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Review and enlightenment of intensive land use in built-up area based on low-carbon travel

The correlation between residents' travel mode and land use characteristics has always been a frontier issue in domestic and foreign research. The built-up area is faced with the dilemma between traffic supply and demand caused by the mismatch between residents' travel mode and land use characteristics. The research on the correlation between low-carbon travel and intensive land use has made an important contribution to eliminate the dilemma. From the three aspects of research elements, research perspective and research method, this paper thoroughly reviews the domestic and foreign research on the correlation. Moreover, the advantages and disadvantages of the existing methods are identified to summarize the general research trend and the existing problems. The research aims to provide a new perspective for the study of intensive land use in built-up areas in three aspects: the consistency of synergetic theories, the quantification of land intensive use indicators based on low-carbon travel and the use of multi-source heterogeneous data for feature recognition.

Keywords: Inventory planning, low-carbon travel, intensive land use, multi-source heterogeneous data, influence mechanism

1. Introduction

Under the new urbanization, efficient land use of "strict increment control and stock revitalization" is the internal demand of Chinese large and medium cities,particularly the urban built-up area, in the transition period. The collaborative planning of stock and increment has become a core research topic. On the premise of constant stock planning of the built-up areas, intensive land use is more suitable for the future development of the built-up areas. As a centralized place of modern urban function and employment, the urban built-up area has gathered the most important commercial, cultural, medical and educational resources and a large number of employment posts, and attracted the most traffic attraction sources. In the past 40 years of urban incremental development, due to the new and old contradictions and the collision between new and old interests, the traffic in urban built-up areas has presented different stage characteristics and formed multi-class and diversified contradiction between traffic supply and demand. In particular, due to the limited land resources, low revamping degree and narrow development space for road transport facilities in most urban built-up areas in China, the lag of low-carbon travel mode based on public transport and the rapid growth of motor vehicles form a strong contrast. Because of the mismatch between residents' travel mode and the characteristics of land use, traffic congestion has become more frequent in urban residents' daily travel during rush hours. In order to solve this problem, foreign and domestic scholars have made extensive and in-depth research on the relationship between residents' travel patterns and the characteristics of land use in built-up areas, and fruitful results have been achieved in both theoretical and empirical models. Most studies demonstrate that residents' travel modes correspond to the characteristics of land use, and specific travel mode can lead to corresponding land use characteristics. Research on cities such as Hong Kong and Tokyo found that the high concentration of urban land use may not necessarily lead to an increase in car use rate. The coordination between low-carbon travel and intensive land use is the key to solve the serious contradiction between traffic supply and demand.

Although significant progress has been made on some key issues related to the relationship between residents' travel mode and land use characteristics, the difficulty in obtaining and integrating multi-source heterogeneous data is limited by the complexity and diversity of the mode and type of land use. The quantitative research on the index system of low-carbon travel and intensive land use, the role relationship and the model method is relatively deficient, which limits the deep understanding of the correlation between residents' travel mode and land use characteristics. Therefore, it is necessary to deeply analyze their characteristics. This research takes the CNKI database in China and the "Web of Science" foreign language database as the retrieval source of the literature. Combined with Note Express document management software, this paper makes an extensive and in-depth reading and analysis of the literature on the relationship between low-carbon travel and intensive land use in the

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past ten years. Firstly, the research progress is reviewed from the two aspects of research element and research perspective. Secondly, the theoretical analysis models and technical analysis methods used in the research methods are summarized, expecting to solve these problems through the literature review. Finally, the relationship between low-carbon travel and intensive land use is studied, and some prospects for future research are put forward.

2. Research elements

2.1. Low-carbon travel element

Low-carbon travel refers to the active adoption of transportation means that can reduce carbon dioxide emissions during travel, the urban travel mode composed of low-carbon travel modes, such as walking, bicycle and public transportation (including conventional public transportation and subway). Under the guidance of low-carbon travel mode, the proportion of various travel modes is appropriate, and urban residents can complete various travel activities through the appropriate low-carbon travel mode, which has the advantages of low energy consumption, low pollution and high energy efficiency[1]. The research on low-carbon travel mainly focuses on influence factors and travel mode.

The influence factors of low-carbon travel behaviour are analyzed from the perspective of travellers' characteristics, including travel times, travel time, travel distance, travel mode, travel purpose and personal socio-economic attributes. Travel distance was the most important factor influencing low-carbon travel behaviour based on the survey of residents' travel[2]. From the perspective of residents' travel awareness, travel attitude, subjective norms, perceptual behaviour control and personal norms have positive effects on the intention of low-carbon travel[3-5]. Under the concept of people-oriented development, urban planners and urban geologists have paid increasing attention to the quality of individual life, and the relationship between environment in urban built area and travel behaviour has become an important research issue in the relationship between land use and traffic behaviour. From the perspective of the environmental influence of urban construction, the characteristics of land use, such as urban form, function, intensity, road infrastructure and urban design, can affect residents' low-carbon travel choice[6-10]. The in-depth research and analysis show that the built environment of small scale block with high density and high mixing degree can guide residents to choose low-carbon travel and reduce travel distance. Meanwhile, the choice of low-carbon travel behaviour is resulted from the interaction of many factors. Some scholars have thoroughly studied the relationship among built environment, low-carbon travel behaviour and residents' travel attitude[11].

With regard to the classification of low-carbon travel modes, according to the study of the sharing rate of all kinds of transportation modes in the planning standards formulated by the state and various departments, the travel modes with the proportion of conventional public transport and rail transit greater than 50% can be classified as public transport orientation. This travel mode is characterized by long travel distance and low trip frequency. The sum of the sharing rates of walking, cycling and electric bikes greater than 50% shall be classified as slow-moving orientation, which is suitable for people with short travel distance and high travel frequency. Table 1 lists the characteristics of the two classification modes of public transport orientation and slow-moving orientation.

Table 1. Classification and features of low-carbon travel mode

Feature classification		Mode classification	
		Public transport orientation	Slow-moving orientation.
Travelers' characteristics	Travel frequency	Low frequency	High frequency
	Travel time	10-50min	10-30min
	Travel distance	Public transport: 5-7km; Subway: about 0.25 time of the line length	Walking: 1-2km; Bicycle: 4-6km; Electric Bicycle: smaller than 10km
	Travel purpose	Middle and long-distance daily living purpose such as working, going to school, and shopping	Middle- and short-distance daily living purpose such as working, going to school, shopping and cultural entertainment, or connecting with other public transport modes. The travel purpose is diversified.
Built environmental characteristics	Land use	High development intensity degree and joint development of peripheral facilities	High development intensity and high functional mixing degree
	Infrastructure	High density of bus networks and stations	High branch network density, road connectivity and public service coverage rate
	Urban design	Space along bus stops and corridors	Small scale space and open space

2.2. Intensive land use elements

In view of the contradiction between land supply and demand in urban built-up areas, the concepts of "compact development" and "inner filling development" have been proposed in the western society. Intensive use of land in built-up areas has become an important way to promote the sustainable development of cities, which has attracted increasing attention from Chinese scholars[12]. Through a series of theoretical and practical studies, domestic and foreign scholars believe that intensive land use refers to the combination of land use on horizontal scale and even a building on vertical scale through a variety of spatial functions. It has four principles: high density, mixed use of function, space diversification and stereoscopic use. There are various elements and methods for measuring intensive land use. Meanwhile, the indicators of land intensive use under different low carbon travel modes are different, including mixing degree, land use intensity, balance between occupation and housing, accessibility, road design and bus supply level. The main content includes three aspects of urban form, function and intensity. Table 2 summarizes the main elements of intensive land use and representative research.

3. Research perspective

The research on the relationship between low-carbon travel and intensive land use is an interdisciplinary subject, which focuses on urban geography, traffic geography, urban planning and transportation planning. Domestic and foreign research on the relationship between low carbon travel and intensive land use focuses on the intensive use of land in built-up areas from two perspectives of public transport orientation and slow moving direction, which has achieved some staged achievements.

3.1. Theoretical research on intensive land use in built-up areas under the public transport orientation

Public transport and intensive use of land in built-up areas have bilateral constraints (Fig. 1). On the one hand, intensive built-up areas need to satisfy the traffic demands through the advantage of high traffic volume of public transport. On the other hand, public transport also needs to be supported by intensive land use to ensure the carrying capacity required for line operation. Cervero (1994) studied the positive influence of rail traffic on the joint development of office real estate, and concluded that the rent of office space developed jointly was proportional to the passenger flow of rail system[42].

Table 2. Elements of intensive land use and representive research

Elements of intensive land use	Contents and measurement methods		Representative research
Function mixing degree	The relative proximity of land (residential, public service, commercial, etc.) with different functions in a given area can be divided into urban, district, block and buildings. The measurement indicators including the proportion of residential land, commercial land, and open space to total land use, dissimilar index, entropy average and mixing use indicator.		Frank and Pivo (1995); Cervero (1996); Kockelman (1997); Ryuichi et al. (1997); Qian (2000); Zhang and Zhao (2017)[13-18]
Land use intensity	The amount and intensity of the spatial distribution of various elements in the unit area of cities, such as population and employment, construction, economic activities and social structure. Measurement indicators: volume ratio is the core control parameter. Building height and building density are relevant control parameters.		Frank and Pivo (1995); Zhou and Yang (2005); Peng and Lu (2007); Zheng and Zhang (2008); Hou et al. (2015)[13,19-22]
Balance between occupation and housing	The ratio of the number of employment positions to the number of households within a given geographical range. Measurement indicator: employment-housing ratio.		Cervero (2006); Long et al. (2012); Ta et al.(2015) [23-25]
Accessibility,	The cumulative opportunities of the plot to a particular destination (e.g. to the nearest park, store, bus stop, etc.) or to all possible destinations and places within a given range.		Geurs et al. (2010); Manaugh et al. (2010); Liu and Gu (2010); Zhou et al. (2013); Hong et al. (2014)[26-30]
Road design	Road network density	Measure the overall accessibility level, which is generally determined by the branch. Measurement indicator: branch network density.	Friedman et al. (1994); Newman et al. (1996); Jacobs (2005); Cervero (2007); Lyu et al. (2017)
	Road network connectivity	The ratio of the total number of connected edges to nodes in the urban road network. Measure indicator: the density of end intersection, T-shaped intersection, and four and above roads.	Cervero and Kockelman (1997); Handy et al. (2003); Dill (2004) [37-39]
Bus supply level	Bus network density	Measure the supply level of public transport.	Peng et al. (2011); Guo et al. (2013)[40,41]
	Bus station density		

Baker (1983) collected data samples in metropolitan areas from 1979 to 1982 to study the impact of rail transit on non-residential facilities. The data showed that 54% non-residential facilities were concentrated in 0.7 miles of the site. The research demonstrated that the distribution of urban public service function space tended to concentrate towards the periphery of rail transit stations[43]. Based on Baker's study, Green and Jones (1993) studied railway stations and areas along corridors, and concluded that the development amount in the surrounding areas and corridor areas of rail transit stations should be higher than that in other areas[44]. The domestic research on the interaction between rail transit and land use started relatively late. Scholars began to carry out theoretical and empirical studies in the late 1990s, mainly from the aspects of urban space form[45], the land development model along the rail transit line and around the station, land use optimization[46,47] and land use intensity control[48,49]. The research on development mode of land around rail transit stations mainly drew lessons from relevant theories and experiences of foreign countries and carried out localization application, including TOD and TJD model. Some scholars believed that the road design under the guidance of public transportation should reflect the characteristics of high density of branch road network and good connectivity of road network. At the same time, the minimum and the maximum block scale were 60m×60m and 180m×180m, which reflected the advantages of dense micro-circulation network.

According to the above literature review, domestic and foreign scholars mainly studied the relationship among public transport, urban spatial structure and form, land use function, land use intensity control and land price, and they generally believed that the measurement of intensive use of urban land was closely related to public transport. Table 3 summarizes the influence of land intensive use element classification and public transport on land intensive use. Under the guidance of public transport, the land use in built-up areas presents high density, mixed functions, and the radial arrangement of employment and residence points along the bus rapid transit line, takes the public transport hub as the core, and emphasizes comprehensive land use, forming the characteristics of multi-center cluster development. In particular, the space along the rail transit line and around the station tends to be a compact form with high density and mixed function.

Table 3. Classification of intensive land use elements in the build-up area by public transport and the effect results

Classification of intensive land use elements		Effect results
Macro	Land value	Positively correlated with the passenger flow of the public transport system
	Urban space structure and form	Increase spatial accessibility and form multi-core clusters and agglomeration centers
Meso	Land use function	Enhance the joint development of facilities around public transport stations and present the development sequence of "business-office-housing-industry"
Micro	Volume ratio	Positively correlated with the volume ratio, and weakened gradually with the greater distance from the bus station
	Building density	Positively correlated with the density of buildings, and weakened gradually with the greater distance from the bus station

3.2. Theoretical research on intensive land use in built-up areas under slow-moving orientation

Because of the diversified travel demand and activity type, residents in the built-up areas under slow-moving orientation will need and guide the land use, road facilities

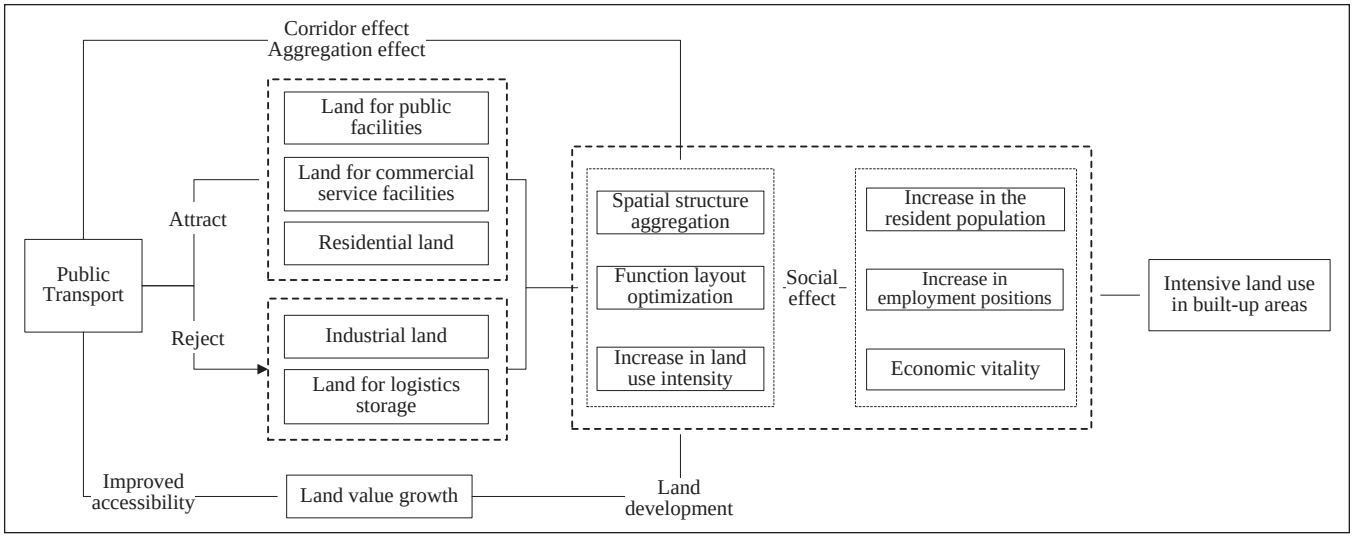

Fig.1: Interaction between public transport and intensive land use in built-up area

and street environment of the block where they live, which promotes intensive land use. There is a close relationship (Fig. 2). Rodrguez and Joo (2004) studied the influence of local facility environment, namely, topography, residential density, availability of pedestrian lanes and bicycle lanes on slow-moving travel[50]. Khanet al. (2014) studied the relationship between the built-up environment and the slow-moving travel choice, and pointed out that the perfect degree of street structure was an important factor attracting people to choose slow-moving travel[51]. Southworth (2005) put forward the six indicators measuring walkability: (1) mixed land use model; (2) road connectivity; (3) convenient connection between walking and other transportation means; (4) infrastructure and quality of pedestrian walkways; (5) safety; (6) aesthetic interest of buildings and landscape along streets[52]. Greenwald and Boarnet (2001) believed that high density mixed land use was positively relevant with walking travel, and the mix and diversity of walking destinations could promote residents to choose walking modes[53]. Kamruzzaman et al. (2016) took Brisbane, Australia, as an example, to determine the correlation between urban morphology and walking using cross-sectional data[54]. Peng (2014) selected three residential areas in Texas, USA, and used GIS tools to measure five indicators that can promote slow travel. The study demonstrated that the small scale high-density grid network and slow traffic infrastructure could improve the slow-moving travel at the community level, and slow-moving travel should be promoted in urban macroscopically land use and traffic structure[55].

These studies have found that some important theoretical achievements have been obtained in the study of slow transit and intensive land use at home and abroad, especially in developed countries like the United States. A large number of studies have pointed out that intensive land use is a significant factor in slow-moving travel. In recent years, increasing domestic researchers began to use GIS tools to quantify the correlation between slow-moving travel and intensive land use indicators such as building density, road connectivity, road accessibility, mixed land use, retail commercial networks, street environments, bus stops and school distribution. Table 4 summarizes the classification of land intensive use elements and the effect of slow-moving travel on land intensive use. The results show that the land use in the built-up area under the slow-moving travel orientation is characterized by small scale, high building density, high volume rate, large public service coverage and mixed function.

Table 4. Classifications of intensive land use elements in the build-up area by the slow-moving orientation and the effect results

Classification of intensive land use elements		Effect results
Land use	Volume ratio	Source and foundation of slow-moving travel
	Building density	
	ABR mixing degree	
	Functional format mixing degree	
Road facilities	Road connectivity	Facilitate the formation of slow-moving conditions
	Road density	
	Intersection density	
	Bus station density	
Street environment	Slow lane area ratio	Strengthen slow-moving accumulation
	Green area ratio of slow lane	

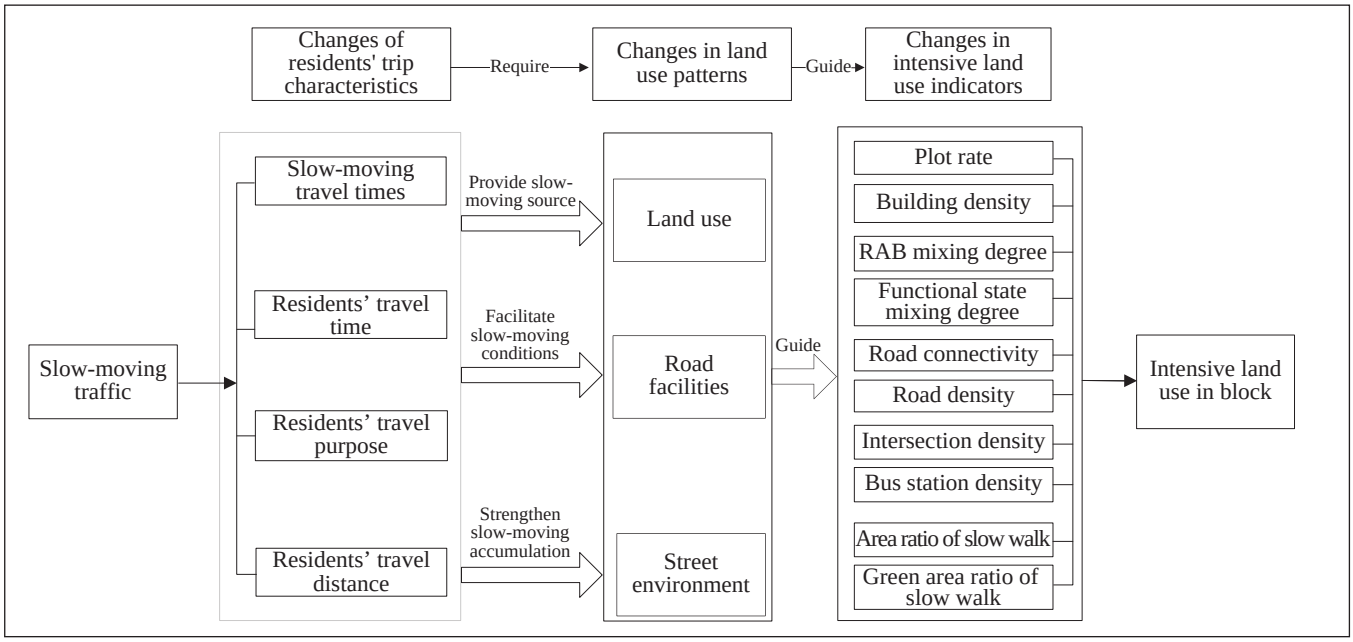

Fig. 2: Interaction between slow-moving travel and intensive land use in built-up areas

4. Research methods

4.1. Theoretical analysis model

In order to clarify the relationship between low-carbon travel and intensive land use, the theoretical model should be analyzed based on the correlation between residents' travel mode and the characteristics of land use. There have been a lot of studies on the effects of residents' travel on land use. However, no consistent understanding of the specific effects on land use, their internal synergistic mechanism, and the influence on land use, has been reached at the theoretical level. Researchers have adopted different research methods, which are mainly qualitative research methods and quantitative research methods, as shown in Table 5. Scholars mainly divided the qualitative research methods into three categories: description, contrast and deduction. In the research methods of correlation quantitative regression analysis, Ren and Dan (2011) generalized the theoretical analysis models into four categories according to the complexity of the relationship between travel mode and land use: specific process description model, derivative requirement model, discrete selection model and activity-based travel model[10]. The specific process description mode is simple and easy to carry out, but lacks the theoretical foundation. Derivative demand model and discrete choice model are widely used because of their mature theoretical basis and explanatory power. Particularly, Logit Model and Probit Model have been widely used by domestic and foreign researchers because of the easy interpretation[56, 57]. Activity-based travel model has recently been taken seriously by researchers because it is regarded as human activity and is in line with the actual situation. Chai et al. (2017) put forward a new idea of urban space and land use research based on residents' spatial mobility and activity behaviour, which made such research more reasonable and have practical significance[58]. However, its wide application is restricted by the requirement of data precision and the complexity of the analysis and operation process.

Table 5. Classifications of research methods on the relationship between residents' travel mode and land use characteristics

Research methods			Property and characteristics	Advantages	Limitation
Qualitative	Descriptive class		Two research methods: case analysis and simple statistical analysis.	Simple form and easy to understand	Lack statistical and persuasive data
	Comparative class	Single element comparison	Based on data summary, the research objects are compared after simple classification and division, and no statistical test is carried out.	The results are more visual	The complex relationship between multiple factors affecting land use is likely to be ignored.
		Comparison of the Comprehensive characteristics of a Model block composed of a single element			
	Deductive class		It is divided into graphical deduction and logical deduction.	The research results are more intuitive and can supplement the quantitative research.	Lack statistical and persuasive data
Quantitative	Regression analysis class	Specific process description model	A simple and common statistical method used to explore the relationship between elements	Simple form and easy to understand	Lack theoretical basis and fail to take into account the inherent relationship between residents' travel modes and land use, which makes it difficult to compare and explain the results.
		Derivative demand model	Simplify travel constraints to time or economic costs	Mature theoretical techniques and explanatory power	——
		Discrete selection analysis model	Models based on stochastic utility maximization theory, including logit model and probit model	Mature theoretical techniques and explanation, strong logic	——
		Activity-based travel model	Take travel as one of people's activities and consider the combination of activities and travel	The research results accord with the reality and have the reality.	High data precision is required, and the operation process is complicated.

In recent years, quantitative statistical analysis and multivariate regression model play a dominant role in the analysis of the relationship between residents' travel modes and land use characteristics, and simple comparative analysis is scarce. This reflects the research on the relationship between residents' travel mode and land use characteristics has become complex and comprehensive.

4.2. Technical analysis method

In the choice of technical analysis methods, domestic and foreign scholars carry out research based on a large number of travel data and land use data. The research idea is divided into three parts: data collection survey-target factor correlation analysis-result analysis and forecast or strategy. The technical analysis method of this study is mainly reflected in travel data collection and survey, that is, data on people's mobility. Traditional mobile data collection methods mainly involve population censuses (migration statistics and workplace statistics) and traffic surveys (recalling method and activity logging). The data acquisition is based on spatial unit rather than human being, and family is the basic unit rather than the analysis of individual mobility. It has the characteristics of small amount of data, partial static state, and emphasis on causality explanation in analysis. With the development of information communication and positioning navigation technology, planning and analysis technology has gradually changed from "small sample" to "large sample" under the guidance of inventory optimization of built-up area. Big data provides important information for the study of residents' spatial activities from different angles. Through mobile phone data, bus data, taxi track data and social media data, massive data such as spatial and temporal data of residents' behaviours are obtained, which is possible to study the travel characteristics of residents at the micro level.

Literature review shows that the research on the relationship between residents' travel mode and land use characteristics based on big data analysis shows an increasing trend of attention and achievements. Wang et al. (2015) construct the evaluation framework of urban built environment through mobile phone signalling data from the microcosmic individual behaviour perspective of relationship between occupation and housing, commuting behaviour and residents' consumption and leisure travel behaviour, and put forward that there were obvious differences in the spatial distribution of residents' activities and travel behaviours, which were significantly affected by land use, traffic, location and other environmental factors[59]. Dinget al. (2016) used mobile phone signalling data to identify the location and residence of mobile phone users in Shanghai, and used the obtained commuter data to measure the employment center system in Shanghai Central City[60]. Long et al. (2012) identified urban functional areas and commute, travel characteristics and laws through traffic card data and residents' travel survey[24]. Guande et al. (2011) analyzed the relationship between carrying capacity and urban social function area through 3 million pieces of taxi GPS data in Hangzhou, finding that carrying capacity was related to the intensity of social activities and the number of passengers varied in different regions[61]. Chen and Zhen (2014) obtained massive sign-on data on Sina Weibo to explore the re-organization of old urban spatial function from the perspective of residents' activities[62].

According to the published literature, although the big data analysis technology has the advantages of large sample size, its representation and precision are poor. Both the quality of big data and the integration of big data and traditional data should be emphasized in practice. Under the guidance of the principle of data sharing, how to identify, screen and integrate the multi-source and heterogeneous data of residents' travel, combine the traditional survey data with the new big data collection to check the size of the data, understand and understand the spatial and temporal behaviour characteristics and land use characteristics of residents' travel from the collected multi-source and heterogeneous data will become the focus and difficulty of this research direction in technological methods.

5. General research trend and prospect of research problems

5.1. General research trend

The research on the relationship between low carbon travel and intensive land use has multi-level, systematic and multi-disciplinary characteristics. Domestic and foreign research on the relationship between low-carbon travel and intensive land use is mainly carried out from the two directions of public transport orientation and slow-moving orientation. The research paradigm follows the combination of theory and practice, focusing on the urban spatial form, function, intensity and other indicators to explore the influence of low-carbon travel on the intensive use of land in built-up areas. It is found that the measurement of land intensive use indicators in urban built-up areas is closely related to low-carbon travel. From the perspective of research methods, quantitative statistical analysis and multivariate regression model play a dominant role in the theoretical analysis model, and simple comparative analysis has become scarce. Among the technical analysis methods, the collection and investigation of travel data based on multi-source and heterogeneous data has become a hot research topic in recent years. Complementary research methods are formed according to the characteristics of different data resources, and multi-source heterogeneous data make the spatial and temporal behaviour characteristics of residents' travel easier to express in land use.

5.2. Prospect of research problems

The above summary of research elements, research perspective and research methods can provide valuable theoretical and practical reference for domestic research. The

research on the relationship between low carbon travel and intensive land use in built-up areas also has the following problems: Firstly, There are many empirical studies but few theoretical studies. There is no consensus on the relationship between low-carbon travel and intensive land use, influence ways and theoretical models. The research on the deep synergistic mechanism in vertical and horizontal aspects is deficient. As a result, some controlling indicators (such as volume ratio, building density and mixing degree) in the relevant research results have strong "local" characteristics. The evaluation criteria with universality should be further summarized. Particularly, as residents' travel characteristics and the stage characteristics of land use in China are not similar to the development process of western cities, the research conclusions are often inconsistent. Secondly, there are more qualitative analyses but fewer quantitative analyses. Due to the lack of investigation means and basic data, the research is mostly guided by a single low-carbon travel mode, and qualitative description of the relationship is carried out through the correlation analysis of empirical cases. At present, most studies mainly focus on the identification of land intensive use feature variables that have significant influence on low-carbon travel characteristics, but the analysis of the influence degree is limited. There is no deep quantitative analysis of land intensive use control indicators for different low carbon travel modes and different land types. Thirdly, the research is limited by multi-source heterogeneous data acquisition and processing method. Feature mining based on multi-source heterogeneous data, especially the analysis and mining of low-carbon travel and land intensive use features, is scarce. There is still a large improvement space in multi-source heterogeneous data mining and feature analysis in this research direction.

6. Conclusions

Although a large number of consistent results have been made in the research on land intensive use in built-up areas based on low carbon travel, due to different regional characteristics, selected research elements and research perspectives, theoretical technical models and data acquisition approaches, a variety of research results have been obtained. Under the influence of individual factors in recent years, it is difficult to sum up universal criteria and quantitative land intensive use control indicators. In order to solve the above problems, future research should pay more attention to the following points.

(1) Consistency between low-carbon travel and the synergy theory of intensive land use in built-up areas

Most of the existing research focuses on one aspect and lacks an overall perspective. It is necessary to strengthen the holistic study of the synergetic theory, such as the internal relationship between low-carbon travel and land intensive use, the influence ways, and the theoretical model, which should be consistent at the theoretical level.

(2) In-depth quantification of land intensive use indicators based on low-carbon travel

The existing research proves that there is a synergistic relationship between low-carbon travel and intensive land use in built-up areas, but the quantitative relationship is still unclear, which leads to the mismatch between low carbon travel and land development in planning practice cases. That is, the imbalance between supply and demand is serious. Therefore, the in-depth quantification of land intensive use control indicators significantly influencing low-carbon travel should be strengthened. Meanwhile, since the spatial distribution of the built-up area has been basically stable for a period of time, it is necessary to focus on the quantitative study on the relationship between low carbon travel and land use function and land use intensity in the built area.

(3) Identification of low-carbon travel mode and land intensive use characteristics through multi- source heterogeneous data analysis technology

In recent years, the diversification of data sources can provide a technical impetus to study residents' time-space behaviours and the complexity of land use in built-up areas. Multi- source heterogeneous data analysis technology can timely understand the relationship between residents' travel patterns and land use characteristics, and further enhance the scientific and rational study of intensive land use in built-up areas.

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References

1. Zhang Y.W., Li J. (2015): "The conception of urban spatial structure based on low-carbon travel orientation".*Urban Problems*, (11), 45-52.
2. D.Stead. (1999): "Relationships between transport emissions and travel patterns in Britain". *Transport Policy*, (6), 247-258.
3. Wang G.R. (2011): "Research on the Low-carbon Travel Mode of Citizens". *Urban Insight*, 12(2), 174-178.
4. Duan M.M. (2015): "Analysis and Empirical Study on Influencing Factors of Low-carbon Travel of Urban residents". *China Collective Economy*, (12), 23-24.
5. Wang Y.R. (2016): "A Study of the Factors Influencing Residents' Intention of Low-carbon Travel". *Journal of Yunnan University for Nationalities (Natural Science Edition)*, 25(3), 280-285.
6. Ewing R. (2001): "Travel and the built environment: A synthesis". Transportation Research Record, 1780(1), 265-294.

7. Handy S, Cao X, Mokhtarian P. (2005): "Correlation or causality between the built environment and travel behaviour? Evidence from Northern California".*Transportation Research Part D*, 10(6), 427-444.
8. Cao X. (2015): "Examining the Relationship between Neighborhood Built Environment and Travel Behaviour: A Review from the US Perspective". *Urban Planning International*, 30(4), 46-52.
9. Sun B.D., Dan B. (2015): "pact of Urban Built Environment on Residential Choice of Commuting Mode in Shanghai". *ActaGeographicaSinica*, 70(10), 1664-1674.
10. Ren J.F., Lv B. (2011): "The Impact of Land Use on Travel". *Urban Planning Forum*, (5), 63-72.
11. Ye R., Titheridge H. (2016): "Satisfaction with the commute: The role of travel mode choice, built environment and attitudes". *Transportation Research Part D*, (52), 535-547.
12. Zhu T.M., Yang G.S., Wan R.R.(2009): "Research Progress in the Domestic and Foreign Urban Land Intensive Use Quantitative Evaluation". *Economic Geography*, 29(6), 977-983.
13. Frank L D, Pivo G. (1995): "Impacts of mixed use and density on the utilization of three modes of travel: single occupant vehicle, transit, and walking".Washington D C: *Transportation Research Record*, 13-42.
14. Cervero R. (1996): "Mixed land-uses and commuting: Evidence from the American Housing Survey". *Transportation Research Part A Policy & Practice*, 30(5), 361-377.
15. Kockelman K M. (1997): "Travel Behaviour as Function of Accessibility, Land Use Mixing, and Land Use Balance: Evidence from San Francisco Bay Area". Transportation Research Record *Journal of the Transportation Research Board*, 1607(1607), 116-125.
16. Kitamura R, Mokhtarian p, Laidet L. (1997): "A Micro-analysis of Land Use and Travel in Five Neighborhoods in the San Francisco Bay Area". *Transpiration*, 24(2), 125-158.
17. Qian L.B.(2000): "The Research on the Relationship between Degree of Mixed Urban Land-use and Spatial Distribution of Trips". *Urban Research*, (3), 7-10.
18. Zhang M, Zhao P. (2017): "The impact of land-use mix on residents' travel energy consumption: New evidence from Beijing". *Transportation Research Part D Transport & Environment*, 57, 224-236.
19. Zhou S.H., Yang L.J. (2005): "The Influence of Urban Land Use Intensity of Urban Traffic". *Urban Planning Forum*, (2), 75-80.
20. Peng H., Lu H.P.(2007): "Using GIS Spatial Analysis to Survey the Relationship between Urban Density and Travel Demand". *Journal of Transportation Systems Engineering and Information Technology*, (4), 90-95.
21. Zheng M., Zhang X.D. (2008): "Determine Appropriate Land-use Intensity according to Road Capacity" A Case Study of Detailed Control Planning for Central District in Beijing". *Urban Transport of China*, 6(5), 15-18.
22. Hou Q.H., Duan Y.Q., Ma R.G.(2015): Collaborative Optimization of Land Use Intensity and Traffic Capacity under Hierarchical Control Rules of Regulatory Detailed Planning". *Journal of Chang'an University (Natural Science Edition)*, 35(2), 114-121.
23. Cervero R, Duncan M. (2006): "Which reduces vehicle travel more: jobs-housing balance or retail-housing mixing?". *Journal of the American Planning Association*, 72(4), 475-491.
24. Long Y., Zhang Y., Cui C.Y. (2012): "Identifying Commuting Pattern of Beijing Using Bus Smart Card Data". *ActaGeographicaSinica*, 67(10), 1339-1352.
25. Ta N., Chai Y.W., Guan M.B. (2015): "The Relationship between the Built Environment and Car Travel Distance on Weekdays in Beijing". *ActaGeographicaSinica*, 75(10), 1675-1685.
26. Geurs, K,Zondag, B, de Jong, G, de Bok, M. (2010): "Accessibility appraisal of land-use/transport policy strategies: More than just adding up travel-time savings".*Transport Research Part D-Transport and Environment*, 15(7), 382-393.
27. Manaugh, K, Miranda-Moreno, LF, El-Geneidy,AM. (2010): "The effect of neighborhood characteristics, accessibility, home-work location, and demographics on commuting distances". *Transportation*, 37(04), 627-646.
28. Liu X.T., Gu C.L. (2010): "A Spatial Analysis of the Modal Accessibility Gap in Nanjing Metropolitan Area". *Urban Planning Forum*, (02), 49-56.
29. Zhou J.P., Chen X.J, Huang W., Yu P., Zhang C.(2013): "Jobs-housing balance and commute efficiency in cities ofcentral and western China:A case study of Xi'an". *ActaGeographicaSinica*, 68(10), 1316-1330.
30. Hong J, Shen Q., Zhang L. (2014): "How do built-environment factors affect travel behaviour? A spatial analysis at different geographic scales". *Transportation*, 41(3), 419-440.
31. A. Friedman, V. Cammalleri. (1994): "Reducing Energy, Resources And Construction Waste through Effective Residential Unit Design". *Building Research & Information*, 22(2), 103-108.
32. Newman P. W. G., Kenworthy J. R. (1996): "The Land Use-Transport Connection an Overview". *Land Use Policy*, 13(1),1-22.
33. Jacobs J. (2005): "The Death and Life of Great American Cities". Yilin Press
34. Cervero R. (2007): "Translated by Yuheng Sustainable Transport Research Centre. Public Transportation in Cities". China Building Industry Press
35. Shi F., Yu S.J. (2016): "A Study of Urban Road Network Structure and System from the Perspective of Transit Orientation". Huazhong University of Science and Technology Press
36. Lyu X, Han Q, Vries B D. (2017): "Procedural modeling of urban layout: population, land use, and road network". *Transportation Research Procedia*, 25, 3337-3346.
37. Cervero R, Kockelman K. (1997): "Travel demand and the 3Ds: Density, diversity, and design". *Transportation Research Part D Transport & Environment*, 2(3), 199-219.
38. Handy S, Paterson R G, Butler K S. (2003): "Planning for street connectivity: Getting from here to there". *Apa Planning Advisory Service Reports*, (515), 1-75.
39. Dill J. (2004): "Measuring Network Connectivity for Bicycling

and Walking. Presented at 83rd Annual Meetingof the Transportation Research Board". Wationgton, D.C.

40. Peng H, Guo J, Wang J, et al. (2011): "Network coupling of urban land use and public transport". *Transportation of China*. IET, 25-30.
41. Guo L., He H., Chen L.L. (2013): "Study on the Characteristics of Conventional Transit-Oriented Urban Transport and Land-use: Taking Huangshi City in Hubei Province as an Example". *Huazhong Architecture*, 31(5), 125-129.
42. Cervero R. (1994): "Rail Transit and Joint Development: Land Market Impacts in Washington, D.C. and Atlanta". *Journal of the American Planning Association*, 60(1), 83-94.
43. C.Baker.(1983): "Tracking Washington's metro". *American Demographics*, (11), 30-35+ 46.
44. Green R D, James D M. (1993): "Rail transit station area development: small area modeling in Washington, D.C.". *PanminervaMedica*, 43(3), 171-185.
45. Bian J.W. (2009): "Development Patterns of Urban Rail Transit and Spatial Structure". *Urban Transport of China*, 7(5), 40-44.
46. Zhang J, Lu H, Li Y. (2010): "A Traffic Efficiency-Based Optimization Model for Land Use around High Speed Railway Station". Tenth International Conference of Chinese Transportation Professionals, 106-116.
47. Tang Z.Z., Li S.Y., Li X., Liu X.P., Chen Y.M., Li W.X. (2017): "Spatio-temporal Effects of Urban Rail Transit on Complex Land-use Chang". *ActaGeographicaSinica*, 72(5), 850-862.
48. Qu T., Cai J.M., Zhang L.Q., Zheng B. (2010): "Research on Floor Area Rate Planning Guide of Railway Traffic". *ActaGeographicaSinica*, 65(2),202-212.
49. Wang J.Y., Zheng X., Mo Y.K. (2011): "Establishment of Density Zoning and Determination of Floor Area Ratio along Rail Transit Line Based on TOD: A Case Study on Rail Transit Line 3 in Shenzhen". *City Planning Review*, 35(4),30-35.
50. Rodrguez D A, Joo J. (2004): "The relationship between non-motorized mode choice and the local physical environment". *Transportation Research Part D*, (9),151-173.
51. Khan M, Kockelman K M, Xiong X. (2014): "Models for anticipating non-motorized travel choices and the role of the built environment". *Transport Policy*, 35,117-126.
52. Southworth M. (2005): "Designing the Walkable City". *Journal of Urban Planning and Development*, (12), 246-257.
53. Greenwald M, Boarnet M. (2001): "Built Environment as Determinant of Walking Behaviour: Analyzing Nonwork Pedestrian Travel in Portland, Oregon". *Transportation Research Record Journal of the Transportation Research Board*, 1780(1),33-41.
54. Kamruzzaman, M., Washington, S., Baker, D., Brown, W.,Giles-Corti, B. Turrell, G. (2016): "Built environmentimpacts on walking for transport in Brisbane, Australia". *Transportation*, 43(1), 53–77.
55. Peng L. (2014): "Empirical Study on American Community Road Network based on Non-Motorized-Traffic". *Planners*, (00), 245-253.
56. Wei Y.P., Pan C.L. (2012): "Urban Land-use Characteristics and Commuters' Travel Pattern: A Case Study of West Hangzhou". *City Planning Review*, 36(03), 76-84+89.
57. Chen Y.P., Song Y., Zhang Y., Peng K., Zhang Q., Jin X. (2011): "Impact of Land Use Development on Travel Mode Choice: A Case Study in Shenzhen". *Urban Transport of China*, 9(5), 80-85+27.
58. Chai Y.W., Tan Y.M., Shen Y., Guan M.B. (2017): "Space-Behaviour Interaction Theory: Basic Thinking of General Construction". *Geographical Research*, 36(10), 1959-1970.
59. Wang D., Zhong W.J., Xie D.C., Ye H. (2015): "The Application of Cell Phone Signaling Data in the Assessment of Urban Built Environment: A Case Study of Baoshan District in Shanghai". *Urban Planning Forum*, (5), 82-90.
60. Ding L., NiuX.Y.,Song X.D.(2016): "Measuring the Employment Center System in Shanghai Central City: A Study Using Mobile Phone Signaling Data". *ActaGeographicaSinica*, 71(3),484-499.
61. Qi G D, Li X L, Li S J, et al. (2011): "Measuring Social Functions of CityRegions from Large-Scale Taxi Behaviours".2011 IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops), 384-388.
62. Chen Y.X., Zhen F. (2014): "Further Investigation into Urban Spatial Function Organization Based on Residents' Activity Data—A Case Study of Nanjing". *Urban Planning Forum*, (5), 72-78.