

Correlation Studies on Residential Pattern and Carbon Emissions from Residents Transportation: A Case Study on Shanghai Caoyang Xincun¹

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Abstract: Population density is relevant to the residence form characteristics and pattern classification, and the carbon emission from residential transportation is logically correlate with population density, facilities variety and traffic site distance. Existing related research shows that urban form cause influence on transportation and carbon emissions, however, on the part of residential scale, the relative research on spatial form and per capita transportation carbon emission still needs more empirical cases. This paper takes Shanghai Caoyang Xincun as the object, researches on the carbon emission with "3Ds" theory, through the investigation questionnaire to estimate the per capita transportation carbon emission of 54 estates sample. From the comparative analysis of the results, the volume ratio of Caoyang Xincun and population density present positive correlation with transportation carbon emissions per capita, but negative correlation with facilities variety. Considering settlements residents of social economy and traffic facilities layout unbalanced factors of traffic sites and accessibility and negatively correlation with transportation per capita carbon emissions. According to the analysis from the logical correlation between the carbon emission and eight residential patterns in the sample, it is concluded that the diversity of per capita transportation carbon emissions is caused by the superposition of variety of socioeconomic and travel needs of the spatial behaviour main body. Before the judgment of low-carbon estate pattern, the structural characteristics of spatial density and society should be clarified first, then the national conditions, regional development condition; socioeconomic factors need to be combined to guide the development of future residential pattern.

Keywords: residential pattern, traffic carbon emission, caoyang xincun

1. Introduction

As the basic unit of the city, residence is the main area of housing, living and consumption that naturally becomes the main source of carbon emissions. China, a rapid developing country, during its nearly 30 years reform and opening-up process, rapidly developed in urbanization and industrialization. According to relative research, it is concluded that by 2020, this country's carbon dioxide emissions will surpass the USA, ranks the first (Claessens) in the world. By 2011, Chinese residential energy consumption had been the country's second largest in the total energy consumption, occupied 23% of the total (total final consumption TFC). At the same time, it was expected that by 2020, Chinese architectural development scale will reach 2.6 billion square meters, residential building will account for 1-1.5 billion of the total. In fact, the Chinese government always in a positive and responsible attitude to response UN's propose to reduce carbon emissions, and adopts various policies and technological innovations to reduce urban carbon emissions. At the same time, a large number of studies to the Chinese cities have also shown (Ma Jin, 2011); Zheng Siqu, 2010) that the residents trip, traffic model choice and carbon footprint is closely related to the residential development pattern. Therefore this study thinks that the optimization of residents form not only takes a long-term and structural effect on energy saving and emission reduction, but also shows an important

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planning path to realize low carbon urban development.

2.Literature Review

2.1 Urban Morphology, Transportation and Carbon Emissions

In terms of urban scale, the city's economic development will inevitably bring the increase of personal income, the expand of housing area and the improvement of car ownership. the understand of relationship between urban morphology and carbon emissions need to be started from the density. For the urban carbon emissions, a large number of research scholars started from the relations of urban structure, land use and transportation (Bourne, 1982; Anderson, et al. 1996), urban morphology influences structurally on residents' daily life behavior, transportation needs and mode, then directly leads to carbon emissions differences. Wahlgren (2007) found that city planning obviously influenced 10% of greenhouse gas (GHGs) on the city scale and 20% the residence scale.

Many researchers agree that if the relationship between urban form and transportation want be confirmed, at first we need to prove that the individual travel choice is due to the factor of urban form rather than other factors, but this would require the time-related inspection to the urban morphology changes impact on traffic behavior. Obviously it is arduous to take continuous monitoring and feedback on individual transportation data as research condition. Based on differences between Chinese and western countries, we need to combine with domestic samples to take further empirical research on the reference of related mature research theories and analysis methods.

The existing studies found that there is negative correlation relationship between urban density and carbon dioxide emissions (Kennedy et al, 2009; Grazi et. Al, 2008), which means the improvement of city density helps to reduce energy consumption and carbon emissions per capita. However, different with the conclusion of the higher urban density, the lower the carbon emissions per capita which is from the large number of research in the Europe and the United States (World Bank, 2010), in China, the "double high" or "double low" residential pattern often corresponds to a larger living space and higher energy consumption. But can this be concluded that there is simple linear growth in per capita transportation carbon emissions with increasing trend of residential volume and expanding of per capita area?

2.2 The transportation of residential scale and the "3Ds" theory

At the level of residential scale, transportation-related spatial form researches are mainly from the following three dimensions: Density , Diversity and Design. (Cervero and Kockelman, 1997), that the density has a significant influence on transportation had been confirmed eraly(Levinson, H., 1963), and the impact of built environment on the residents' transportation has become the focus of academic research in recent years. This study argues that the density is not only the strength index of the residential development, but also the guarantee of residents employment and the walking accessibility of service facilities; Residential diversity can mix up land function and the social classes, meanwhile, it can increase the concentration of service facilities; And the distance of residential interior to public transportation sites determines the walking accessibility and convenience degree to the destination. Therefore, the "3Ds" theory of Density, Diversity and Distance to transit is promoted based on the background of present China's fast urbanization and the much higher residential development intensity compared with the density of the European and American countries. This theory shows more pertinency and feasibility on the low carbon oriented residential morphology research.

2.3 Residential type pattern and carbon emissions

Residential morphology is closely related to the environmental sustainable development and energy use. Residential density under different urban scales contains different connotation of space development (Tsai, 2005). There exists interaction in factors of housing material form and urban system, land use, functional structure. The classification to the residential morphology and the description to the features can be defined and divided from the perspective of the density (1). Under the constraint of China's population and land resource, the type of residential morphology is more than just the physical space, also expresses the social-evolution logical characteristics of pattern types. Meanwhile, it reflects the residents' daily activities and functional requirements, thus determines the logical correlation between residential pattern types and traffic carbon emissions.

3.The object and analysis method

3.1 the object selection

Founded in 1951, Shanghai Caoyang Xincun is China's first workers new village. During the historical evolution process of the planned economy to market economy, it gradually formed the social class and the diversification of the spatial structure. Caoyang Xincun covers an area of 2.14 square kilometers, include 200 square meters plus residential construction area, with a total population of 13241 (2010 Shanghai six general statistics), the population density is 62000/km².

The selection of Caoyang Xincun as a object of correlation of residential density and transportation carbon emissions is based on the following three aspects: First, in terms of physical space, in a certain area, it has formed the low, medium and high density of coexistent residential pattern (figure 1). Secondly, after decades of evolution, it has formed a complete public facilities system and clear grade of service. Finally, its social structure morphology presents characteristics of strata hybridization in professional type and degree of education, etc.


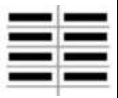

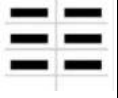









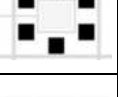




Figure 1. Current spatial texture of Caoyang Xincun

3.2 The division of data and residential type

The study selected 54 community and gained basic spatial data through GIS. The per capita transportation carbon emissions are gained through the statistical analysis software based on 54 communities equidistant sampling and recycled questionnaires. Questionnaires are 1500 in total, 1023 valid with effective rate 68.2%. As the Xincun shows multi-gradient and multiple class in density structure, the research summarized eight typical residential pattern from the perspective of typology (table 1).

Table1. Density feature and spatial patterns in Caoyang Xincun

Development intensity	Characteristic of spatial morphology	Type of model	Characteristic pattern of residential			Intensity indicator				
			Typical form of Caoyang Xincun	Typical form of Caoyang Xincun	The serial number of the models	Volume ratio	Building density	Density of population (families/ha)	Family density (families/ha)	House area for each inhabitant (m ² /people)
Low-volume ratio	<3F	Building arrange in line			Type1	0.97	31.7%	1343.67	297	14.97
Middle-volume ratio	4F-6F	Building arrange in line			Type2	1.72	38.2%	2015.75	417	19.29
	4F-6F	Building arrange in mix of line and point			Type3	1.84	35.5%	2210.25	436	19.18
	4F-6F	Building arrange in circle			Type4	2.39	36.7%	816.50	355	35.58
High-volume ratio	7F-14F	Building arrange in line			Type5	3.07	34.2%	1583.80	374	39.45
	7F-14F	Building arrange in circle			Type6	3.55	31.1%	1192.60	260	54.87
	>15F	Building arrange in points			Type7	4.50	29.2%	1213.80	578	34.01
	>15F	Building alone			Type8	4.51	29.4%	823.25	346	58.32

In theory, improving the land plot ratio is the most effective way to increase the population density, but from the analysis of Caoyang Xincun data comparison, it can be found that the low plot ratio

pattern and high plot ratio pattern shows no significant differences in population density. If the higher spatial density carried more population capacity, then the high plot ratio in the sample of this survey cannot simply be understood as high density. On the one hand, the increase of the intensity of the per capita living space is along with residential development increasing, accompanied by the decrease of residential units and the population density, on the other hand, the mixture of residential pattern also reflects social structural differences between residents and family organization.

3.3 Comparison on residential pattern and per capita residents carbon

From per capita traffic emission of different residential types, the multilayer residential pattern (pattern two, three, four) and point small high-rise emission are significantly higher than other types, and the determinant low-rise, determinant small high-rise and enclosing type emissions are similar, single high-rise type is the lowest. Therefore, in Caoyang Xincun, the correlations between residential pattern types and per capita residents carbon emissions can not directly explained by the physical form. The difference of per capita transportation carbon emissions is caused due to the facility layout factors. It is not a simply linear corresponding relation between residential morphology and per capita traffic carbon emissions.

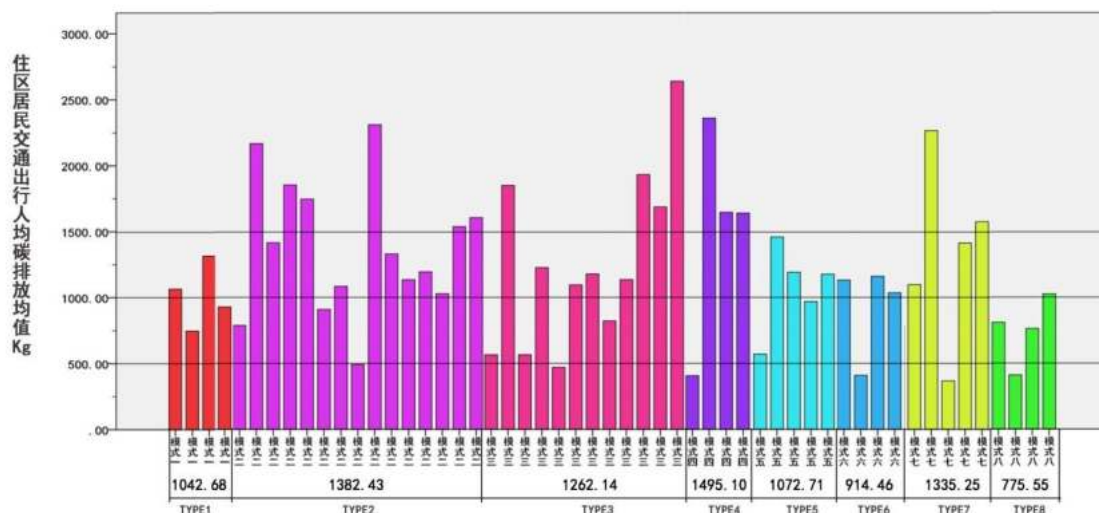


Figure.2 Current spatial texture of Caoyang Xincun

4. The correlation studies on per capita traffic carbon emissions based on the 3Ds theory

4.1 Plot ratio, population density and per capita traffic carbon emissions

From the comparison curve of different residential pattern plot ratio and per capita traffic emissions (figure 3), it shows that the curve slope is relatively flat in the determinant low-rise, the multi-layer, the mixed and enclosed pattern, and corresponds the volatility change of per capita traffic emissions, but it presents a positive correlation relationship between them. However, when the pattern changes from point high-rise to single high-rise, the mean plot ratio shows little variation, and per capita residential transportation energy consumption suddenly fall a turning point. the above characteristics shows that the strength of residential development in some extent can affect residents' transportation mode, but for high plot ratio estate, its per capita transit emission is slightly lower than the low and medium plot ratio estate, and shows difference distribution of pattern characteristics, mainly caused by

the population density. It could be further validated in the curve comparison of average population density and per capita traffic carbon emissions (figure 4), the change rule of both is quite similar.

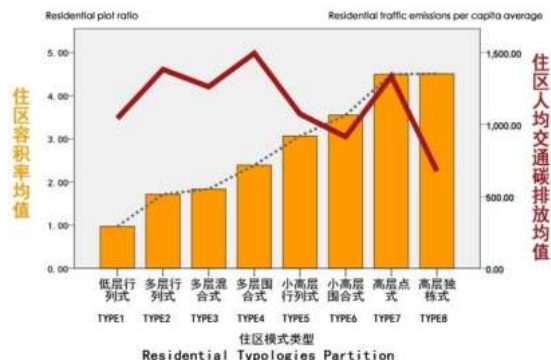


Figure.3 Current spatial texture

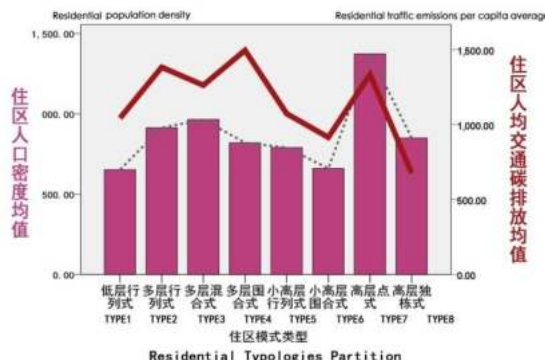


Figure.4 Current spatial texture

4.2 Facilities diversity and per capita traffic carbon emissions

From the type and quantity of public service facilities in Caoyang Xincun, its internal supporting facility construction standard is high and variety in types, thus in a certain extent, it reduces using behavioral requirements of external facilities. Caoyang Xincun, meanwhile, also influenced by negative space factors as the cut-off of waterfront and entrance guard settings. For the residents of different residential patterns, the imbalance of the accessibility level of some internal facilities is likely to increase external leisure travel probability. The type, size and accessibility of internal service facilities play a decisive role in maintaining residents' daily life and reduce the motorized transportation.

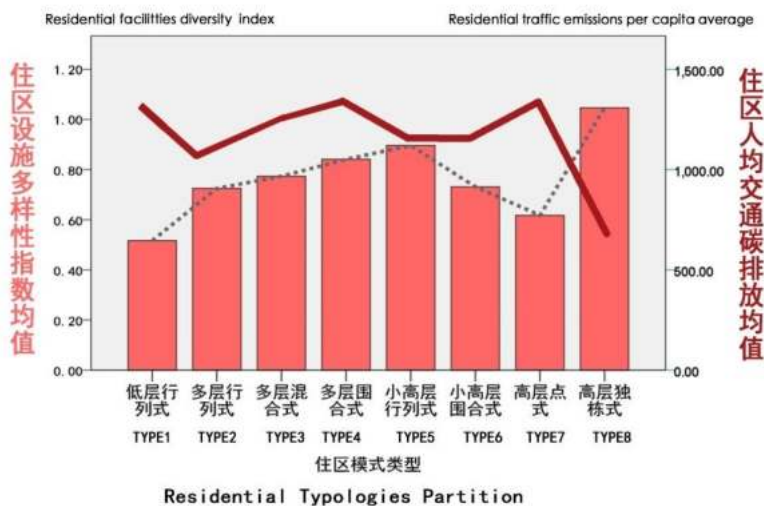


Figure.5 Current spatial texture

The research combined with GIS data takes diversity standardized calculation to the density of service facilities in different types of residential patterns, then obtains the diversity index by cumulative sums of the diversities value of medical, culture, education, business and other service facilities. From the average curve comparison of facilities diversity index from different residential pattern and per capita traffic emissions (figure 5), it shows that the multilayer and determinant small high-rise residential

facilities diversity index are relatively homogenization, but the low-rise and point high-rise pattern is relatively poor. At the same time, it shows negative correlation relationship between facilities diversity and per capita traffic emissions, i.e. the more abundant the surrounding facilities and the more convenient the accessibility, the lower the per capita residential traffic emissions.

4.3 traffic site accessibility and per capita traffic carbon emissions

After comprehensive comparison of the average curve of residential public site accessibility index of different pattern types(4) and traffic emissions(figure 6), the positive correlation is shown obviously between the bus site accessibility and per capita traffic emissions, which means that the distance of residence to bus site will have an immediate impact on the decision of taking bus. That is to say, the higher bus site accessibility will reduce the use of private vehicles, and the traffic energy consumption carbon emissions could be reduced by increasing the proportion of residents' public transportation.

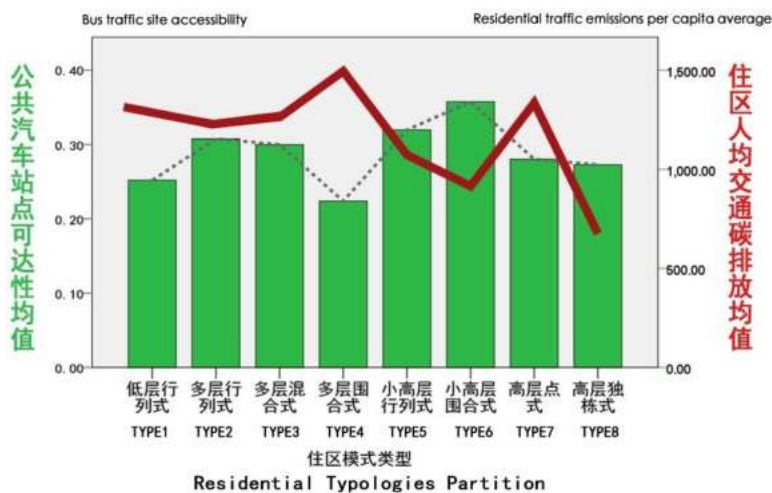


Figure.6 Current spatial texture of Caoyang Xincun

In the corresponding relationship between the rail transit site accessibility and per capita traffic carbon emissions (figure 6), the determinant multilayer, mixed, enclosed and determinant small high-rise patterns are positively correlated with carbon emissions, it shows differences with distributions of public transportation site accessibility. It is need to be explained that in Caoyang Xincun, the urban rail transit site is located in the southeast area, so it reduces the accessibility for part of the multilayer and high-rise residential space. In terms of the social structure, the multi-layer mixed residents are mainly migrant workers and private cars takes a higher percentage, thus increases the per capita transportation carbon emissions; And multilayer enclosed and small high-rise determinant patterns are update projects since 2000 with higher commercialization degree, the residents are at high-income levels, the rail transit site accessibility may cause the adoption of other motorized traffic way. In conclusion, under the combined action of the spatial and socio-economic structure factors, the per capita traffic emissions of above three patterns shows no obvious negative correlation with rail transit stations accessibility. If with exclusion of socio-economic factors influence on transportation mode choice, the residential and public transport distance and site accessibility level is negatively related to the per capita traffic emissions.

5.Conclusion

Under the background of global warming and China's economic and social transformation, the theory and empirical researches on relationships between the residential planning pattern and carbon emission characteristics are significant to guide China's practices; With the increasing of people's income and improving of living conditions, the carbon emission effect from residential energy consumption gradually become a core issue of academia and government departments. The study selected Shanghai Caoyang Xincun, from the classification of residential form, divided into high, medium and low density and reflected that the population density of the physical form characteristics and the pattern characteristics of per capita living area. From the correlation analysis of different residential pattern and per capita transportation carbon emissions, residential development intensity and population density was positively correlated with carbon emissions, and negatively correlated with service facilities diversity distribution and traffic site accessibility. The essence of residential pattern types and the carbon emissions is that the density index is spatial significant in development intensity and social structure, meanwhile is related with facility layout, supplement scale and traffic site accessibility. The diversity of per capita transportation carbon emissions is caused by the superposition of variety of spatial socioeconomic and travel needs. Under the background of rapid urbanization in China, the selection of residential pattern types should not be copied simply, the government needs to make quantitative evaluation on residence sustainable development and density characteristics from the angle of carbon emissions, at the same time also needs to plan appropriate residential density and increase the employment of residential land and accessibility of public service facilities, provide more multiple class affordable housing planning with the goal of implement of low-carbon city development.

Notes

- ① From the point of conception, "Type" is the distribution law of things and the abstraction on the co characteristics, but the "Pattern" is the methodology to solve one kind of problem, which concl the ways to analyse and solve certain things and rise to theoretical level. Residence is the mo fundamental and important content in human activities. Residential morphology types covers the contents as material, economy, and society, and residential pattern is the systemization a structuralization to the residential morphology elements. From residential pattern system, this st thinks that residential pattern includes material and non-material elements. The material eleme include housing, facilities, roads and landscapes, etc., the non-material mainly include the soc relations, humanistic spirit, life style, etc. The density is the important quantitative indicat in residential patterns.
- ② In quantitative research, the uniform distribution extent description often uses the Simpson in on the different categories of numerical value of the same research object, the index is more u to calculate the concentration degree of economic composition, the formula is expressed as 1 mi the quadratic sum of each object value occupied in the whole structure, as:

$$D = \frac{1}{\sum_{i=1}^n \frac{1}{C_i^2}}$$

When small changes are adopted on the above calculation method that obvious the distance of unif distribution on the objects from different levels, then a new formula is generated as:

$$D_{\text{facility}} = \frac{1}{\sum_{i=1}^n \left[\frac{1}{C_i^2} \left(\frac{1}{C_i} - \frac{1}{C_j} \right)^2 \right]}$$

In this formula, D_{facility} is for residential facilities diversity measurement index, C_i is for the classification level value of one object, $1 / C_i$ is defined as the classification quantity wei factor, the smaller the factor value, the more the classification level. Formula in parentheses indicates the average relative distance between each class target value 1 and the actual measured va The smaller value means the smaller distance between the distribution form and the structur distribution target, also means that the greater quantity density of the distribution level of

i type facilities. From this formula, the facilities diversity index parameter value is between 0 and 1, the value more close to 1 indicates the facilities diversity distribution more uniform.

- ③ In the public facilities spatial accessibility evaluation method, the geographic information system analysis platform is an indispensable technical support. With its support, there are a lot of evaluation methods, mainly including ratio method, nearest-neighbour distance method, isoline method, gravity model method, buffer method, travel cost method, accumulation method based on opportunity, and method based on spatial interaction, etc. This research adopts the potential evaluation model based on spatial interaction, the formula is

$$A_i^p = \frac{M_j}{D_{ij}^{\alpha} V_j}$$

A_i^p means the spatial accessibility of residential place i to all facilities; M_j means the service ability of j facility; V_j means the population scale impact factor; D_{ij} means the travel impedance of i to facilities j (distance or time); α represents travel friction coefficient; N means public service facilities quantity.

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