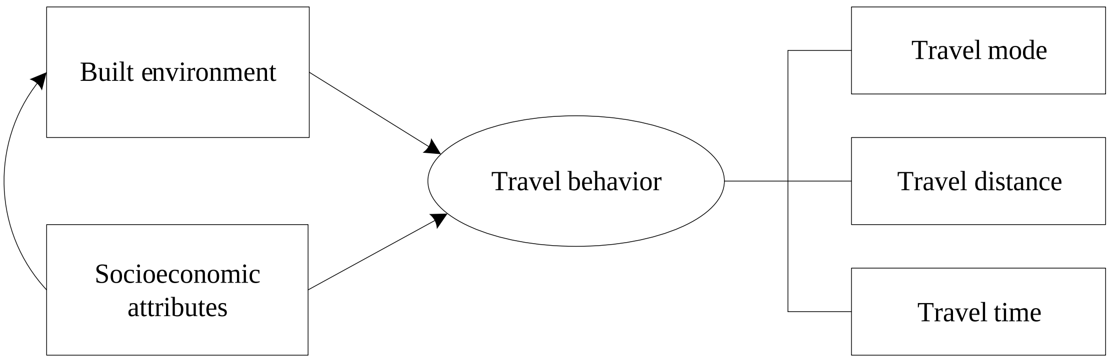


Figure 32 Conceptual framework for effects of built environment on travel behaviour based on correlation analysis

The variables employed in the model are described as Table 10 shows.

Table 10 Definition of SEM variables

Latent variable	Observed variable	Variable name	Latent variable	Observed variable	Variable name

Socio-economic attributes	X1	Gender	Transit service	X10	Service frequency
	X2	Age		X11	Evaluation
	X3	Income			
	X4	Education background			
	X5	Car-ownership			
Built environment	X6	Residential density	Transit trip features	Y1	Travel distance
	X7	Mixed POI		Y2	Travel time
	X8	Distance to transit		Y3	Transit mode choice
	X9	Bus stops within 500m			

Transit trip features include travel mode choice, distance and time. Transit mode choice is explained as expression (33) shows.

$$Transit\ \ mode\ \ choice\ \ (Y3) = \begin{cases} 1, yes \\ 0,\ no \end{cases} \tag{33}$$

Specially, variables X6-X11 are interpreted in Table 11.

Table 11 Interpretation and measurement of X6-X11

Latent variable	Observed variable	Variable name	Interpretation/ Measurement
Built environment variables	X6	Residential density	Residential density of each residential unit
	X7	Mixed land use	An entropy measured index
	X8	Distance to transit	Walking time from home to the nearest bus stop (min): 1.<5min;2. 5-10min ;3. 10-20min; 4. >20min
	X9	Bus stops with in 500m	Number of bus stops within 500m
Transit service	X10	Frequency	Actual waiting time at bus stops (min): 1.<5min; 2.5-10min; 3.10-20min; 4. >20min
	X11	PT service evaluation	Evaluation for transit service: 1.Good; 2.Fair; 3.Poor

The correspondence of measurement variables and latent variables is shown in Figure 33.

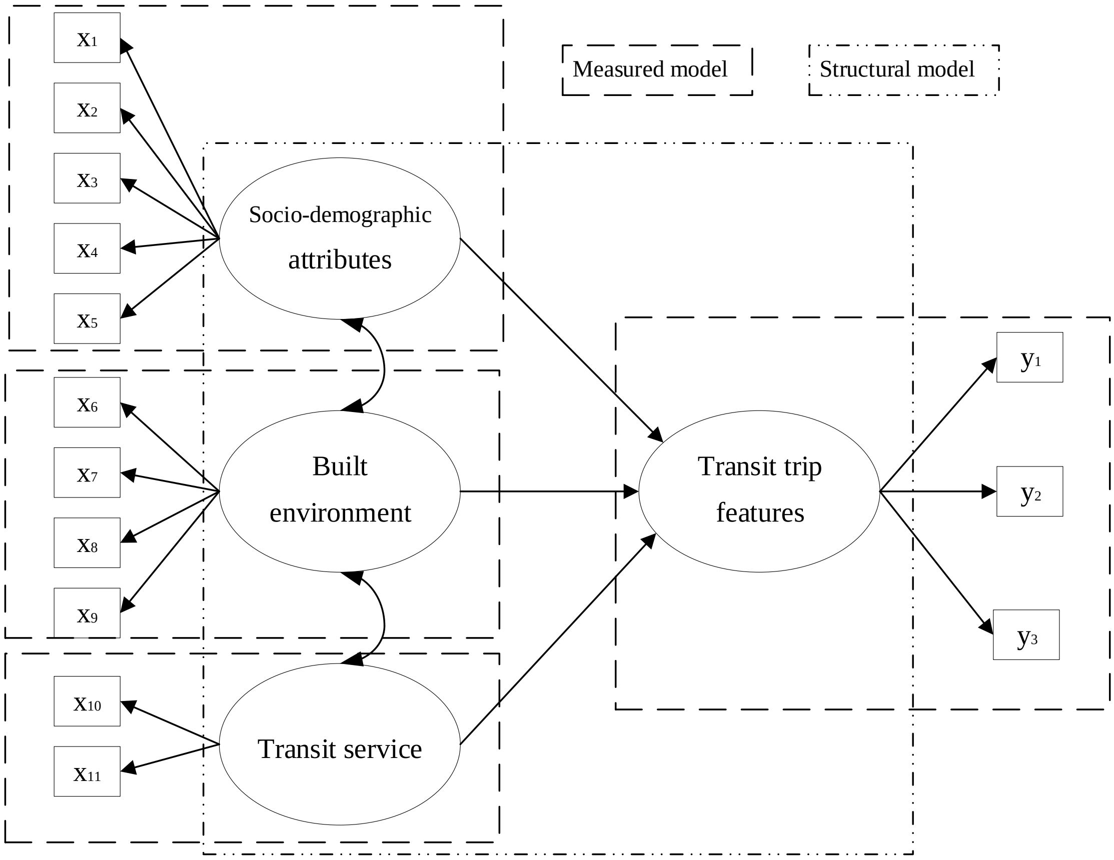


Figure 33 Conceptual framework for SEM-Logit construction

In this chapter, I attempt to control for residential self-selection employing a form of research design raised by Cao and Yang (2017) that if the socio-demographic attributes or attitude preference has a significant influence on built environment, and meanwhile the socio-demographic or attitude preference has a significant influence on travel behaviour, it indicates that there exists residential self-selection effect. Further, under this circumstance, if the influence of built environment on travel behaviour is still significant, it means that after considering the self-selection, the built environment has a significant impact on travel behaviour (Xiaoshu Cao & Yang, 2017).

Therefore, by hypothesizing an influential path from socio-demographic variables and transit service (X11 is an attitudinal variable) towards the built environment, the SEM model has taken residential self-selection into account as shown in Figure7. Besides, considering that the impact of the car-ownership (X5) on the transit travel behaviour is not independent, variables could affect travel behaviour via affecting car-ownership

(Klöckner & Friedrichsmeier, 2011; Shengxiao Li & Zhao, 2017), car-ownership is set as a mediation variable in a modified SEM framework shown in Figure 34.

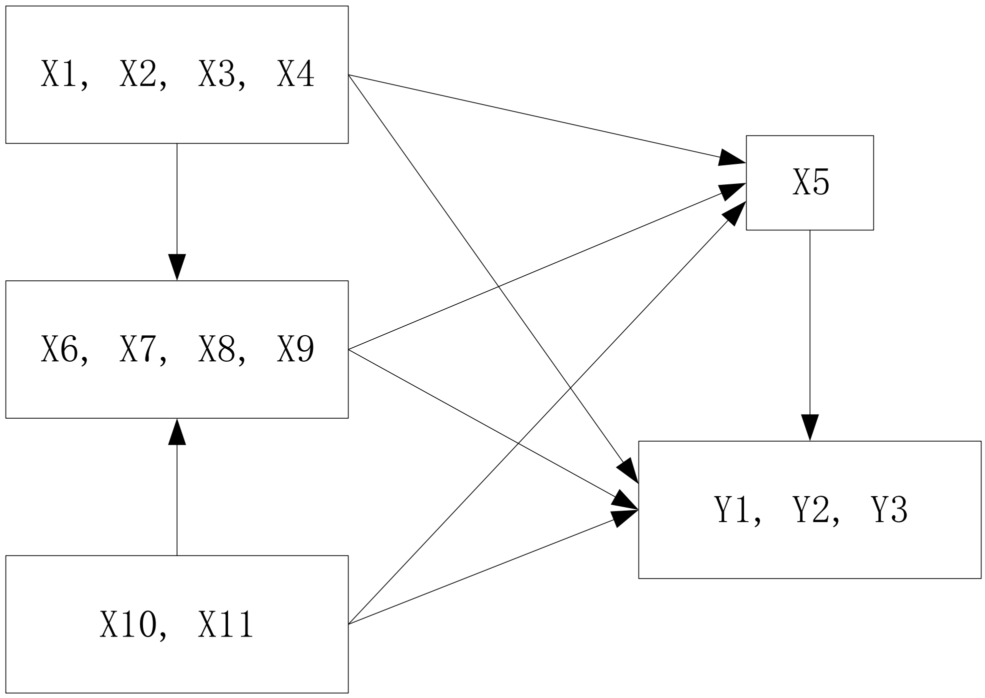


Figure 34 Modified SEM framework with consideration of residential self-selection (simplified)

5.5 Results

Since the raw data does not follow multivariate normal distribution, the traditionally used maximum likelihood estimation will be biased, so the Bollen-stine bootstrap estimation method is used in this research. To modify the model, various approaches are employed, including adding a covariation relationship between the influence path and the error variable which can improve the degree of model adaptation, deleting the path with insignificant influence, and re-improving the model after each correction, until the modification indices (M.I.) table does not prompt to modify the model, and the significance level of each path is above 1%.

The results of model fit indices are shown in Table 12. All the indicators show that the model and data in context of both urban villages and commodity housing model are well fitted.

Table 12 The model fit indices for SEM

Model fit index	Reference	Urban village	Commodity housing
Chi-square	-	746.063	861.286
df	-	51	51
Bollen-stine bootstrap P	>0.05	0.514	0.478
GFI	>0.9	0.912	0.983
AGFI	>0.9	0.978	0.996
CFI	>0.9	1.000	1.000

Table 6 and Table 7 demonstrate the paths with significant influence (at the significance level above 1%) between variables.

First, these two tables tell that some socio-demographic variables have a significant direct impact on built environment variables. This indicates that people of different socioeconomic attributes choose to live in communities with different built environment characteristics according to their own attitudes or preferences, and show specific travel behaviour characteristics, that is, there is a residential self-selection effect. Second, under this situation, built environment variables still affect public transit variables with significantly total effect, which indicates that after considering residential self-selection, built environment still have significant effect on public transit behaviour. Figure 34 and 35 are diagrammed to demonstrate the above two categories of paths. Third, it is obvious that there is a big difference between the influence paths of urban villages and those of commodity housing, almost completely different, which is consistent with our hypotheses that the urban villages express specialty. For clarity, the significantly influential path for urban villages and commodity housing will be interpreted separately. Finally, comparing Figure 35 with Figure 36, the effect of socio-economic variables on built environment for urban villages (Figure 35) is much less than that for commodity housing (Figure 36), which indicates that the self-selection effect of urban villages is much lower than that of commodity housing. This is consistent to the hypothesis raised by Cao and Yang (2017) who proposed this research design to reflect self-selection in the Guangzhou case, where they presented that tenants living in low-income residences like urban villages had less flexibility and the freedom of residential choice, so they were less affected by residential self-selection (Xiaoshu Cao & Yang, 2017).

Table 13 SEM path for urban villages

Path	Estimate	S.E.	C.R.	P
X6<---X2	-1.195	0.136	-8.771	***
X8<---X2	0.381	0.036	10.516	***
X9<---X2	2.747	0.459	5.988	***
X6<---X3	-0.295	0.088	-3.366	***
Y1<---X6	-6.149	3.546	-4.555	***
Y2<---X6	-0.659	0.138	-4.775	***
Y3<---X6	-0.288	0.082	-3.535	***
Y1<---X9	-4.025	0.938	-4.29	***
Y2<---X9	-0.152	0.038	-3.982	***

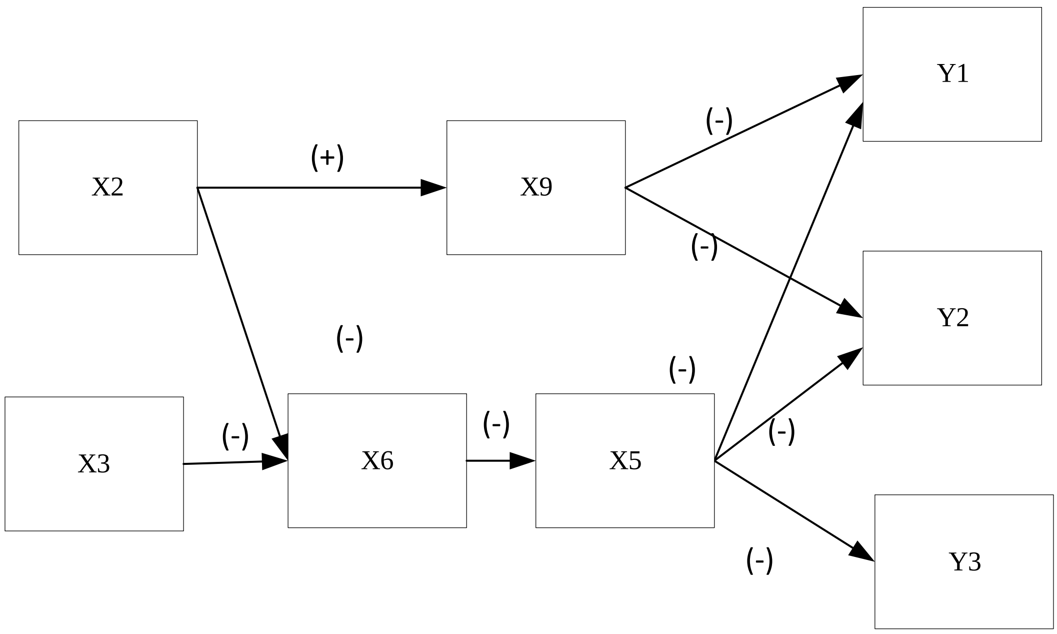


Figure 35 Influential paths for urban villages

For urban villages, as shown in Table 13, the built environment exhibited a significant influence on public transport travel behaviour and was simultaneously affected by socio-demographic attributes. Residential density (X6) possessed negative effect on travel distance (Y1), travel time (Y2) and transit mode choice (Y3). That is, for residents living in urban villages, when residential density increased, their travel distance and time decreased, and they less chose public transport for travelling. Bus stops within 500m (X9) presented negative effect on travel distance (Y1) and travel time (Y2). That is, people spent less time and shortened their trips if bus stops were more available and accessible. Therefore, a brief summary to the impact of built environment is that apart from the impact of density on transit mode choice, other findings are consistent with previous common findings (W. Choi et al., 2016; Ewing & Cervero, 2010; J. Wang & X. Cao, 2017). As to the unusual impact of density, one of the possible explanations may be that for urban villages, the reality is most people choosing transit for motorized travel instead of car or taxi (see Figure 32), and this may approximate to a saturated state, so if the population density increased, transit availability per capita could decrease, and it makes sense that the increased density will restrain people from choosing transit mode for trips in urban villages.

Noticeably, mixed land use to transit had no significant effect on transit travel behaviour. This result is consistent to a minority of studies (Sun et al., 2017; D. Wang & X. Cao, 2017), and most previous studies found mixed land use restrain car use and promote public transit choice (Xinyu Cao et al., 2019; Xiaoshu Cao & Yang, 2017; J. Feng, 2017; Mengzhu Zhang & Zhao, 2017).

Besides, in terms the association between the socio-demographic attributes and built environment, age (X2) had a negative effect on residential density (X6) and a positive effect on mixed land use (X7) and bus stops within 500m (X9). That is, with age, people preferred less dense residence, more bus stops and residences with more diverse land-use. However, income (X3) had negative effect on residential density (X6), meaning that people of higher income prefer less dense residences.

Table 14 SEM path for commodity housing

Path	Estimate	S.E.	C.R.	P
X7<---X1	0.004	0.001	6.068	***
X9<---X1	-0.633	0.145	-4.373	***
X6<---X2	-2.09	0.286	-7.32	***
X7<---X2	-0.01	0.001	-9.138	***
X8<---X2	0.332	0.059	5.648	***
X9<---X2	2.514	0.235	10.701	***
X7<---X3	-0.004	0.001	-5.998	***
X9<---X3	0.738	0.116	6.39	***
X6<---X4	1.004	0.164	6.108	***
X7<---X4	0.008	0.001	13.064	***
X5<---X6	-0.034	0.005	-6.765	***
Y3<---X5	-0.17	0.044	-3.909	***
Y3<---X6	0.546	0.136	4.024	***
Y1<---X7	-3.357	7.675	-3.426	***
Y2<---X7	-1.276	2.18	-5.172	***

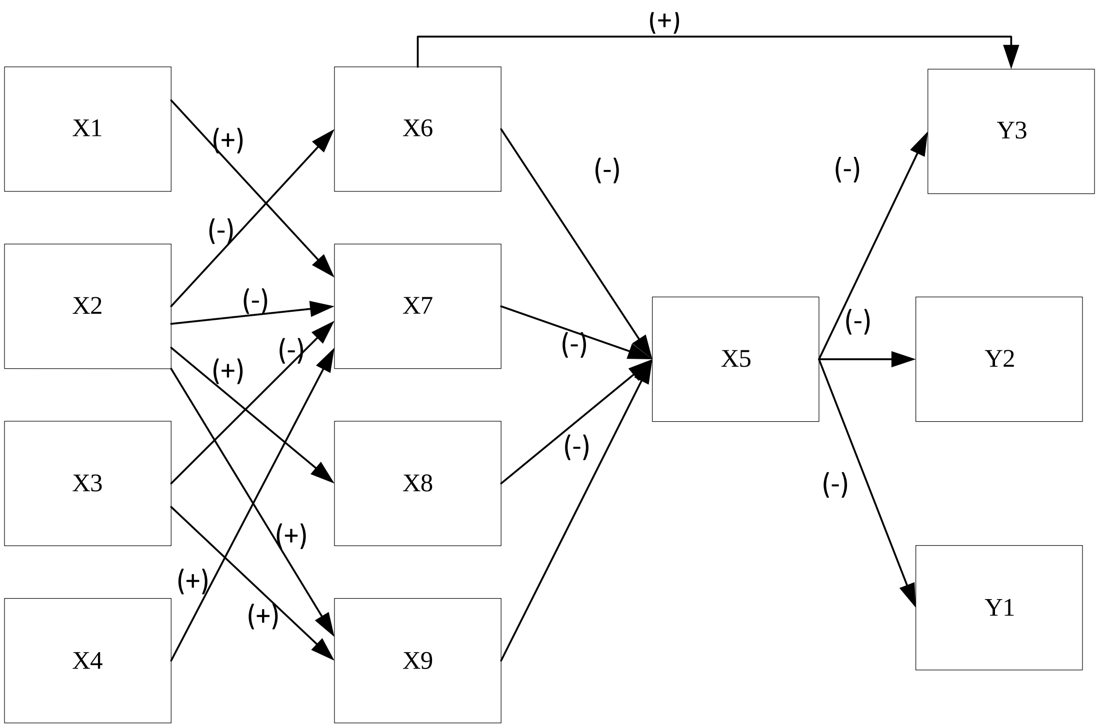


Figure 36 Influential paths for commodity housing

For commodity housing , as shown in Table 14, residential density (X6) possessed positive effect on transit mode choice (Y3), and this finding is opposite to the effect for urban villages, but consistent with previous findings (W. Choi et al., 2016; Ewing & Cervero, 2010; J. Wang & X. Cao, 2017). In addition, residential density (X6) affected car-ownership (X5) negatively, that is, when residential density increased, car-ownership decreased. Besides, mixed land use (X7) had a negative effect on travel distance (Y1) and time (Y2). That is, the more diversified the land use, the less distance and time people will travel. As to socio-demographic variables, Gender (X1) had a negative effect on bus stops within 500m (X9), which means female prefers residential area with more stops than male in commodity housing. Age (X2) had a negative effect on residential density (X6) and a positive effect on bus stops within 500m (X9). That is, with age, people prefer less dense residence and more bus stops.

Table 13 and Table 14 have displayed the direct effect between variables, while some indirect effect could be further detected by the mediation variable. Meanwhile, Table 13 and 14 have proved residents of different socio-demographic attributes will choose communities with different built environments, which proved the existence of residential self-selection. After considering the residential self-selection and mediation effect of car-ownership, there is still significant effect (total effect) of built environment on transit travel behaviour (Table 15).

Table 15 Total, direct and indirect effects of endogenous variables on endogenous variables

Endogenous variables	Effects	Urban villages				Commodity housing			
		X6	X7	X8	X9	X6	X7	X8	X9
Y1	Total	-5.803	/	/	-3.934	0.449	-2.253	0.831	-0.515
	Direct	-6.149	/	/	-4.025	0	-3.357	0	-0.503
	Indirect	0.346	/	/	0.091	0.449	1.104	0.831	-0.012
Y2	Total	-0.627	/	-0.836	-0.144	/	-1.233	/	/
	Direct	-0.659	/	0	-0.152	/	-1.276	/	/
	Indirect	0.032	/	-0.836	0.008	/	0.043	/	/
Y3	Total	-0.25	/	0.13	/	0.573	0.237	/	/
	Direct	-0.288	/	0	/	0.546	0	/	/
	Indirect	0.038	/	0.13	/	0.027	0.237	/	/

For urban villages, residential density (X6) had significant total effect on travel distance (Y1), travel time (Y2), and transit mode choice (Y3). Bus stops within 500m (X9) had significant total effect on travel time (Y2) and transit mode choice (Y3). The influence level of residential density (X6) and bus stops within 500m (X9) weakened when measured by total effect other than direct effect, indicating that if residential self-selection was not considered, the effect of built environment could be overestimated. Distance to transit (X8) showed no direct effect on transit behaviour, but when taking indirect effect into account, it showed negative total effect on travel time (Y2) and positive effect on transit mode choice (Y3). That is, X8 could affect transit behaviour associating with car-ownership. Mixed land use exhibited no significant effect on public transit behaviour.

For commodity housing, residential density (X6) and bus stops within 500m (X9) had significant total, direct and indirect effects on travel distance (Y1), and the influence level strengthened when measured by total effect other than direct effect. Mixed land use (X7) had significant total, direct and indirect effects on travel distance, and the influence level weakened when measured by total effect other than direct effect. Distance to transit (X8) showed no direct effect on transit behaviour, but when taking indirect effect into account, it showed positive total effect on travel distance (Y1). The same situation happened on effect of residential density (X6) and mixed land use (X7) on transit mode choice. Broadly, car-ownership, as a mediation variable, was more active in context of commodity housing than that of urban villages. It makes senses that dwellers in commodity housing have a much higher level of car-ownership than those in urban villages (as show in Table 8).

Overall, the features of relationship between built environment and travel behaviour for commodity housing in China have similarity with those in developed countries. In contrast, for urban villages, the influence showed some difference. First, the increase of residential density restrained instead of promoting people to choose public transit. Second, the mixed land use had no significant impact on transit behaviour. Urban villages residents tend to have lower car ownership, which limits their mobility options.

Notably, both in urban villages and commodity housing models, I found no significant effect in the relationship between frequency (X10) and transit travel, or between evaluation (X11) and transit travel. One possible interpretation for these insignificance is that the correlation may not be linear. Only when a certain threshold level is reached, could the frequency and evaluation make a difference.

After considering the residential self-selection effect, the built environment of urban villages still has a significant impact on travel mode choice, travel distance and travel time (total effect). Some of these effects are direct effects, and some are transformed into indirect effects on travel by affecting the car ownership rate. By comparison with the results of commercial housing communities, the built environment of urban villages has more direct effects on travel behaviour, and is less affected by residential self-choice.

6. Interacting with the spatial dependence effect

6.1 Spatial dependence effect of urban villages

Spatial dependence refers to the correlation between sample observations in one area and observations in other areas. The theoretical basis is the first law of geography, that is, everything is related spatially, but similar things are more closely related. The degree of correlation among the observation data will be affected by the relative position and absolute position between regions, indicating that there will be spatial interactions between economic and geographic behaviors occurring between different regions.

The built environment data of urban villages have spatial attributes, so the influence of spatial dependence cannot be ignored, thus spatial dependence analysis is required. Spatial characteristics of economic variables are related to spatial location, distance, and spatial arrangement, as well as spatial measurement, estimation, testing, and prediction methods used to analyze the quantitative regularity of economic activities in space and time dimensions (D. Wang & Lin, 2017). If the spatial effect is ignored, it may lead to overestimation or underestimation of the impact of the built environment on travel behaviour (G. Cheng et al., 2016; Yaoyu Lin et al., 2014).

The spatial hierarchy is determined by the characteristics of the spatial structure of the data itself. Although the built environment characteristics can be analyzed by deconstruction, that is, the variables of the TAZ level are assigned to each trip sample that they belong to, and then it can be treated as one of the attributes of each traveller (De Grange et al., 2013), the spatial characteristics of the built environment variables cannot be ignored. However, the hierarchical structure of spatial data still exists, especially in the context of the reconstruction of urban villages in this research. The mutual influence of geographic space, including spatial dependence and spatial heterogeneity, will affect the transformations (C. Bhat & Zhao, 2002).

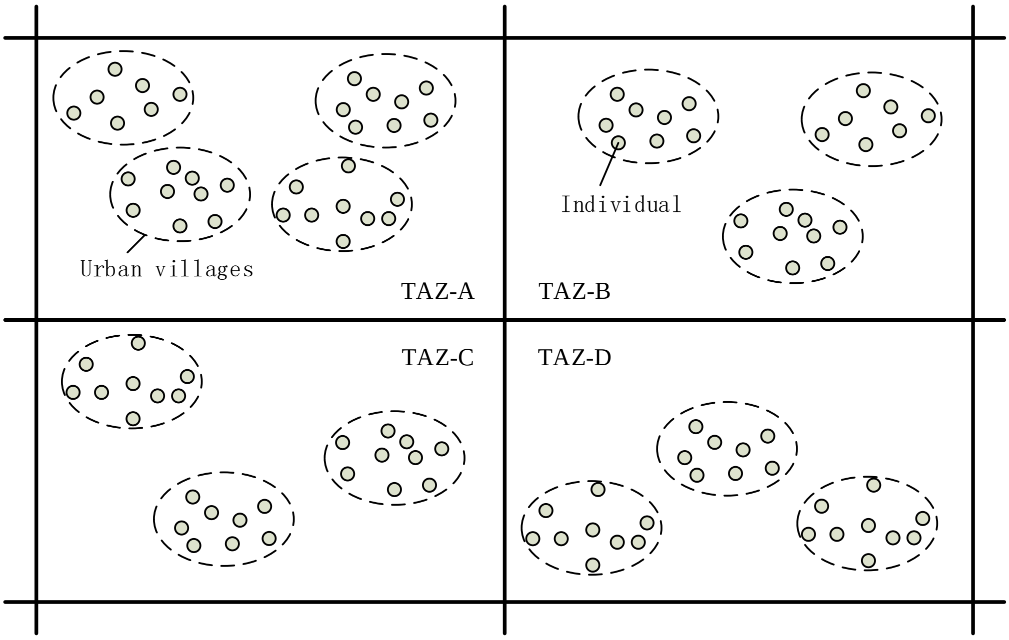


Figure 37 Spatial hierarchy of travel behaviour and urban villages

At the same time, from the perspective of the dynamic performance of space, since the regeneration of urban villages is a spatial action, the impact of spatial changes will inevitably have an effect. Generally speaking, the distance between residential place and employment place of residents is increasing. Price, environment and job accessibility are the main reasons that affect residents' decision on moving and changing jobs. In the case of not having short-distance commuting, many residents choose to trade long distance commutes for better living and employment conditions (Hong & Shen, 2013). In addition, location and personal attributes also affect the spatial distance between the residence and employment. In terms of location, the attractiveness of employment in central urban areas is still outstanding. Usually, residents living close to the central area commute in a short distance, and they tend to choose to relocate or choose another job within a short distance; in terms of personal attributes, the middle-income population moves and changes jobs relatively more frequently than other income groups (De Grange et al., 2013). On the macro level, the mismatch between urban residence and employment space, the urban space expansion, the structure of land under the single-function, and individual socio-economic transformation affect the distance between residence and employment.

6.1.1 The spatial characteristics of urban villages

The spatial distribution of urban villages shows a feature of agglomeration and fragmentation, and the spatial differentiation is obvious. On the one hand, informal houses are clearly concentrated along the main roads of urban villages, and have a certain level of hierarchy, showing the agglomeration characteristics consistent with the formal commerce of urban space; on the other hand, due to the marginal and ambiguous property rights system of rural collective land, which has led to the blind expansion of informal residences with villagers' homesteads as the basic unit, forming a fragmented "mosaic" spatial pattern, which is significantly different from the urban formal commercial space. Using the Kernel interpolation method of ArcGIS spatial analysis to calculate the density distribution of urban villages in Shenzhen, it is found that the spatial agglomeration characteristics of urban villages are obvious and it forms several agglomeration areas (Figure 38).

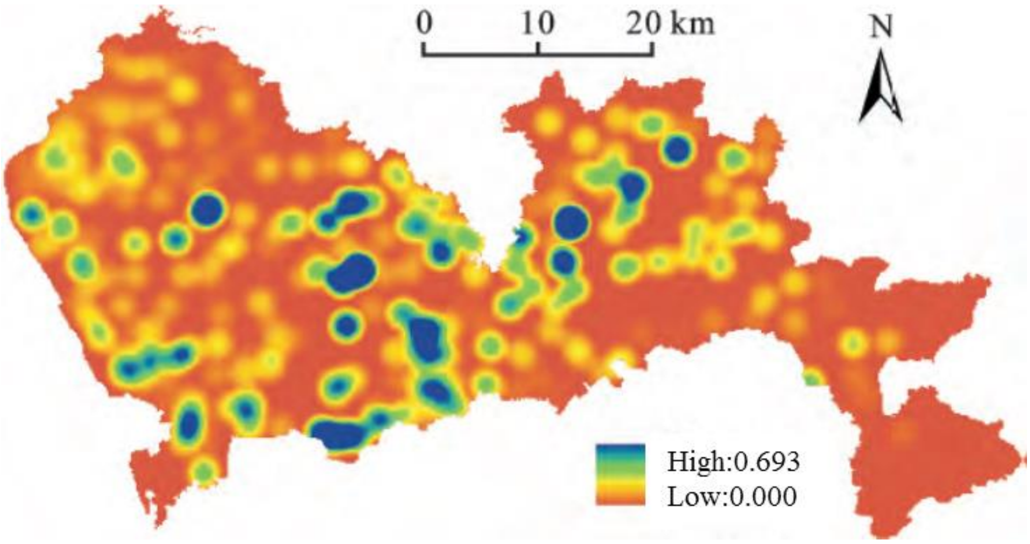
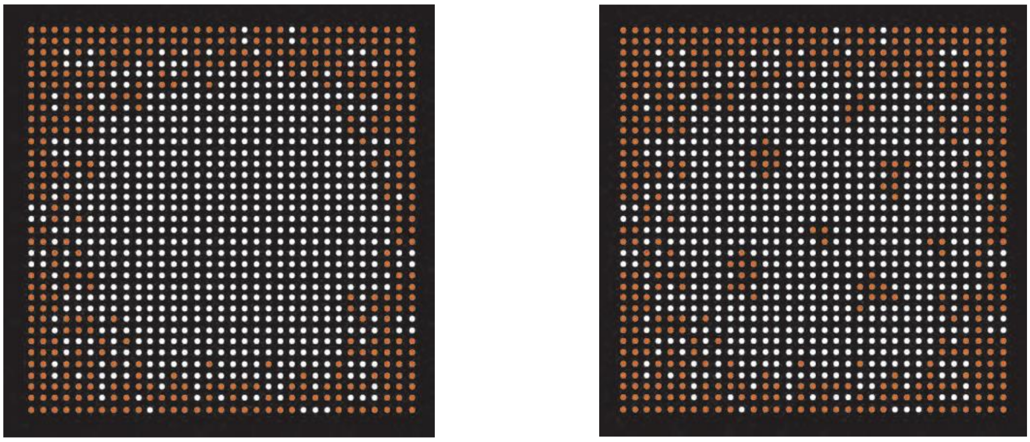


Figure 38 Distribution density of urban villages

6.1.2 Differentiation of living space

Residential space differentiation is a typical feature of urban space differentiation, and it is a phenomenon that people of different socio-economic characteristics and classes live in different areas of the city. The differentiation of residential space in China is becoming more and more serious, and its cause must be traced to the economic system reform since the reform and opening up. Since the 1980s, China’s economic system has gradually changed from a planned economy to a market economy. The social and economic structure and spatial resource allocation have undergone tremendous changes. The housing distribution system has also entered the era of commercial housing. In the process of rapid urban development and the gradual prosperity of the real estate market, the differentiation of urban residential space has become increasingly serious. The solidification of poverty has affected the allocation of market resources, thereby further exacerbating residential isolation, which is manifested in the high housing prices and rents in urban centers and the urban marginalization of residential areas for low-income groups.

However, urban villages have certain positive effects on the differentiation of urban space in terms of space and functional configuration. The urban village has influenced the heterogeneous orientation of urban space with its special spatial and social form. With low rents and convenient location conditions, the rental market of urban villages has attracted a large number of migrant workers. Due to the low overall cultural quality of residents and tenants in urban villages, it can be regarded as a homogeneous community with low living costs. On the one hand, on the scale of the district, there is a huge isolation and difference between the urban village and the surrounding urban space, which is a regional heterogeneous space; on the other hand, on the urban scale, the heterogeneity of the urban village also alleviated the spatial homogeneity of the city center and increased the diversity of the city center. The ideal urban space should be relatively homogeneous. The emergence of urban villages is the result of spatial resistance, and it acts as a "relief device" to the heterogeneity of urban space.



a) Differentiation of living space b) Urban villages break the differentiation of living space

Figure 39 The role of urban villages in breaking the differentiation of living space

6.2 Descriptive analysis

This chapter employs the DiDi trips data in a large scale where the whole city is incorporated and the built environment is measured in a TAZ scale.

Since the departure and arrival types have been limited to “urban village” and “commercial building” in the data preprocessing stage, DiDi Travel during the commuting period can reflect the occurrence and attraction of commuting trips and the distribution of employment and residence, and departure in the morning peak (Morning origin, MO) and evening peak arrival (Evening destination, ED) locations can reflect the distribution of residences(urban villages), and morning peak arrivals (Morning destination, MD) and evening peak departures (Evening origin, EO) locations can reflect the location of the workplace. The distribution of DiDi commuting trips occurred in urban villages in the morning peak hours and evening peak hours on the scale of 490 TAZs in Shenzhen is shown in Figure 40-43.

Table 16 Description of DiDi commuting trips

Travel frequency	Max	Min	Mean	S.D.
MO	1752	1	285.1	264.7
MD	2836	1	271.1	329.0
EO	2338	3	365.9	364.5
ED	2294	3	365.7	365.8

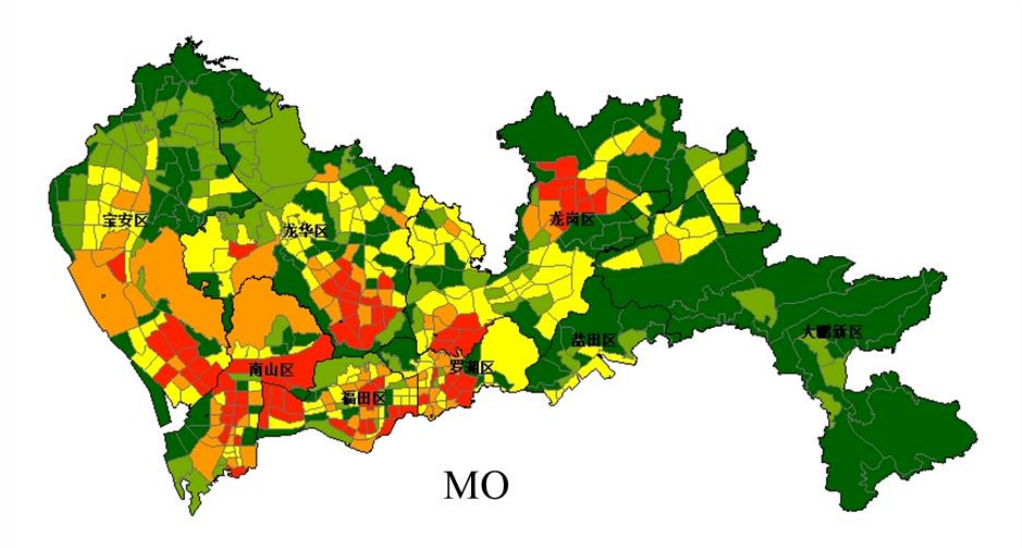


Figure 40 Distribution of DiDi trips in MO

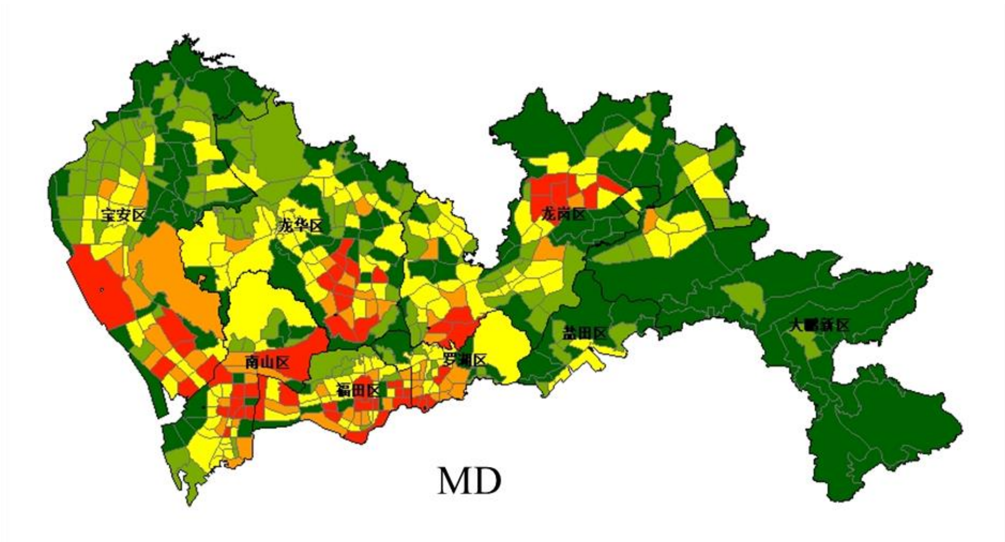


Figure 41 Distribution of DiDi trips in MD

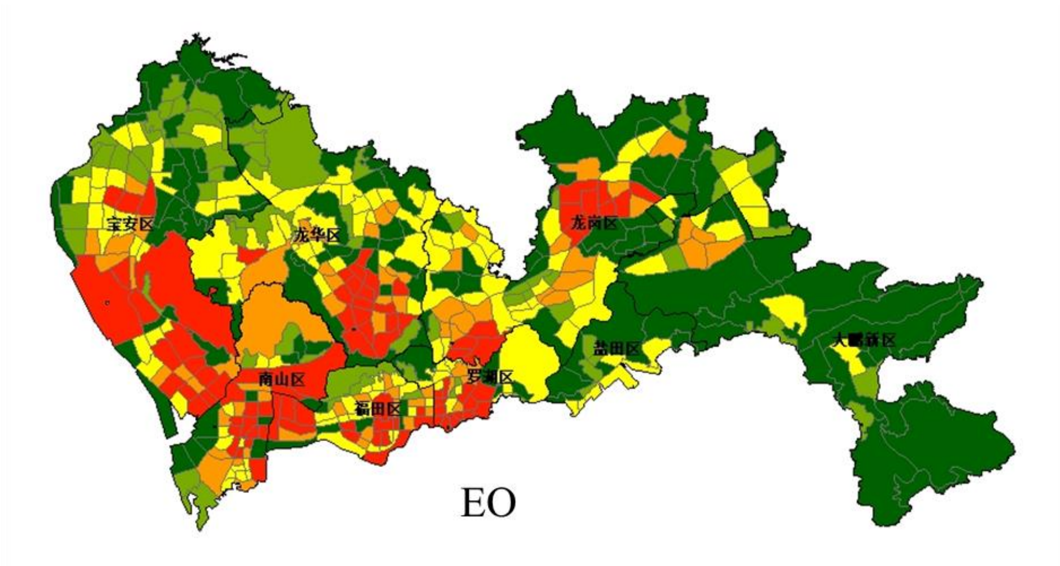


Figure 42 Distribution of DiDi trips in EO

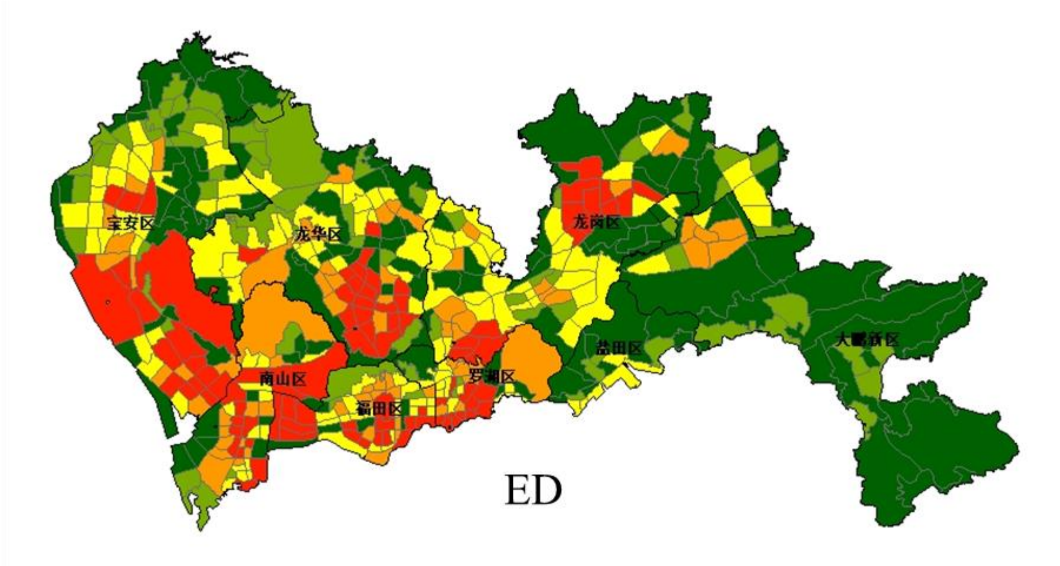


Figure 43 Distribution of DiDi trips in ED

It can be seen from Figure 40-43 that DiDi's commuting travel demand shows a certain degree of agglomeration in space, most of which are concentrated in the central and south-western central areas, which also reflects the agglomeration and distribution of job-housing in Shenzhen. Figure 40-43 and Table 16 also reflect the uneven distribution of DiDi commuting trips in each community. Although both MO and ED can reflect the distribution of residential areas, the agglomeration characteristics of the two are not exactly the same. Also, the agglomeration characteristics of MD and EO are not exactly the same, so it is necessary to study the four types of trips separately.

Table 17 Description of built environmental variables

Category	Name	Unit	Max	Min	Mean	S.D.
Density	Population density	10,000/km^2	8.004	0.003	2.150	1.781
	Building density	m^2 / km^2	0.378	0.001	0.201	0.086
Diversity	Mixed land use	Nil	1.891	0.486	1.357	0.227
Design	Road network density	km / km^2	17.282	0.408	7.986	3.173
	% of non-motorized lane	Nil	1.000	0.287	0.799	0.143
	Road width	m	19.871	6.232	11.773	2.222
	Road length	km / km^2	4.011	0.024	0.992	0.693
Public transit	Bus line density	km / km^2	35.069	0	3.599	4.550
	Bus stops density	No./ km^2	52.283	0.100	12.936	7.777

As to the built environmental variables in this chapter, nine indicators are measured in a TAZ scale, including population density, building density, mixed land use, road network density, percentage of non-motorized lane, road width, road length, bus line density and bus stops density. The statistical characteristics of the built environmental variables is shown in Table 17.

6.3 Modeling spatial dependence effect

The spatial dependence effect can be described from several aspects. Generally, spatial correlation can be reflected in the following three aspects.

First, when there is a spatial correlation between the dependent variables, the spatial model is expressed as equation (34), which is called Spatial Auto regression.

$$\boldsymbol{y} = \lambda \boldsymbol{W}\boldsymbol{y} + \boldsymbol{\varepsilon} \tag{34}$$

Among them, $\boldsymbol{W}$ represents the spatial weight matrix, and the commonly used spatial weight matrix is binary adjacency matrix, which represents the spatial adjacency relationship between TAZs. The built environment variables of each TAZ are used as independent variables. After the independent variables are introduced, the SAR model equation is shown in equation (35). That is, the spatial autoregressive model not only explains the demand for DiDi trips in the built environment of a certain TAZ, but also reflects the spatial dependence of DiDi travel demand among TAZs.

$$\boldsymbol{y} = \lambda \boldsymbol{W}\boldsymbol{y} + \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \tag{35}$$

Secondly, on the basis of SAR model, travel demand is not only affected by the built environment variable in the self-TAZ, but also may depend on the adjacent TAZs. For the built environment variables of the residential area, the spatial Durbin model (SDM) can be constructed at this time as shown in equation (36).

$$\boldsymbol{y} = \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{W}\boldsymbol{X}\boldsymbol{\delta} + \boldsymbol{\varepsilon} \tag{36}$$

Third, the spatial dependence can also be embodied by the error term. When the missing variables that are not included in the independent variable but have an impact on the dependent variable which have spatial correlation, or the unobservable random variable has spatial correlation. That is, the impact is the unobserved DiDi travel demand in TAZs. A spatial error model (SEM') can be constructed as equation 37 shows:

$$\boldsymbol{y} = \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{\mu} \tag{37}$$

Among them, the generation process of the disturbance term is shown in equation (38).

$$\boldsymbol{\mu}=\rho \boldsymbol{W}\boldsymbol{\mu}+\boldsymbol{\varepsilon}, \quad \boldsymbol{\varepsilon}\sim\mathbf{N}(\boldsymbol{0},\sigma^2\boldsymbol{I}_{\mathbf{n}}) \tag{38}$$

Further, it can be assumed that there is a spatial correlation between the observed and unobserved independent variables. On the basis of SAR, combined with the characteristics of SDM and SEM', the spatial lag characteristics and the spatial error characteristics are combined to construct multiple spatial correlations to be developed as a new model called Spatial Durbin Errors Model (SDEM). The previous research generally only used a single SDM or SEM' for spatial correlation analysis, and did not consider and verify the combination of the two models. The SDEM constructed in this chapter is shown in formula 39.

$$\boldsymbol{y}=\lambda\boldsymbol{W}\boldsymbol{y}+\boldsymbol{X}\boldsymbol{\beta}+\boldsymbol{W}\boldsymbol{X}\boldsymbol{\delta}+\boldsymbol{\mu} \tag{39}$$

Equation (39) indicates that the DiDi travel demand, built environment independent variables, and unobserved independent variables based on the TAZ are all spatially correlated , that is , the DiDi travel demand of a TAZ is not only affected by the built environment of its own TAZ, but also spatial dependent with other variables in 3 dimensions: ①DiDi travel demand of a TAZ is affected by the built environment of urban villages in other TAZs; ②At the same time, there is a spatial interaction between DiDi travel demand among TAZs; ③The spatial error term that affects DiDi travel demand also has spatial dependence.

The SDEM model constructed under the above assumptions will be tested by the model's applicability test statistics in the next part of this chapter. If the applicability test passes, it means that the assumption of considering multiple spatial correlations is established and the constructed SDEM model is reasonable; if the applicability test fails, the applicability of SDM, SEM', and SAR can be checked in turn.

6.4 Results

Before performing spatial regression, a multi-collinearity analysis is conducted on the built environment independent variables. Variables with a variance expansion factor greater than 5 are removed by a stepwise method. Finally, seven built environment variables included in the model.

The Moran's I test of spatial correlation can reflect the similarity of the unit attribute values in the neighborhoods of the space. If the dependent variables is the observed value of the area, then the Moran's I value of the variable is expressed as equation (40):

$$\text{Moran's I} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}(Y_i - \overline{Y})(\overline{Y} - Y_j)}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}} \tag{40}$$

$$S^2 = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \overline{Y})^2 \tag{41}$$

The value of Moran's I statistic is generally between [-1,1]. When the value is smaller than 0, it means negative correlation. When it equal to 0, it means incoherent. When it is greater than 0, it means positive correlation.

Based on the spatial relationship of 490 TAZs in Shenzhen, the software GeoDa and Stata are applied to generate the first-order adjacency matrix of the traffic district, reflecting the spatial adjacency relationship of the traffic district, and then the value of Moran's I statistic is obtained as shown in Figure 44-47.

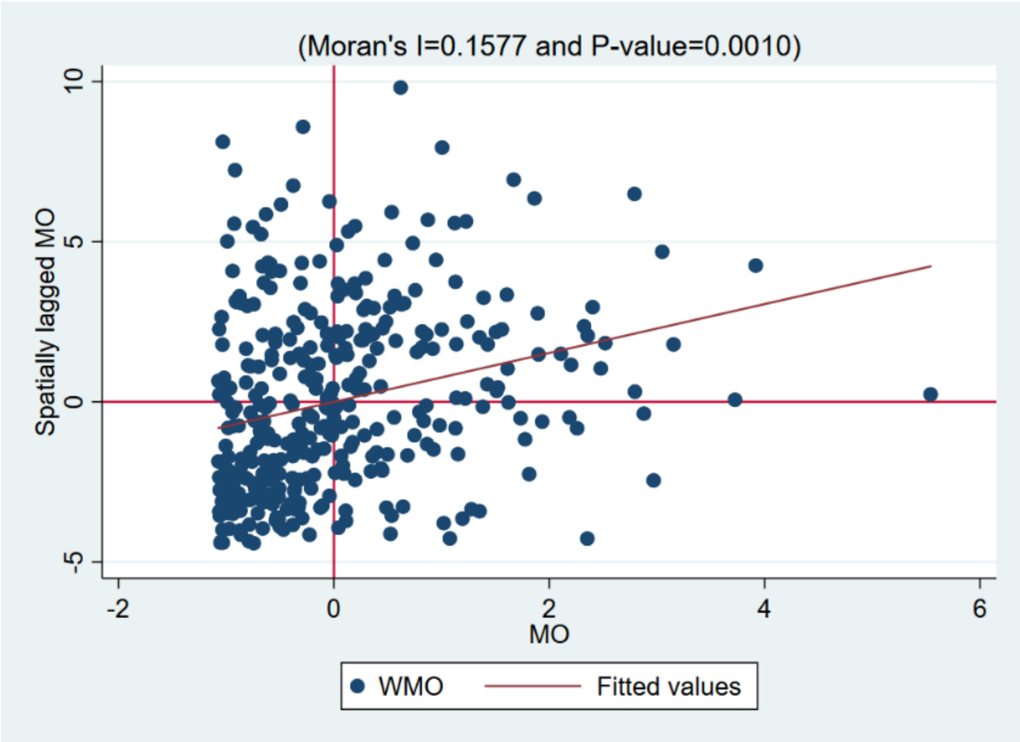


Figure 44 Moran’s I statistic for MO

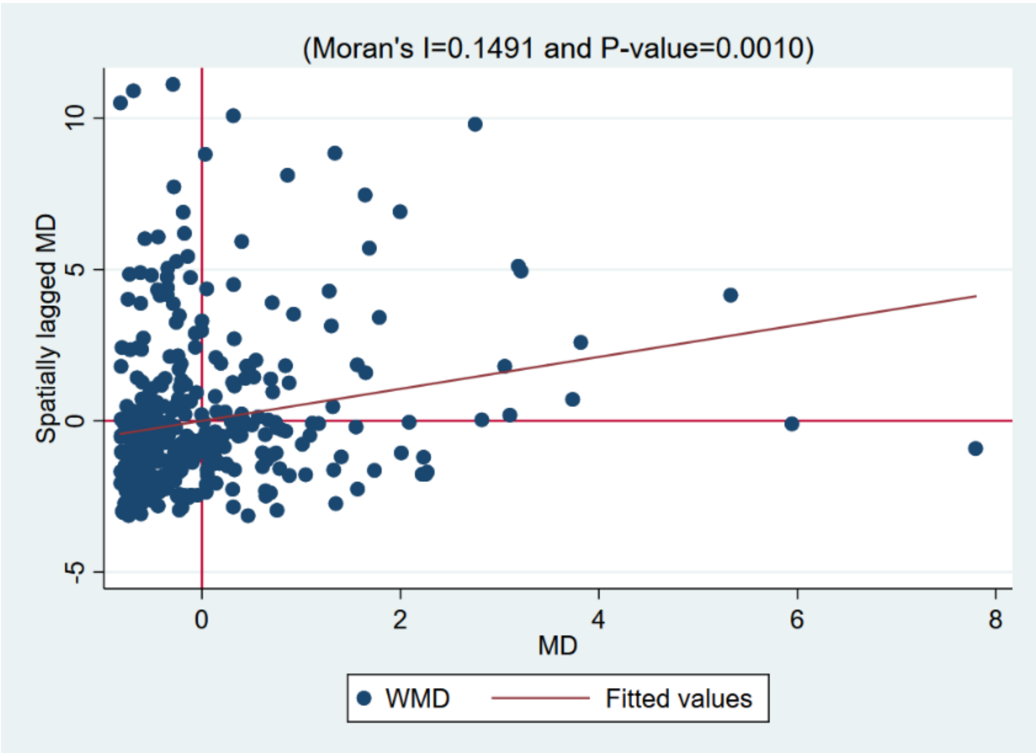


Figure 45 Moran’s I statistic for MD

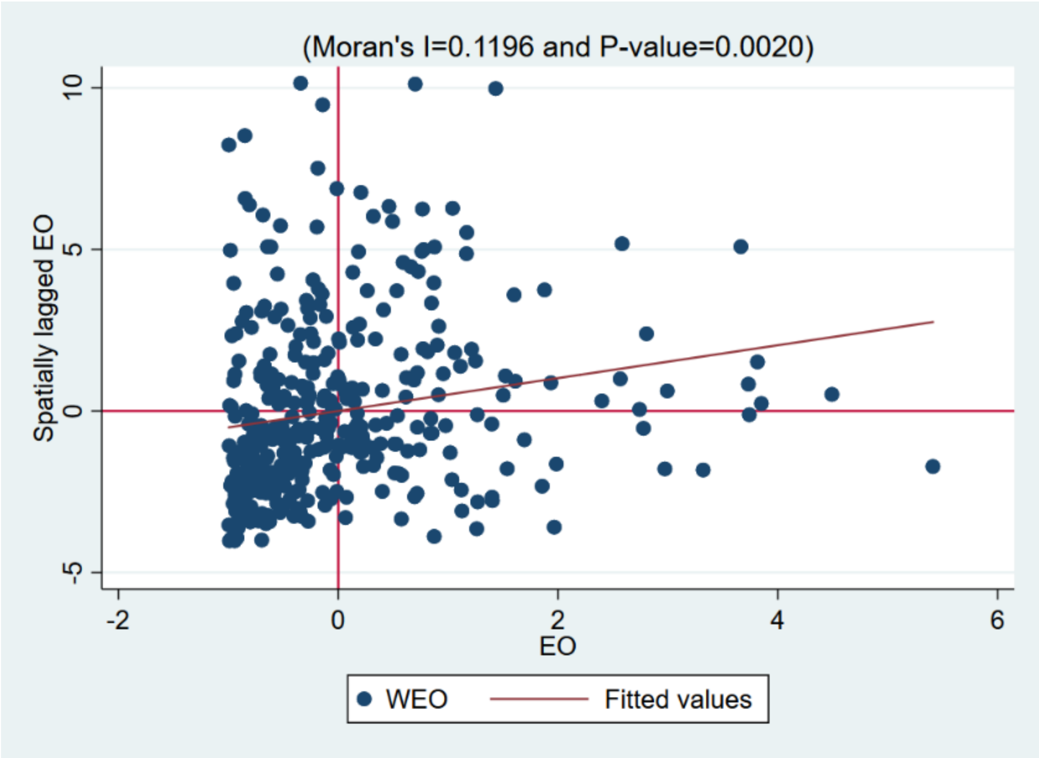


Figure 46 Moran’s I statistic for EO

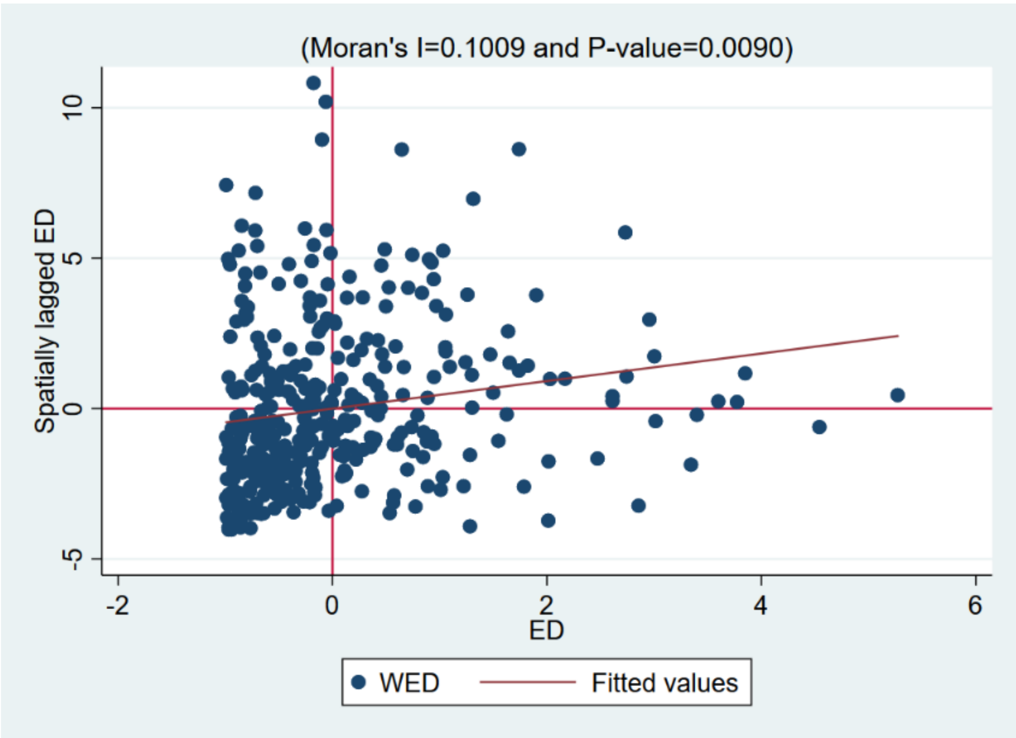


Figure 47 Moran’s I statistic for ED

It can be seen from Figure 44-47 that the Moran's I statistics of DiDi travel demand for MO, MD, EO and ED within a TAZ are all greater than 0, and passed the 1% significance level test. The results mean that the spatial distribution of DiDi commuting travel activities is not completely random. In general, its positive spatial correlation characteristics indicate that the characteristics of DiDi travel are similar in space.

The applicability of the SDEM model established in this chapter was tested, and it was found that the test statistics of Lagrange Multiplier (error) and Lagrange Multiplier (lag) were very significant (Table 18), which can determine that the spatial Dubin error model of this chapter is applicable. It means that the dependent variables of DiDi's travel demand based on the geographic unit of the TAZ, the independent variables of the built environment, and the unobserved error variables all have spatial correlation. Therefore, the explanatory power of the SDEM model in this chapter is better than that of SAR, which only considers spatial lag, and also better than SDM model or SEM model, which only considers spatial error.

Table 18 Application test for SDEM model

Index	MO	ED	MD	EO
Lagrange Multiplier (lag)	0.563**	3.016***	5.211**	0.258***
Lagrange Multiplier (error)	3.254**	0.491**	7.629**	4.363**

In terms of parameter estimation methods, Generalized Method of Moments (GMM) is applied because it does not need to know the accurate distribution information of the random error term, and allows the random error term to have heteroscedasticity and sequence correlation. It is more effective than other parameter estimation methods such as least square method, maximum likelihood method and instrumental variable method. The parameter estimation results of the SDEM model are shown in Table 19.

Table 19 Estimation results of SDEM model

Variables index	Variables name	Urban villages		Workplace	
		MO	ED	MD	EO
	Constant	-1.562**	0.638**	0.913	-2.336**
X1	Population density	0.391***	0.007**	2.197**	0.955*
X2	Building density	0.517**	0.366**	0.793***	0.955***
X3	Mixed land use	-1.327**	-1.809**	-2.286*	-2.674**
X4	Road network density	0.537	0.183*	0.097	0.247
X5	% of non-motorized lane	-0.989	-0.721*	-0.235	-0.699
X6	Bus line density	-0.042*	-0.448**	-0.485**	-0.616*
X7	Bus stops density	-0.038***	-0.091**	-0.908***	-0.209***
W_{X1}	^{W}Population density	-0.708**	-0.832**	-0.448***	-0.341**
W_{X2}	^{W}Building density	-0.903	-0.606	-0.809	-0.396
W_{X3}	^{W}Mixed land use	0.593**	0.257**	0.666**	0.299**
W_{X4}	^{W}Road network	-0.797	-0.753	-0.996	-0.905
W_{X5}	^{W}% of non-motorized lane	-0.699	-0.081	0.708	-0.255
W_{X6}	^{W}Bus line density	0.642	0.057	-0.213	0.598
W_{X7}	^{W}Bus stops density	-0.557*	-0.812**	-0.766*	-0.488*
/	ρ	0.351***	0.296***	0.262***	0.414***
/	R^2	0.796	0.638	0.621	0.665
/	log-likelihood	563.8	601.3	589.1	543.2
/	LR-test	463.4	511.5	488.6	426.7

The parameter estimation results corresponding to X1-X7 in Table 19 represent the relationship between the built environment variables of a certain TAZ and the commuting travel demand of the TAZ. For urban village areas, built environment variables have basically the same influence on MO and ED of online car-hailing commuters. First, population density (X1) and building density (X2) play a significant positive role in promoting the demand for online car-hailing commuting travel, and the variable coefficients are both positive, indicating that the higher the population and building density, the greater the demand for online car-hailing commuting travel. The possible reason is that high density means more commuting activities and travel demand. Second, mixed land use (X3), bus line density

(X6), and bus stops density (X7) have a significant inhibitory effect on online car-hailing commuting trips, and the variable coefficients are all negative, which is consistent with most scholars' beliefs. Third, the road network density (X4) and the proportion of non-motorized lanes (X5) have a significant negative impact on ED. The reason may be that increasing in road network density and the proportion of non-motorized lanes in residential areas has promoted non-motorized travel to a certain extent, thereby inhibiting the demand for online car-hailing travel. For the workplace, the impact of built environment variables on the EO and MD of DiDi's commuting trips is basically the same as that of urban villages, while the road network density and the proportion of non-motorized lanes no longer show a significant impact, so the number of impact factors in the workplace is even smaller. It is worth noting that the absolute value of the correlation coefficient of the significant influencing factor of the workplace is higher than that of the urban village areas, so the influence of the workplace is greater.

The interaction items of the weight matrix and the built environment variables (WX1 -WX7) are spatially lagging variables, and the corresponding parameter estimation results indicate that the DiDi commuting travel demand of a certain TAZ is affected by the space lag effect of the built environment of urban villages. When the coefficient sign of the cross term (WX1 -WX7) is consistent with the coefficient sign of the original built environment variable (X1-X7), it indicates that there is a spatial spillover effect, that is, the built environment is positively correlated to the travel demand of the area and the neighboring area. Adversely, it is the spatial competition effect.

It can be seen from Table 19 that population density (WX1), mixed land use (WX3), and bus stops density (WX7) all have significant spatial lag effects. Among them, WX7 manifests as a spatial spillover effect, which means, when increasing public transit in a certain TAZ, it can not only suppress the DiDi commuting travel demand in this TAZ, but also reduce the DiDi commuting trips in other adjacent TAZs, indicating that the increase in public transport facilities can attract more people from nearby areas to choose public transport instead of individual motorized travel mode. WX1 and WX3 show a spatial competition effect, that is, an increase in population density (WX1) in a certain TAZ will increase the demand for DiDi travel in this TAZ, but will lead to a decrease in travel demand in other TAZs. In addition, increasing the mixed land use (WX3) of a TAZ will reduce DiDi commuting trips in the TAZ, but it will increase the demand for DiDi travel in other adjacent urban village TAZ.

7. Discussion and conclusions

The findings is this thesis provide some insights into transit-oriented urban renewal. When transforming urban villages, emphasis should be put on enhancement of transit availability, and the mixed land use could be put in the last consideration with limited time and funds. This thesis contributes to the knowledge by addressing a special type of neighbourhood in order to narrow down the research gap in this domain. The findings help to suggest effective measures to satisfy public transit demand efficiently and also provide a transit-oriented perspective for urban regeneration. Specifically, the conclusions are as follows.

7.1 The impact of built environment of urban villages on travel mode choice

Urban villages highlight a spatial advantage of gathering a large population of Public Transport (PT) demand for research significance and convenience. This research has focused on a better understanding of the associations between the built environment and PT choice behaviour in urban villages, particularly in China. To discover the particularity and generality of the connection, Chapter 4 has experienced three steps generally. First, a framework of influential factors was set up on the basis of previous related research and the need for this research. To be specific, four dimensions of variables were developed in the model, and they were socio-demographic, PT service, daily travel features, and most importantly the built environment attributes. Second, commodity housing was incorporated as a contrast to highlight the special nature of urban villages. Third, travelling by non-motorized transport or by car were set as reference dependents when implementing multinomial logistic regression models to make it clear to explain the findings.

Generally, the regression results showed that built environment factors had significant influences on PT choice behaviour in urban villages, and notably played an eco-friendly and land use effective role to encourage PT choice and consequently to reduce car use. Increasing bus stops and residential density displayed a positive effect on PT choice, which was a consensus with most previous studies in the context of developed countries (Ding et al., 2017; F. Su, Schmöcker, & Bell, 2009b), while people from urban villages showed a much higher probability of choosing PT than those from commodity housing. That is, for policy implications, adding bus stops around urban villages would bring a more evident effect on PT incentives and would relieve regional traffic congestion correspondingly. Interestingly, in terms of mixed land use, it did not show a positive impact on PT choice in the case of urban villages, as most previous studies have claimed (Ewing & Cervero, 2010; Zailani et al., 2016; L. Zhang et al., 2012), although the influence was still significant. The rapid urbanization has led cities into more compact and mixed-use direction, so the inconsistency of urban villages with the developing trend could urge the regeneration of urban villages to some extent. Therefore, the findings relating people's choice of PT with the built environment in urban villages not only provide references for traffic policymakers but also offer well-founded guidelines for urban planners.

7.2 Controlling for residential self-selection effect

In chapter 5, first, a framework of influential factors was set up on the basis of previous related research and the need for this research. The most important conclusion of Chapter 5 is that after controlling residential self-selection effect, built environment factors still had significant influences on public transit choice behaviour in urban villages, and notably played an eco-friendly and land use effective role to encourage public transit choice and consequently to reduce car use.

Increasing bus stops and residential density displayed a positive effect on public transit choice, which was a consensus with most previous studies in the context of developed countries (Ding et al., 2017; F. Su, Schmöcker, & Bell, 2009a), while urban villages showed a much higher probability of choosing public transit than commodity housing. That is, for policy implications, adding bus stops around urban villages would bring a more evident effect on public transit incentives and would relieve regional travel congestion correspondingly. Interestingly, in terms of mixed land use, it did not show a positive impact on public transit choice in urban villages as most previous studies claimed (Ewing & Cervero, 2010; Zailani et al., 2016; L. Zhang et al., 2012), although the influence was still significant. The rapid urbanization has led cities into more compact and mixed-use direction, so the inconsistency of urban villages with the developing trend could urge the regeneration of urban villages to some extent. Therefore, the findings relating public transit choice with the built environment in urban villages not only provided references for transport policymakers but also offered well-founded suggestion for urban planners.

Apart from built environment attributes, other variables like gender, occupation, income, attitudes, and travel features were also discovered to be crucial determinants for public transit choice in urban villages, and at the same time, they displayed a difference in categories and influential levels between urban villages and commodity housing. These results have proved the particularity of public transit choice behaviour in urban villages from various aspects, strengthening the understanding that context-specific and neighborhood-specific are of vital importance in this domain.

7.3 Interacting with the spatial dependence effect

In Chapter 6, a Spatial Dubin Error Model is developed to express the spatial dependence effect. The built environmental variables of the urban village and employment are measured based on the geographic unit of TAZ, and the demand for online car-hailing commuting travel is obtained by using the DiDi trips data. Two main conclusions are obtained from Chapter 6.

(1) The demand for online car-hailing commuting travel is spatially dependent in urban villages and workplaces. The built environment of urban villages and employment areas has basically the same impact on online car-hailing commuting travel. However, overall, the built environment of urban village areas has more factors, and the coefficient of the built environment variable of the employment site is larger in absolute value, indicating that the improvement of the built environment of the employment site has a more significant effect on guiding DiDi travel demand. The built environment factors need to be considered more comprehensively if the DiDi travel is guided from the urban village areas.

(2) The impact of built environment variables on online car-hailing commuting trips simultaneously shows spatial competition effects and spatial spillover effects. Since the spatial spillover effect represents a wider range of the impacts of influencing factors, when formulating an online car-hailing travel demand management strategy, in order expand the scope of the influence, the built environment variables (bus stops density) with spatial spillover effects can be adjusted first. Then the general spatially related variables (building density, bus line network density, road network density and non-motorized vehicle lane ratio) can be taken into account. Finally, the variables with spatial competition effects (population density and mixed land use) should be put in the end.

8. Implications and limitations

8.1 Implications

The regeneration of urban villages is often limited to the transformed urban villages themselves without relating to other planning areas. However, the regeneration of urban villages is a task to improve the overall image of the city and the level of urbanization. It should not be confined to the relatively static and closed perspective of urban villages, but should be positioned in a broader perspective. The urban villages' renewal is the second development opportunity for land use and transportation planning. To strengthen the coordination and cooperation between urban transportation planning and urban land use planning, to simultaneously formulate urban land use planning and urban transportation planning, and coordinate with land use layout is the essential way to realize the coordinated development of the city and transport. Urban renewal is an important development process for the city's self-improvement, and it also provides a valuable development opportunity for the reshaping and error correction of the urban transportation system. This thesis starts from individual travel behavior of urban villages, discovers the key built environmental factors and the interaction between the elements in the regeneration of urban villages, and proposes specific strategies to promote the regeneration of urban villages to the direction of transit-oriented renewal (TOR).

(1) Encouraging the urban renewal of small grid neighborhoods.

When the road network around the urban village is dense (higher road density), the proportion of walking is relatively high. The main reason may be that the small grid road network structure is not only conducive to creating a pleasant walking environment, but also more conducive to attracting commercial facilities to gather, creating a living environment with superior accessibility to public service facilities; therefore, it will encourage residents living in urban villages to walk more instead of using motorized mode, thereby reducing energy consumption. Therefore, in the process of urban village renewal, to encourage the urban renewal of small grid neighbourhoods is an effect strategy to promote green travel modes.

(2)Increasing support for the construction of public service facilities

From the perspective of travel behavior characteristics, due to the relatively large number of migrant population and low-income population in urban villages, under normal circumstances, residents in urban villages have relatively weak motorized capabilities, but still have a high travel demand. It should be recognized that the residents of urban villages have an increasing demand for daily travel. In terms of travel mode, public transit is the main travel mode for residents of urban villages. Therefore, in public transportation planning, it is necessary to further evaluate the matching degree between the travel demand of urban villages and the supply of public service facilities. The improvement of public transportation service level will not only help alleviate traffic congestion in the area of urban villages, but also help slow down the growth of private cars.

From the perspective of the built environment factors affecting the choice of travel mode for urban villages, shortening the walking time to the bus station and increasing the density of the bus station have a great impact on the travel mode choice of residents. Regardless of whether the residential self-selection effect is considered, improving the accessibility of bus stops has significant positive significance in promoting residents' green transportation modes. Therefore, in the process of comprehensive renovation of urban villages, in addition to the enhancement of bus stops, attention should also be paid to shortening the walking time to the bus stops, and designing highly accessible residential areas.

(3) Encouraging a job-housing balance oriented renewal

The commuting distance of urban villages is significantly lower than that of commercial housing communities, but the proportion of non-motorized and public transport trips is significantly higher than that of commercial housing communities. This is mainly due to the higher employment accessibility of urban villages. At present, in the process of renewal and regeneration of urban villages in large cities, there is a widespread phenomenon of separation of residence and employment, which has caused the commuting distance to be artificially lengthened and commuters are forced to choose individual motorized travel methods.

Therefore, the reasonable layout of urban villages and employment locations should be paid attention through reasonable urban renewal strategies. Reasonable thresholds for the proportion of employment positions show be formulated within the radius of suitable walking and non-motorized travel scales around densely populated areas as the lower standard for the planning and construction of employment centers, especially through the construction of large-scale urban complexes in the process of urban villages' renewal.

8.2 Limitations

(1)Due to the limited amount of data obtained, results in this thesis could be incomplete. If larger data samples can be obtained for repeated tests and verification, the reliability and influence of research results could be improved. Also, with larger sample size, different types of urban villages and regeneration methods could be further studied. If attitudes data of urban villages' travelers could be collected, it could better interpret the influence of residential self-selection effect.

(2)Methodology could be improved in terms of comprehensive spatial hierarchical model, by incorporating spatial latent variables, with the consideration of spatial scale effect by measuring BE variables in different geographic unit scale.

(3)As to the model structure, there could be non-recursive interactions among outcome variables (travel distance, travel time, travel mode choice). Although the interactions have been tested in this thesis, resulting not significant, if larger sample size were employed, the significance may appear.

(4)As to the dynamic renewal of urban villages, the urban villages is a temporary informal residence and its ultimate destination is regeneration, no matter how long it takes and what measures to be taken. The regeneration of urban villages is a dynamic process. It must not only conform to the blueprint of urban planning, but also pay attention to the feasibility of implementation of regeneration measures. To make the regeneration of urban villages better coordinated with urban development, dynamic renewal strategies deserve attention. Moreover, the requirements for the regeneration of urban villages in different stages of urban development may also change. Therefore, the regeneration of urban villages must reserve space for future development, make good use of the flexible role of urban villages in urban development, and release transport vitality and land vitality.

Therefore, although the conclusions obtained from this thesis is applicable to the upgradation of urban villages at current stage, with the development of urbanization and transportation, more influential factors and comprehensive relationships could be considered in the future.

Appendix: Questionnaire for household travel survey

个人特征及出行特征表（4周岁及以上人士均需进行调查，如有人临时不在家，则请其他人士代为回答）

个人编号	年龄	居住	职业	工作地或学校详细地址	工作地或学校至常用公交地铁站步行/等候时间
	___岁	1. 户籍 2. 住1年以上非户籍 3. 住半年以上1年以内非户籍 4. 住1月以上半年以内非户籍 5. 少于1月非户籍	1. 采矿/制造/供(电/燃气/水)/建筑业 2. 金融/房地产/商业服务业 3. 卫生/教育/文化体育 4. 批发零售/酒店/餐饮 5. 交通/仓储/邮政/电信 6. 科学研究和专业技术 7. 学生 8. 机关团体和社区服务 9. 退休/无业 0. 其它	______区 ______街道 ______路(口)名 ______建筑物名 附近小区/公交地铁站/学校/医院等名称 ______	步行时间是____ 候车时间是____ 1. ≤5分钟 2. 6-10分钟 3. 11-20分钟 4. 21-30分钟 5. >30分钟

出行情况[1]（记录从“昨天”凌晨五点到“今天”凌晨五点的所有出行，必须是工作日）如果您没有出行，请注明原因______

若出行方式为摩托车、的士、单位班车、私家车及单位配车、单位业务车时，需填写该项。

次序	出行目的[2]	出发时间[3]	出发地点[4]	到达时间[3]	到达地点[4]	出行方式[5]	车内人数[7]	换乘情况1[6]：换乘方式[6]	换乘情况1[6]：换乘站名[6]	换乘情况1[6]：步行时间[6]	换乘情况1[6]：候车时间[6]	换乘情况2[6]：换乘方式[6]	换乘情况2[6]：换乘站名[6]	换乘情况2[6]：步行时间[6]	换乘情况2[6]：候车时间[6]

个人编号	年龄	居住	职业	工作地或学校详细地址	工作地或学校至常用公交地铁站步行/等候时间
	___岁	1. 户籍 2. 住1年以上非户籍 3. 住半年以上1年以内非户籍 4. 住1月以上半年以内非户籍 5. 少于1月非户籍	1. 采矿/制造/供(电/燃气/水)/建筑业 2. 金融/房地产/商业服务业 3. 卫生/教育/文化体育 4. 批发零售/酒店/餐饮 5. 交通/仓储/邮政/电信 6. 科学研究和专业技术 7. 学生 8. 机关团体和社区服务 9. 退休/无业 0. 其它	______区 ______街道 ______路(口)名 ______建筑物名 附近小区/公交地铁站/学校/医院等名称 ______	步行时间是____ 候车时间是____ 1. ≤5分钟 2. 6-10分钟 3. 11-20分钟 4. 21-30分钟 5. >30分钟

出行情况[1]（记录从“昨天”凌晨五点到“今天”凌晨五点的所有出行，必须是工作日）如果您没有出行，请注明原因______

若出行方式为摩托车、的士、单位班车、私家车及单位配车、单位业务车时，需填写该项。

次序	出行目的[2]	出发时间[3]	出发地点[4]	到达时间[3]	到达地点[4]	出行方式[5]	车内人数[7]	换乘情况1[6]：换乘方式[6]	换乘情况1[6]：换乘站名[6]	换乘情况1[6]：步行时间[6]	换乘情况1[6]：候车时间[6]	换乘情况2[6]：换乘方式[6]	换乘情况2[6]：换乘站名[6]	换乘情况2[6]：步行时间[6]	换乘情况2[6]：候车时间[6]

个人编号	年龄	居住	职业	工作地或学校详细地址	工作地或学校至常用公交地铁站步行/等候时间
	___岁	1. 户籍 2. 住1年以上非户籍 3. 住半年以上1年以内非户籍 4. 住1月以上半年以内非户籍 5. 少于1月非户籍	1. 采矿/制造/供(电/燃气/水)/建筑业 2. 金融/房地产/商业服务业 3. 卫生/教育/文化体育 4. 批发零售/酒店/餐饮 5. 交通/仓储/邮政/电信 6. 科学研究和专业技术 7. 学生 8. 机关团体和社区服务 9. 退休/无业 0. 其它	______区 ______街道 ______路(口)名 ______建筑物名 附近小区/公交地铁站/学校/医院等名称 ______	步行时间是____ 候车时间是____ 1. ≤5分钟 2. 6-10分钟 3. 11-20分钟 4. 21-30分钟 5. >30分钟

出行情况[1]（记录从“昨天”凌晨五点到“今天”凌晨五点的所有出行，必须是工作日）如果您没有出行，请注明原因______

若出行方式为摩托车、的士、单位班车、私家车及单位配车、单位业务车时，需填写该项。

次序	出行目的[2]	出发时间[3]	出发地点[4]	到达时间[3]	到达地点[4]	出行方式[5]	车内人数[7]	换乘情况1[6]：换乘方式[6]	换乘情况1[6]：换乘站名[6]	换乘情况1[6]：步行时间[6]	换乘情况1[6]：候车时间[6]	换乘情况2[6]：换乘方式[6]	换乘情况2[6]：换乘站名[6]	换乘情况2[6]：步行时间[6]	换乘情况2[6]：候车时间[6]

个人编号	年龄	居住	职业	工作地或学校详细地址	工作地或学校至常用公交地铁站步行/等候时间
	___岁	1. 户籍 2. 住1年以上非户籍 3. 住半年以上1年以内非户籍 4. 住1月以上半年以内非户籍 5. 少于1月非户籍	1. 采矿/制造/供(电/燃气/水)/建筑业 2. 金融/房地产/商业服务业 3. 卫生/教育/文化体育 4. 批发零售/酒店/餐饮 5. 交通/仓储/邮政/电信 6. 科学研究和专业技术 7. 学生 8. 机关团体和社区服务 9. 退休/无业 0. 其它	______区 ______街道 ______路(口)名 ______建筑物名 附近小区/公交地铁站/学校/医院等名称 ______	步行时间是____ 候车时间是____ 1. ≤5分钟 2. 6-10分钟 3. 11-20分钟 4. 21-30分钟 5. >30分钟

出行情况[1]（记录从“昨天”凌晨五点到“今天”凌晨五点的所有出行，必须是工作日）如果您没有出行，请注明原因______

若出行方式为摩托车、的士、单位班车、私家车及单位配车、单位业务车时，需填写该项。

次序	出行目的[2]	出发时间[3]	出发地点[4]	到达时间[3]	到达地点[4]	出行方式[5]	车内人数[7]	换乘情况1[6]：换乘方式[6]	换乘情况1[6]：换乘站名[6]	换乘情况1[6]：步行时间[6]	换乘情况1[6]：候车时间[6]	换乘情况2[6]：换乘方式[6]	换乘情况2[6]：换乘站名[6]	换乘情况2[6]：步行时间[6]	换乘情况2[6]：候车时间[6]

（超过四人的户，从第2张调查表起，需填写“本户地址、共几张、第几张”，户特征只填写“编号”）

您好！深圳市即将开展新一轮居民出行调查，其目的是为了收集与市民工作、生活有关的交通出行资料，以便更好地制定交通规划，为改善城市交通条件提供依据，更好地为您服务！根据《中华人民共和国统计法》相关规定，我们将对您提供的信息严格保密，感谢您的大力支持！

2010年深圳市居民出行调查表

制表单位：深圳市城市规划发展研究中心
批准机关：深圳市第六次全国人口普查领导小组办公室
深圳市规划和国土资源委员会
批准文号：深人普办通[2010]38号
有效日期：2010年12月31日

本户地址：________区________街道________普查区__________普查小区____________（详细地址如居住区名、周围路口名、标志性建筑物或公交站名）

本户共______张　第______张　调查日期：______年_____月_____日　星期____　调查员签名：__________　检查员签名：　　编码员签名：

户特征(询问户主)

一、编号	二、户类型	三、本户实际居住人数	四、本户实际居住人数(4周岁及以上)	五、全年户收入(万元)	六、住房来源	七、车辆拥有情况	八、家庭是否有新购小汽车计划	九、住处至常用公交/地铁站的步行时间及候车时间
建筑物编号____ 房屋编号______	1. 家庭户 2. 集体户 (住户成员之间有直系亲属关系的为家庭户，否则为集体户。)	男_____人 女_____人	男_____人 女_____人	1. ≤2 2. 2—4 3. 4—6 4. 6—8 5. 8—10 6. 10—15 7. 15—20 8. 20—30 9. >30	1. 租赁廉租住房 2. 租赁其他住房 3. 自建住房 4. 购买商品房 5. 购买福、微利房(含原公有住房) 6. 周转房(单位提供) 7. 购买保障房 8. 集体宿舍 9. 其它 建筑面积是__________平方米	1. 自行车 _____辆 2. 助动车 _____辆 3. 摩托车 _____辆 4. 私人小汽车 _____辆 5. 单位配车 _____辆 6. 小货车 _____辆 7. 其他 _____辆	1. 计划两年内购买 2. 计划五年内购买 3. 五年内不会购买	步行时间是______ 候车时间是______ 1. ≤5分钟 2. 6—10分钟 3. 11—20分钟 4. 21-30分钟 5. >30分钟

户特征(拥有或配备小汽车的户填写)

十、小汽车的停车情况

居住地点	工作地点
1. 停在路边划线泊位 ________辆 2. 停在停车场划线泊位 ________辆 3. 其它 ________辆	1. 停在路边划线泊位 ________辆 2. 停在停车场划线泊位 ________辆 3. 其它 ________辆

意向性问题(询问户主)

十一、您(上下班、学)常用的出行方式及选择的原因：		十二、2011年大运会您打算乘坐何种交通工具前往赛场(若有公交线路直达赛场)：	十三、您对我市交通的总体评价	十四、您认为公交(行人)系统在哪些方面最应改善(选三项)	十五、您认为道路交通系统在哪些方面最应改善(选三项)	十六、影响您使用自行车出行的主要因素有哪些(选三项)	十七、您对深圳市交通还有哪些建议，请在以下空白处填写
您(上下班、学)常用的出行方式[5]是： ________	您选择该出行方式的原因是(选一项)： 1. 费用 2. 时间 3. 舒适 4. 安全 5. 尽管不方便，但没有其他选择 6. 距离很近，适合步行	请填写打算采用的出行方式[5] ________	1. 好 2. 较好 3. 一般 4. 较差 5. 差	1. 加快修建地铁 2. 调整或增加公交线路 3. 增加公交运力 4. 提高车辆档次 5. 改善候车环境 6. 改善公交站周边步行环境 7. 增加行人过街设施(天桥、地道、信号灯) 8. 提高行人设施档次(如过街天桥增加顶棚、自动扶梯)	1. 新建道路 2. 改造拓宽现有道路 3. 优化交通组织、完善交通设施 4. 加强对交通违章的管理 5. 增加停车设施 6. 实行交通需求管理(如提高停车收费、中心区拥挤收费等)	1. 缺乏安全可避雨停车设施 2. 天气不适合(较热、下雨或台风等因素) 3. 空气污染 4. 拥有其他可替代的交通方式 5. 耗费体力 6. 自行车道过少、路面不平、坡度较大 7. 骑车中受干扰较多(行人、机动车、助动车等)	

说明：

1. **出行——指基于某种确定目的从甲地(出发地点)到乙地(到达地点)的一次单向移动，要求记录调查日前一工作日("昨天")凌晨5点到次日("今天")凌晨5点的24小时内每一次出行，特别需要注意的是以下行为不计入：营运车辆(长途汽车、公交巴士和的士)驾驶员和乘务员执行任务时的出行；在同一商业区内几个商场之间的移动；在一幢大楼内部的移动；在同一封闭管理的小区、学校或单位内的移动。例：上班是一次出行，下班回家是一次出行；如果下班购物后再回家，则下班后购物是一次出行，购物后回家又是另一次出行。**

2. **出行目的——**

上班:0	上学:1	回家:2	公务或业务:3	回单位(学校):4	购物:5	娱乐(包括就餐、体育运动):6	访友:7	看病:8	接送人:9	其他:10

3. **出发时间和到达时间**——出发及到达时间以24小时制登记，编码时用四位编码。例如：上午八点表示为0800，下午六点二十五分表示为1825。

4. **出发地点和到达地点**——出发地点及到达地点均要求填写区名、街道名、路(口)名、建筑物名；同时尽量填写附近的公交站名、标志性建筑、学校、医院等公共设施名。出发地点或到达地点是家或单位(学校)时，务必直接填写"家"或"单位（学校）"。

5. **出行方式**——指出行中所采用的交通方式，用下述编码表示。当填写个人出行特征表时，只有步行时填入步行；同时有步行和交通工具时，填入交通工具；当存在多种交通工具时，填入第一次乘坐的交通工具，并填写换乘情况。

步行:0	自行车:1	摩托车/助动车:2	地铁:3	公共大巴:4	公共中小巴:5	的士:6	单位班车/小区巴士/购物巴士/校车:7	私家车/单位配车(含皮卡):8	单位业务车及其他:9

6. **换乘情况**——如在一次出行中使用一种以上交通工具时(不包括步行，但包括公交不同线路间的换乘)，请在换乘方式中依次填写换乘工具(填法同说明5)，并注明换乘站名，以及换乘两种交通工具之间所花的步行时间及等候时间(单位：分钟)。

7. **车内人数**——如在出行中方式为摩托车、的士、单位班车、私家车及单位配车、单位业务车时，请在车内人数中填写所乘坐交通工具中所有人数，包括司机。

8. 编码框为阴影的不要填写，供调查后另行编码用。

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