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The Impact of Spatial Parameters on Carbon Dioxide (CO_2) Emissions: A Comparative Study between Cities in China and India

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ABSTRACT: This project discovers the key determinants of CO_2 emissions associated with urban households in Xi'an (China) and Bangalore (India). Data was collected through household surveys in both cities. Descriptive statistics and multiple linear regression analysis were used to test the hypothesis that household CO_2 emission is a function of household attributes and the urban built environment. The findings show that ownership of motor vehicles and the use of electricity as well as income levels positively influence the level of household CO_2 emissions. The mix of job opportunities in a neighbourhood space has shown an inverse relationship with the level of household CO_2 emissions. The research calls for policy innovations in land-use and transportation planning for building low carbon cities.

KEYWORDS: *carbon dioxide emissions, low carbon city, urban planning, China, India*

Introduction

Rearranging urban spatial parameters, such as land-use mix and transportation, could reduce CO_2 emission because urban form influences the volume of CO_2 generated by households. This influence is felt in part through the design and density of residential buildings, which foster different energy consumption behaviour. Another part relates to lower transport energy use (Moriarty, 2002; Troy, Holloway, Pullen, & Bunker, 2003). The reduction could be more significant as the transportation sector alone contributes to a quarter of greenhouse gas (GHG) emissions in some cities (Stead, 1999). Despite the general recognition that land-use change can influence the use of certain transportation modes (Ewing & Cervero, 2001), and that the reduction of travel and modal split are relevant to GHG emission control (Department of Infrastructure, 2001), two major questions remain to be answered: (1) How do urban spatial parameters affect household CO_2 emissions?; and (2) What urban planning policies can be introduced to change these parameters?

Methodology

The central hypothesis is that household CO_2 emission is a function of household attributes and urban spatial parameters, expressed in the formula below:

» household CO_2 emission = f (household attributes, spatial parameters) (1)

Data was collected through questionnaire surveys of 1200 and 1967 sample households in Xi'an and Bangalore, respectively. These samples were selected using a stratified random sampling procedure (Figures 1 and 2). The analysis included a series of statistical procedures that identified and removed outliers, tested whether the assumptions about homoscedasticity, collinearity and multilinearity were met, and calibrated regression models that assessed the effects of the independent variables.

Results

Unique Spatial Patterns

A concentric ring pattern of CO_2 emissions is discernible among household samples in Xi'an, waving downward from the inner city then upward towards the outer ring. In Bangalore, the high level emission households are distributed sporadically, interspersed with low emission households in multiple clusters all over the space.

Distinctive Family Characteristics

Families in Xi'an are smaller than their counterparts in Bangalore. About 60% of the households in Xi'an are three-member families. In Bangalore three member families only account for 15% of the samples. Instead, almost half of the samples in Bangalore are four-person families. In Xi'an four-person families only account for 10% of the samples. The largest family reported in the Xi'an sample has 8 persons, while the largest in Bangalore has 33 persons. About 2% of the household samples in Xi'an have 6 persons or more, but in Bangalore about 13% of the samples have 6 members or more.

Distinctive Housing

The majority of the households in Xi'an live in walk-up apartments (64%) or high-rise apartments (32.5%), while in Bangalore a large proportion of the households live in single storey houses (41%) and walk-up apartments (42%). A larger proportion of households live in newer apartments in Xi'an than in Bangalore, and the unit size of housing is smaller but less varied in Xi'an as compared with Bangalore.

Modernisation as a Key Driver Towards High CO_2 Emissions

In both cities the ownership and usage of motor vehicles show positive influence on CO_2 emissions, though the ownership and usage vary greatly. About 20% of the family heads commute by car or motorcycles in Xi'an but in Bangalore the proportion is above 60%. However, among the families that use motor vehicles, the average

HIGHLIGHTS

» Household CO_2 emissions show unique spatial distribution patterns.

» There are distinctive household structure, housing form, neighbourhood environment and commuting patterns.

» Modernisation is a key driver of household CO_2 emissions.

» A 1 km spatial unit can be used in planning low carbon cities.

level of petrol consumption in Xi'an (149 litres per month) is higher than that in Bangalore (45 litres per month); this is due to the popular use of motorcycles in Bangalore. In contrast, more than half (52%) of the family heads and their spouses in Xi'an walk or cycle to work, while in Bangalore only about 11–20% of the family heads and their spouses walk or cycle to work.

The use of electricity is measured by the number of household appliances in Xi'an but the use of electricity for cooking in Bangalore. This choice of measurement reflects the different characteristics of on-site energy use in the two cities. About 56% of the families in Xi'an use six or more electric appliances such as refrigerator, microwave, TV, etc. In Bangalore, about 54% of the families use electricity for cooking.

In terms of income, the proportion of samples in each of the highest three bands (US$ 1668 and more) are quite similar between Xi'an and Bangalore. But the poorer households form a larger proportion in Bangalore (25%) than that in Xi'an (7%). According to the accumulative percentage values, there are 5% more samples that earned a monthly income of US$ 833 and less in Bangalore than that in Xi'an.

The 1 km zone as a Planning Unit to Reduce CO_2 Emissions

A rich mix of economic activities within a neighbourhood space (about 1 km radius from home) is associated with low household CO_2 emissions. This is confirmed by both the aggregate household emissions model and the commuting-related emissions model in Xi'an. A related finding is that a rich mix of services and facilities, such as kindergartens, primary and secondary schools, supermarkets, banks and hospitals, in the immediate vicinity (within 500 m radius) of a household is associated with higher emissions from the household. These results are not contradictory as they represent different aspects of the built environment. The provision of more services and facilities within the immediate zone contributes to the formation of a prestigious residential environment, thus higher house values and wealthier families are more likely to be found in the area – apparently, wealthier families are associated with higher CO_2 emissions.

Households in Xi'an are more likely to be surrounded by a richer mix of services, facilities and jobs than their counterparts in Bangalore. In the immediate vicinities of households in Xi'an, more than 60% of the samples are surrounded by eight or more service and/or facility types. This same measurement is much smaller in Bangalore (less than 30%). Less than 4% of the sample households in Xi'an are surrounded by one or two service or facility types, while the same measurement reads 20% in Bangalore. Within the neighbourhood space, more than 50% of the sample households in Xi'an are surrounded by four or more job types, while in Bangalore the same measurement is about 12%. About 30% of the samples in Xi'an are surrounded by one or two job types, while in Bangalore the percentage is as high as 73%. This same pattern is true for the extended neighbourhood defined by a 5 km radius from home.

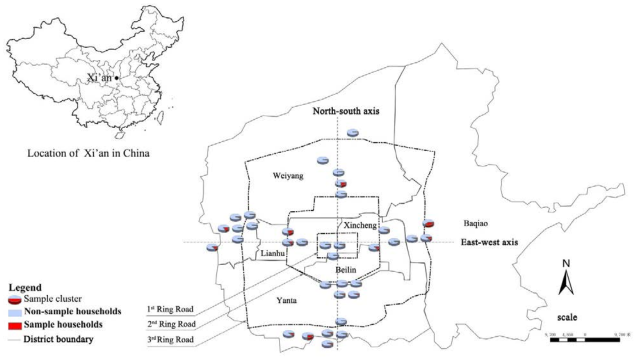

Figure 1. Sample households selected from housing blocks/groups including market housing, municipal housing and work-unit housing.

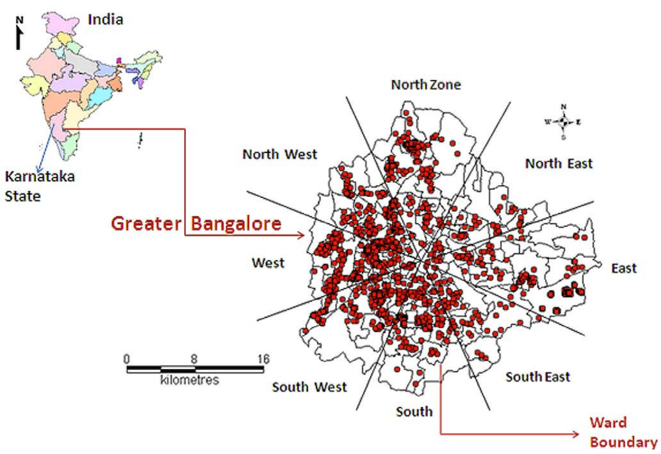

Figure 2. The spatial distribution of sample households in Bangalore.

Conclusion

This project pioneers the inquiry in comparative low carbon city research by examining the characteristics of urban households, their built environment, and the spatial distribution of CO_2 emissions in Bangalore and Xi'an. With the aid of statistical analysis, the research shows robust findings on determinants of urban household CO_2 emissions in both cities. The results not only confirm that modernisation is a common factor which drives the increase of CO_2 emissions, but also discover that the 1 km zone has emerged as an important planning unit in amending land-use schemes. Policy changes are required in order to promote low- or zero-carbon transport such as walking, cycling and public transportation. Functional separation of land-use zones needs to be reconsidered; incompatible land-uses need to be properly arranged but not at the expense of the formation of an improved land-use mix within the neighbourhood space.

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PROJECT INFORMATION

Title:	The Impact of Spatial Parameters on GHG Emissions: A Comparative Study between Cities in China and India
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