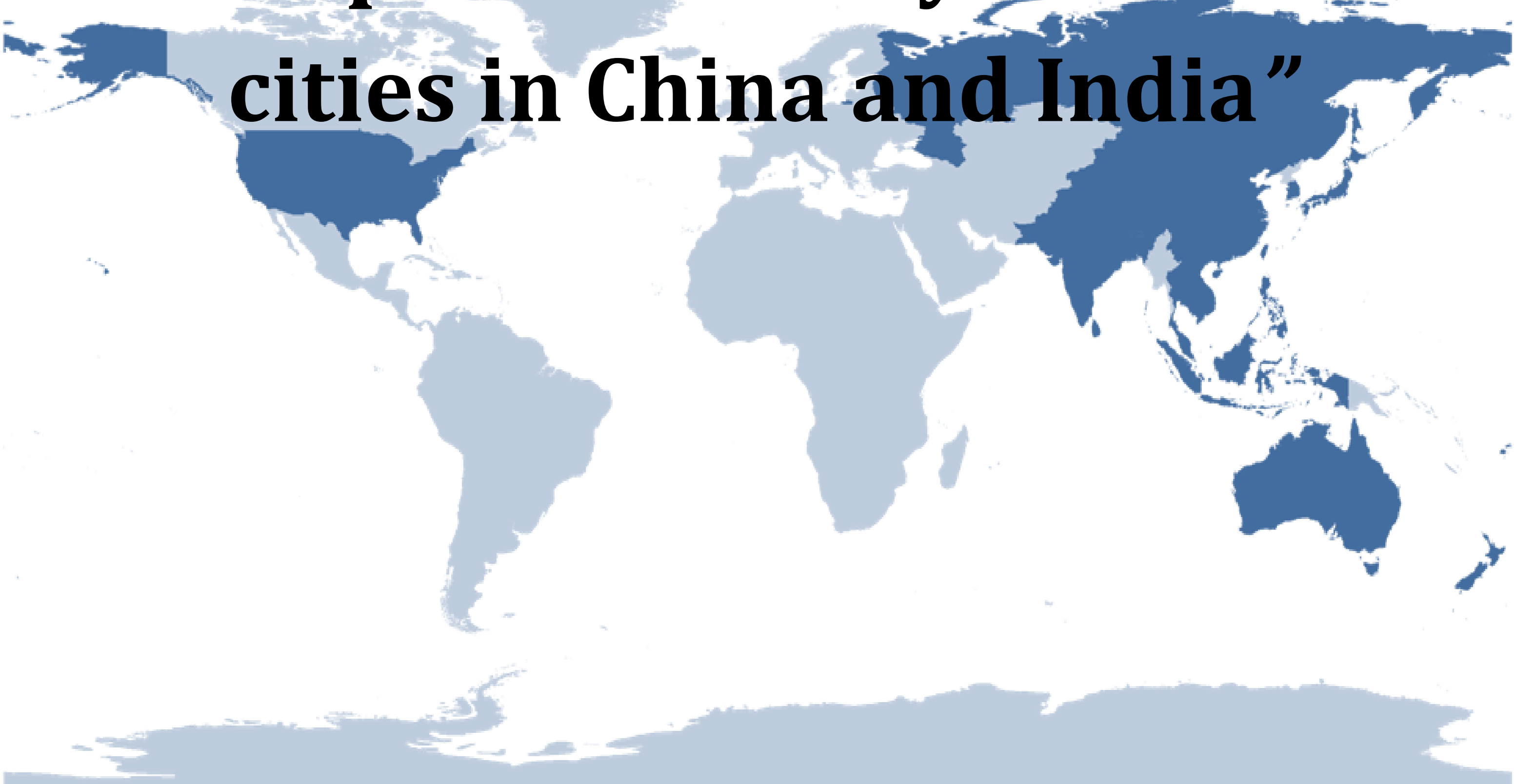
APN
Asia-Pacific Network for Global Change Research

FINAL REPORT for APN PROJECT

Project Reference Number: ARCP2011-07CMY-Han

"The impact of spatial parameters on GHG emission: a comparative study between cities in China and India"



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“The impact of spatial parameters on GHG emission: a comparative study between cities in China and India”

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Final Report submitted to APN

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OVERVIEW OF PROJECT WORK AND OUTCOMES

Minimum 2pages (maximum 4 pages)

Non-technical summary

< 200 words >

This project compares the characteristics of urban households, their urban built environment, and the spatial distribution of carbon emissions between Xi'an and Bangalore, and discovers the key determinants of carbon emissions associated with urban households. Data are collected through household survey in both cities. Descriptive statistics and multiple linear regression analysis are used to test the hypothesis that household carbon emission is a function of household attributes and the urban built environment. The findings show distinctive spatial distribution of carbon emissions. The level of emission forms a set of concentric rings in Xi'an with higher emission volumes found in the outer rings, while in Bangalore the distribution pattern is more sporadic. Households in Bangalore are larger and poorer but use more motor vehicles than their counterparts in Xi'an. Households in Xi'an live in an urban built environment with a richer mix of services, facilities and jobs. In both cities ownership of cars and electric appliances as well as income influence the level of household carbon emissions positively. In Xi'an the mix of job opportunities in a neighborhood has an inverse relationship with the household carbon emissions. In Bangalore the size of housing demonstrates a positive relationship with household carbon emissions.

Objectives

The main objectives of the project were:

1. To build a research team on comparative low carbon cities research;
2. To examine the characteristics of urban households, their urban built environment, and the spatial distribution of carbon emission between Xi'an and Bangalore;
3. To discover the key determinants of carbon emission associated with urban households in Xi'an and Bangalore;
4. To discuss the planning policies associated with carbon emission control.

Amount received and number of years supported

The Grant awarded to this project was: US$ 41,560 for Year 1; US$ 38,440 for Year 2.

Activity undertaken

1. Questionnaire survey in Xi'an and Bangalore (2010 – 2011) – stratified random sampling procedures were applied; 1200 valid questionnaires were returned in Xi'an; and 1967 valid questionnaires were returned in Bangalore;
2. Team coordination meeting in Xi'an (November 2011) – the project team shared their experiences in conducting the surveys, and discussed methods for questionnaire coding (using EpiData) and for hypothesis testing;
3. Policy workshops in Bangalore (April 2012) and Beijing (January 2013) – preliminary findings were disseminated to policy makers and researchers;
4. Data analysis and report drafting (2012-2013) – manuscripts were prepared for conference presentations and publication in peer reviewed journals.

Results

A team of researchers who study low carbon cities particularly in rapidly urbanization regions has formed and expanded. Three pieces of evidence testify the success in research team building. First, a large number of young scientists were trained during the project life span. Tables AIII-1 to AIII-4 in the appendix provide details of these young scientists including their involvement and contributions. Second, several key grants were secured to extend the essential inquiry set up in this project. Funding was awarded by the National Natural Science Foundation of China to research collaborators in both Xi'an and Beijing (Tables AII-2 and 3 in Appendix). Third, new researchers were drawn to the team from other universities to expand the geographic scope of the research comparison. In the Beijing policy workshop, researchers from Shanghai, Tianjin and Haerbin participated in the discussions (Table AI3-2 in Appendix).

New knowledge has been discovered through comparison of the characteristics of urban households, their urban built environment, and the spatial distribution of carbon emission between Xi'an and Bangalore.

- The spatial distribution pattern of carbon emission is unique. A concentric ring pattern is discernible in the case of Xi'an, moving downwards from the inner city then upwards towards the outer ring, while in Bangalore, the high level emission households are distributed sporadically.
- The mode of commuting is very different. Walking and cycling are popular modes of commuting in Xi'an but driving is the most common mode in Bangalore. However, the wide use of motorbikes means that the level of petrol consumption is lower on average for motor vehicle users in Bangalore than those in Xi'an.
- The type of housing is very different. Majority of the households in Xi'an live in walk-up apartments or high-rise apartments, while in Bangalore a large proportion of the households live in single storey houses and walk-up apartments. Housing stock in Xi'an seems newer than that in Bangalore.
- The neighborhood environment is very different. Households in Xi'an are more likely to be surrounded by a richer mix of services, facilities and economic activities than their counterparts in Bangalore.
- The family characteristics are distinctive. Families in Xi'an are smaller but richer than their counterparts in Bangalore.

Both common and distinctive determinants were identified in explaining household carbon emissions. The results of statistical models point to modernization as a key driver towards high emission. Motorization, use of electric appliances, and higher income, are all associated significantly with higher carbon emission. In Xi'an, a 1 km zone stands out as a possible planning unit to reduce carbon emission. A rich mix of economic activities within the 1 km radius from home is associated with low household carbon emission. In Bangalore, the size of housing which reflects the family structure shows positive relationship with household carbon emission.

Dissemination of the research findings in the two workshops in Bangalore and Beijing has generated interest in exploring the policy implications of this research. Ideas were debated about the connection between the findings and planning practices such as New Urbanism and Transit-Oriented Development. The planners from Beijing Municipal Government are considering the continuation of the enquiry on different scales.

Relevance to the APN Goals, Science Agenda and to Policy Processes

This project is strongly embedded in APN's science agenda, policy agenda and institutional agenda. The assessment of household carbon emission and the impact of urban built environment generate knowledge about the physical and human dimension of land-use and energy in cities which play a major role in change in the Earth's ecological system. The research is closely linked to policy- and decision-making processes and provides opportunities to address mainstream environmental concerns on low carbon development by relating those concerns to the structure and organization of cities. The findings will provide information that will underpin policy- and decision-making in the sample cities; it thus has a close relationship with APN's policy agenda. Further, the research will strengthen member governments' sense of ownership of the knowledge generated, and the database compiled via the involvement of national officials in the policy workshops, so contributing to the APN's institutional agenda.

Self evaluation

The project has been executed successfully with significant findings that not only contribute to the literature but also add to the planning tool box for low carbon urban development planning. The methodology is novel, the results are robust, and the findings have formed a solid base for future enquiry about urban sustainability associated with climate change.

Potential for further work

The research team is keen to continue the comparative efforts collectively and discover new knowledge and urban planning know-how. An immediate research area to focus on is the relationship between economic diversity and space utilization at land-use and building levels. The quantification of economic activities, land-use mix, and building space provides an opportunity to develop new research methods, especially in developing countries where data and information are lacking. The inquiry will also provide an opportunity to verify the findings in this completed project and validate the results using different cases and perspectives.

Publications (please write the complete citation)

1. Vishnu Bajpai, Gouri Kulkarni, Sun Sheng Han and Ramachandra T. V, 2012., Carbon Emissions due to Electricity Consumption in the Residential Sector., In Proceedings of LAKE 2012:National Conference on Conservation and Management of Wetland Ecosystems, 06th - 09th November 2012, School of Environmental Sciences, Mahatma Gandhi University, Kottayam, Kerala., URL: http://wgbis.ces.iisc.ernet.in/energy/lake2012/fullpaper/vishnu_b_fullpaper.pdf
2. Gouri Kulkarni,Vishnu Bajpai, Sun Sheng Han, Ramachandra T. V., 2012., Carbon Footprint of Municipal Solid Waste in Greater Bangalore., In Proceedings of LAKE 2012:National Conference on Conservation and Management of Wetland Ecosystems, 06th -09th November 2012, School of Environmental Sciences, Mahatma Gandhi University, Kottayam, Kerala., URL: http://wgbis.ces.iisc.ernet.in/energy/lake2012/fullpaper/gouri_fullpaper.pdf
3. Wang Yuanqing, Wang YaoWen, Guo Lu, Han S S (2011) Different influencing factors of housing price of developed zones in similar geographical location in China-A case study of Xi'an High-Tech zone and Feng Wei new district. IEEE International Conference on Super Networks and System Management. https://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=5921184&contentType=Conference+Publications&sortType%3Dasc_p_Sequence%26filter%3DAND%28p_IS_Number%3A5914416%29%26pageNumber%3D3%26rowsPerPage%3D50

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Acknowledgments

Acknowledgment to collaborating institutions, resource persons, etc., should be placed here

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TECHNICAL REPORT

Minimum 15-20 pages (excluding appendix)

Preface

Limit to 100 words

GHG emission control in large economies such as China and India is critical in dealing with the urban and environmental problems caused by climate change. Despite the rapid increase of research interests in GHG emission control, little efforts have been placed on urban households. 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 carbon emission in Bangalore and Xi'an. With the aid of statistical analysis the research shows robust findings on determinants of urban household carbon emission in the two case study cities.

Table of Contents

1.0 Introduction

This section should include background information, scientific significance, objectives, and other relevant information leading to the development and justification of the current project.

Cities are major geographical centers of population, economic activities, energy consumption and carbon emissions. Reports from the United Nations suggest that over half of today's world population lives in urbanized area (UNDESA, 2008); more than 80% of the total global GDP is generated by cities (UN HABITAT 2011a, p8); and cities are responsible for up to 70% of the global harmful greenhouse gases (UN-HABITAT 2011b). Information about energy consumption in individual countries shows that cities are main energy users. For example, in China cities consumed 81 percent of energy in the country in 2004, and 84 percent in 2006 (Dhakal, 2009).

At the Rio Earth Summit in 1992, urban development was recognized a major cause of global environmental change in 'Agenda 21' (Breheny, 1992; Roelofs, 1996; Langston and Ding, 1997; Williams, et al. 2000). Since then, considerable efforts has been focused on reducing carbon emission in cities as the core task in order to achieve the 'sustainability' goal and to combat global climate change (Low et al. 2005; Garnaut, 2008; Lynas, 2008).

Past studies on the urban dimension of the emissions reduction have either been framed in terms of aspatial resource and energy flows through cities (Wolman, 1965; Baccini and Brunner, 1991; Costa, Marchettini and Facchini, 2004), or in broad scale but unconfirmed claims about urban density (Newman and Kenworthy, 1999), or in terms of urban form at a finer grain of analysis, for instance focusing on 'urban villages' and transit-oriented development (Newton, 1997; Cervero, 1998). The last two research domains embrace the spatial dimension but the findings on the impact of large scale differences in urban form remain inconclusive. In the USA, Ewing and Rong (2008) made a connection between residential energy use and urban form, focusing on the transmission losses of energy, energy requirements for different housing stocks, and the space heating and cooling requirements associated with the urban heat island effect. Some Australian research has addressed the large scale spatial dimension using area-based (i.e., CD, SSD, LGA) census data. Moriarty (2002), for instance, examined energy and water consumption in Australia's five largest cities and compared consumption levels of inner metropolitan versus outer suburbs. He found that 'only a part of the emissions that each household produces directly (that is excluding intermediate production) will vary with settlement density or location' (ibid. p. 241). However, surface travel will vary (ibid.). Troy et al. (2003) investigated localities in Adelaide with varying density characteristics and distances from the central area. They found that while housing density (with its associated housing types) was not a strong determinant of energy consumption overall, 'those living in the outer suburbs use more transport energy than those living closer in. This difference is more likely a function of the structure of the city and therefore the disposition of activities than the form of housing.' (ibid. p. 29). Thus the amount of travel undertaken by households appears to be associated with differences in urban form.

In fast urbanizing countries such as China and India, urban forms evolve rapidly as they develop rings of new suburbs and networks of new transport infrastructure. Travel behavior and transport opportunities in Chinese and Indian cities are changing fast. Han and his colleagues investigated the travel behavior of urban residents and household carbon emission in Beijing and Wuhan (Qin and Han 2013; Huang et al 2013). It was found that land-use mix and the polycentricity of cities are closely related to the emission volumes. These new efforts partially confirm the claims by Zhou and Szyliowicz (2005), that 'the settlement structure and the developed infrastructure have a huge effect on the transportation needs. By developing an urban structure where all kinds of services for the inhabitants are provided, less transportation is needed'. But more evidences of the impact of spatial parameters on household energy use need to be discovered.

The question of urban form in relation to travel and transport energy (and therefore carbon emissions), and particularly the relative impact of large scale and fine grain structural features, deserves further empirical research in different spatial and methodological contexts. Given the scale of the greenhouse abatement task, no means of reducing greenhouse emissions should be overlooked, whether it comes from reduction in energy consumed – for instance by reducing travel – or from the production of carbon neutral ('green') energy. In rapidly growing cities the question of urban form remains extremely important.

This project aims to examine the impact of urban spatial parameters on greenhouse gas (GHG) emission in cities in two rapidly growing economies but with distinctive cultural contexts – China and India. There are many measurements for urban spatial parameters such as the level of land-use mix, population density, and transport network design in cities. In this paper, the mix of economic activities in different geographical zones surrounding the households is considered. For GHG emission, the research focuses on household generation of carbon dioxide due to energy consumption at home (i.e., use of electricity and gas) and non-home locations (i.e. use of fossil fuel for travel to work and/or to conduct other non home-based activities).

Realignment in the arrangement of urban spatial parameters could reduce GHG emission because urban form influences the volume of GHG generated by households. This influence is felt in part through the design and density of residential buildings, which foster different energy consumption behavior. Another part relates to the way that compact urban forms are associated with lower transport energy use (Moriarty 2002; Troy et al 2003). The reduction could even be considerable as the transportation sector alone contributes to a quarter of GHG emission in some cities (Stead 1999). Despite the general recognition that land use change can influence the use of certain transportation modes (Ewing and Cervero 2001), and that the reduction of travel and the modal split are relevant to GHG emission control (DOI 2001), two major questions remain to be answered:

1) How do urban spatial parameters affect household GHG emission?
2) What urban planning policies can be introduced to change these parameters?

This project explores these two umbrella questions in two distinctive urban settings – Bangalore, India and Xi'an, China. These two cities are both experiencing rapid urbanization and economic growth, but with distinctive cultural and institutional contexts. Given the future perspective of industrial and urban development in China and India, the focus of this project is not only on knowledge discovery but also on research capacity building and dissemination of the research outcomes. As such, the following four objectives are targeted[1]:

1 To build a research team on comparative low carbon cities research;
2 To examine the characteristics of urban households, their urban built environment, and the spatial distribution of carbon emission between Xi'an and Bangalore;
3 To discover the key determinants of carbon emission associated with urban households in Xi'an and Bangalore;
4 To discuss the planning policies associated with carbon emission control.

2.0 Methodology

Explain how you carried out the project, which should follow logically from the aims. Depending on the kind of data, this section may contain subsections on experimental details, materials used, data

[1] The technical report elaborates on the methods and results associated with objectives 2 and 3 only. For objectives 1 and 4, the results are briefed in the 'Overview of project work and outcomes'.

collection/sources, analytical or statistical techniques employed, study field areas, etc. Provide sufficient detail for a technical/scientific audience to appreciate what you did. Include flowcharts, maps or tables if they aid clarity or brevity.

2.1 Hypothesis

This project uses the household as basic research unit, and associates household GHG emission with spatial planning parameters. The central hypothesis organizing the research is that household GHG emission is a function of household attributes and urban spatial parameters, expressed in the formula below

Household GHG Emission = f (household attributes, spatial parameters) (1)

Household GHG emission is the sum of emission at the house site and off-site. These are derived by converting power and gas consumptions (i.e. Power c and Gas c) at household location and off-site consumption (i.e. travel to work and other places, activities in non-work related sites)

Household GHG Emission = f (in-house consumption, off-site consumption) (2)

In-house consumption = f (Power c, Gas c) (3)

Off-site consumption = f (travel by public transit and private car, off-site household activities) (4)

On the other side of equation (1), household attribute and the spatial parameters are defined as

Household attribute = f (household size, income, member attributes) (5)

Spatial parameters = f (house characteristics, precinct characteristics, neighborhood characteristics) (6)

House characteristics are measured by house type, age, structural features, and orientation towards the Sun. Precinct and neighborhood characteristics are measured by the mix of services, facilities and economic activities.

2.2 Questionnaire design

A household questionnaire survey was used to collect data. Four groups of information were sought. The first group focuses on the urban built environment. Major data items include the type, size, year of construction of the house and/or apartment units; the range of services and facilities accessible within a 500 m radius; and availability of job types within a radius of 1 km.

The second group focuses on energy consumption associated with commuting. Major data items include distance from home to employment; mode of commuting including walking, cycling, public transport, company shuttle, car/motorbike, and taxi; and the time required using the given mode. Petrol consumption was also asked if the members of household drove. Three members of the household were required to provide the details specified above.

The third group focuses on the use of electricity and gas at home. Major data items include appliances in use; electricity consumption in different seasons; and gas consumption per month. Attitude questions about residents towards the environment were also included.

The fourth group focuses on household information. Major data items include household composition; age, education attainment, and job type of household head; and household income.

In Bangalore, an additional section was added to gather information about solid waste generation and disposal. Data items include type and quantity of waste generated; method and frequency of waste collection; and residents' perception about the problems associated with household wastes.

2.3 Case study cities and sampling

2.3.1 Xi'an, China

Xi'an locates in China's west region, with about 7.8 million residents. More than half of the population (i.e., 4.731 million) lives in an area encircled by the third ring road, occupying about 348 km^2 of land. The central area is marked by the ancient city wall which was built in the Ming Dynasty (AD1368-1644). Xi'an has been served as the main political, economic and cultural centre of the western region.

Urban expansion in Xi'an has progressed at a rapid pace since the year 2000. New clusters of services, employment, and residential buildings were added to the areas in between the 2nd Ring Road and the 3rd Ring Road. This has increased the urban residents by 2.587 million within the 3rd Ring Road. With rapid economic development and urban expansion, there have been remarkable changes in residents' travel behaviour, the level of traffic congestions and transport related environmental pollution.

A spatial stratified random sampling procedure was applied for sample selection. Spatial focus was given to key locations such as the main roads in north-south directions and east-west directions, and their intersections with the ring roads. In selecting the residential projects for survey, considerations were given to the types of housing so each location was selected to include housing administered by the municipal government, work-unit housing, and market housing. In one of the locations housing owned by farmers was included. Table 1 shows the details of project names, addresses and size of samples. Figure 1 shows the location of the main residential areas where questionnaire surveys were conducted. A total of 1228 questionnaire were collected. 1200 valid questionnaires were entered into the dataset. The success rate was 97.7%.

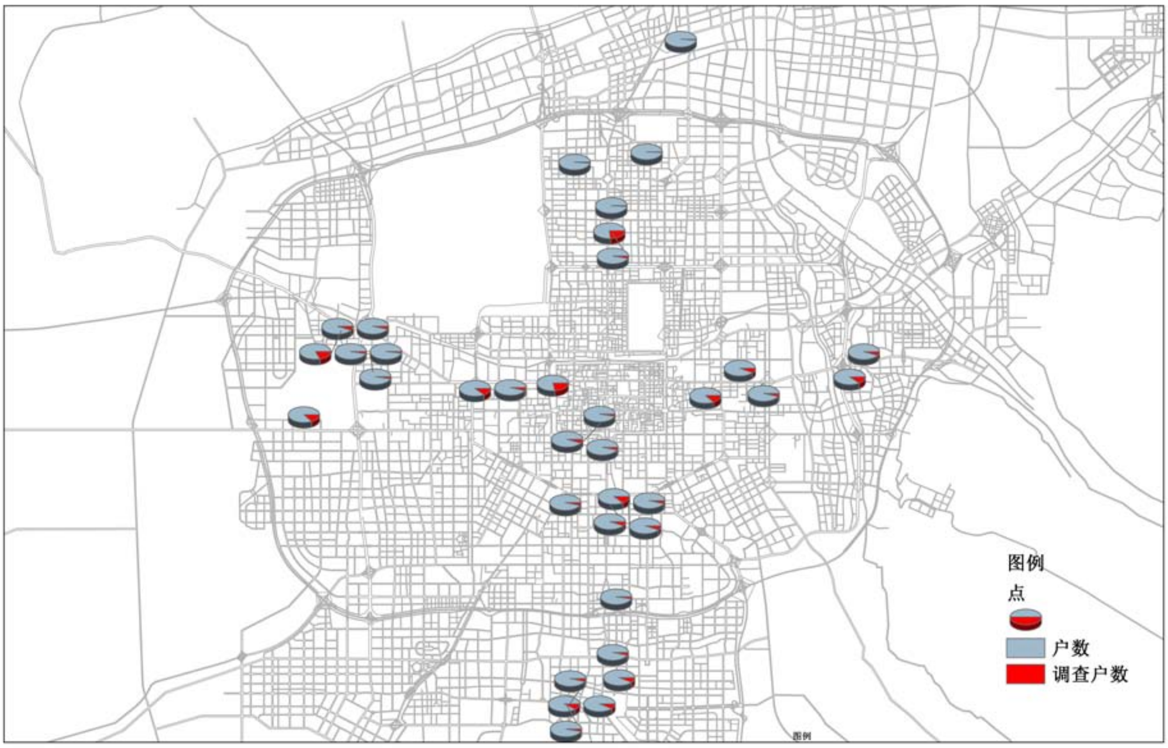
Table 1 Sample distribution in Xi'an

	小区名称 Project name	具体位置 address	小区住户总数 Total residents	小区性质 Type of housing	预计调查户数 Planned sample size	实际调查户数 Actual sample size	各点调查汇总 Sum of sample
城区内							
城区内 Inside the city wall	德福巷东区	西大街与南大街西南角粉巷与大车家巷	650	市管房 City housing		40	100
	钟楼小区	西大街与南大街西南角竹笆市	1200	市管房		40	
	教育局家属区	西北三路与青年路，习武园路东	480	单位房 Work-unit housing		20	
西向							

西二环 2nd Ring Road West	西开鑫园小区	西二环-大庆路附近	100	单位房	40	28	105
	百花明珠	桃源西路-丰登北路附近	400	商品房 Market housing	30	57	
	西材新园	丰登北路-桃园西路	400	单位房	30	20	
西三环 3rd Ring Road West	武警学院家属楼	阿房二路西口	500	单位房	40	12	123
	陕棉家属院	阿房二路西口	1000	单位房	30	32	
	园丁苑	武警路	200	商品房		45	
	富居花园	牛曹堡	150	商品房		7	
	秦龙泉小区	阿房四路-西三环十字	800	商品房	30	27	
西三环外围 3rd Ring Road West, outer	新店小区	西兰公路南侧（新店村）	500	农民房，有的租出去 Farm house for rental	50	33	99
	西围新嘉园&和平村	西部大道（绕城高速西边）	400	商品房	50	66	
北向							
二环 2nd Ring Road	长庆石油	凤城四路与未央路	2036	单位房		25	102
	银河华庭	凤城三路与未央路交叉口右侧	456	商品房		17	
	西北石油管道	凤城三路与未央路交叉口右侧	198	单位房		60	
三环 3rd Ring Road	红旗厂家属区	渭清路	10000	单位房		103	113
	白桦林居	凤城九路与明光路的东南角	570	商品房		10	
北三环外围 3rd Ring Road North, outer	未央湖小区	东风路与阳光路	200	商品房		3	3
东向							
二环内 Inner 2nd Ring Road	居安物业	长乐东坊	100	商品房		0	31
	出租车公司家属院	长乐东坊	250	单位房		0	
	兴庆路建行家属院 93 号	兴庆路	200	单位房		31	
二环以外 Outer 2nd Ring Road	黄河机械厂 万寿中路十四街坊	万寿中路	1000	单位房		48	94
	昆仑厂（九街坊）	万寿中路	570	单位房		46	
三环 3rd Ring Road	浐河化工厂	半坡博物馆对面	350	单位房		46	46
三环外 3rd Ring Road, Outer	西北电建器材厂	纺建路-新医路		商品房		97	127
	西北电建四公司			商品房		0	
	纺织厂			单位房		30	
南向							
二环	育才住宅小区		308	单位房		20	82

2nd Ring Road	雅荷翠华小区		300	商品房		20	
	崇业路长大社区			单位房		13	
	长安大学家属区			单位房		9	
	Ø 西安文理学院翠华路住宅区		420	单位房		20	
三环 3rd Ring Road	吉泰小区		500	商品房		42	103
	西安市结核医院家属区			单位房		10	
	Ø 206 所家属区		1100	单位房		51	
三环外 3rd Ring Road, Outer	兴龙花园		139	商品房		15	100
	玉秦苑			商品房		15	
	Ø 长安信合小区		340	单位房		30	
	Ø 长乐小区		855	商品房		40	
Total							1228

Figure 1 Location of residential projects for questionnaire survey in Xi'an, 2010

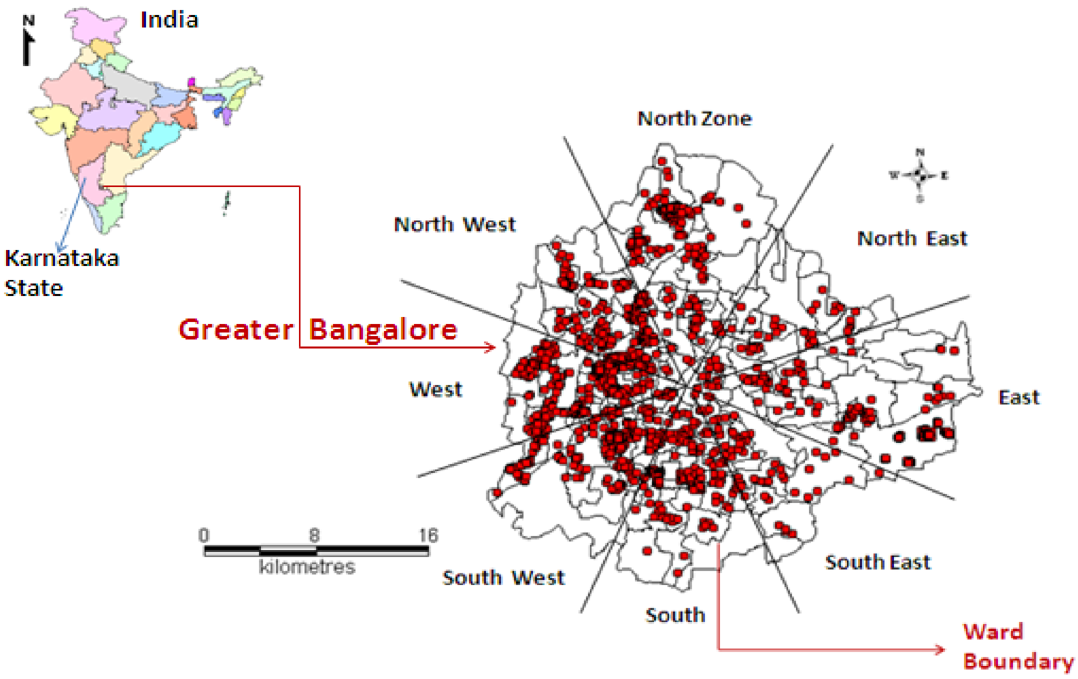


2.3.2 Bangalore, India

Greater Bangalore lies between 12°39'00'' to 13°13'00'' N and 77°22'00'' to 77°52'00'' E with an area of 741 sq. km. (Figure 1). It is the centre of administration, culture, commercial activities, industrial production, and knowledge generation of the state of Karnataka, India. Rapid urbanization led to expansion of its administrative boundary in 2006 when the existing area of Bangalore city spatial limits merged with 8 neighbouring Urban Local Bodies (ULBs) and 111 Villages of Bangalore Urban District. Bangalore has grown spatially more than ten times since 1949 (~69 square kilometers to 741 square kilometers) and is the fifth largest metropolis in India currently with a population of about 8.5 million (Ramachandra and Kumar 2008). Bangalore city population has increased enormously from 65,37,124 (in 2001) to 95,88,910 (in 2011), accounting for 46.68 % growth in a decade. Population density has increased from 10,732 (in 2001) to 13392 (in 2011) persons per sq. km (Ramachandra et al., 2012). The per capita GDP of Bangalore is about $2066, which is considerably low with limited expansion to balance both environmental and economic needs.

There are 198 administrative wards in Bangalore. Wards were prioritized for sampling based on type, economic activities and social aspects. The survey was carried out during 2011-12 in selected sample households chosen on the basis of a stratified (economic status) random selection procedure. The validation of sampled data was done during 2012-13. The survey covered 1967 households representing heterogeneous population belonging to different income, education, and social aspects. The spatial distribution of sampled household is depicted in Figure 2.

Figure 2 Sample location in Greater Bangalore



2.4 Variables

A list of variables is reported in Table 2.

Table 2 The dependent and independent variables

	Variable name	Definition
Dependent variable	Etotal	Household total CO2 emission; sum of Ecommuting, Eelectricity and Egas; in kg per annum.
	Ecommuting	Household CO2 emission generated by commuting to work including petrol consumption for those who drive to work, CO2 emission generated by using public transport and/or taxi, in kg per annum.
	Eelectricity	Household CO2 emission generated by electricity consumption in house; in kg per annum.
	Egas	Household CO2 emission generated by gas consumption in house; in kg per annum.

Independent variable	Hsize	Unit size of house measured by sq m
	Hage	Age of house measure d by year of construction
	Htype1	Type of house measured by the number of storeys
	Htype2	Type of house measure by source of supply
	Hdirection	Orientation of house measured by the directions that the main rooms face
	Precinct500	Land use diversity measured by number of activity/service types within 500 m radius from house
	N1km	Land use diversity measured by number of job establishment types within 1 km radius from house
	Zone1to5km	Land use diversity measured by number of job establishment types within the 1 – 5 km belt from house
	Income	Household income measured by total annual income
	Househdsize	Number of members in household
	Carowner	Carownership measured by dummy variable
	ElectApp	Use of electrical appliances measured by the number of appliances in use
	EviAttitude	Attitude towards environment measured by dummy variable

2.4.1 Deriving CO2 emission generated by commuting

The calculation of CO2 emission is based on data items obtained from the questionnaire surveys directly whenever possible. CO2 emission generated by commuting trips includes those generated by car/motorbikes, public transport/company shuttles, and taxis. For emission generated by car and/or motorbikes, the consumption of petrol is used together with an emission factor. Petrol consumption is reported by household members 1 and 2 if they drive, while the emission factor is taken from the website of the National Forestry Bureau of China. For family members who use public transport or company shuttles, the commuting distance is used to compute the emission with a public transport emission factor. In data sorting, thus, the family members who use public transport are first identified. Then the commuting distance is extracted from the dataset. The public transport emission factor is taken from the Carbon Emission Website Beijing. For people who use taxi, the commuting distance is multiplied by an emission factor. There is almost no family member who uses taxi as the mode for daily home-job commuting in Xi'an, but in Bangalore there are 21 individuals from the member 1 category, 22 individuals from the member 2 category and 60 individuals from the member 3 category recorded as daily taxi users. The emission factor is taken from the National Forestry Bureau website using the small car types.

The annual emission was calculated as the total emission generated by car/motorbikes, public transport/company shuttle, and taxi by all the three members of the family surveyed, for 5 days a week and for 52 weeks a year.

2.4.2 Deriving domestic energy consumption and CO2 emission

Emission due to electricity use in the domestic sector is quantified using equation 7 considering quantity of electricity consumption and emission factor. The emission factors and net calorific values (NCV) for different sectors are listed in Table 3.

$$C = \beta E \quad (7)$$

Where, C is carbon dioxide emission; β is emission factor (Table 3) and E is consumption of electricity.

Table 3 Emission factors and net calorific values (NCV)

Source		Emission Factor	Net calorific value (NCV)	References
LPG	Bangalore	63t/Tj	47.3 Tj/Gg	Ramachandra and Shwetmala, 2012
Gas	Xi'an	2.17 kg/m^3		NFB[1]
Electricity	Bangalore	0.81t/MWh		CEA, 2011
	Xi'an	0.96 kg/kwh		NFB

[1] NFB stands for National Forestry Bureau of China.

Emissions due to LPG consumption: LPG is the principal fuel used for cooking in Bangalore. Emission due to LPG consumption is computed using equation 8.

$$E = Fuel * NCV * EF_{GHG} \qquad (8)$$

Where E is the emission; Fuel is the quantity consumed; NCV is net calorific value; EF_{GHG} is the emission factor of LPG (given in Table 3).

2.5 Model calibration

2.5.1 Data preparation

Case selection: In both Xi'an and Bangalore, cases are selected based on the variable Hdirection. All four categories of the directions, i.e. facing east, west, north and south are included in analysis.

Recoding dummy variables: All qualitative variables are recoded into dummy variables. These include Htype1, Htype2 and Hdirection. For any given categorical variable with j categories, only j-1 new dummy variables are entered in the regression estimation, as the last category is used as the base group for comparative analysis.

2.5.2 Multivariate regression diagnostics

Outliers and normality of residual: outliers are identified and removed with the assistance of data transformation and the normality of residual test. The procedures include 1) reporting the leverage values, standardized residuals, and the Cook's D; 2) generating the scatterplot of the leverage and the standardized residual for both pre- and post-data-transformation; 3) analyzing the distribution of residuals both pre- and post-transformation; 4) removing outliers from the post-transformation dataset; and 5) testing the normality of residuals after removing the outliers from the post-transformation dataset.

Homoscedasticity: A scatterplot of the studentized residual against the fitted value is used to examine whether the assumption of homoscedasticity is met.

Collinearity and multilinearity: The variance inflation factor (VIF) is used as a rule of thumb. A variable with a VIF value greater than 10 may need careful examination.

Independence of errors: The Durbin-Watson test is used to assess whether the errors associated with one observation are correlated with the errors of any other observations.

Model specification: Two new variables are used to test whether the model has included all the relevant variables and excluded irrelevant variables. One is the predicted value and the other is the square of the predicted value. The significance of these two variables is compared.

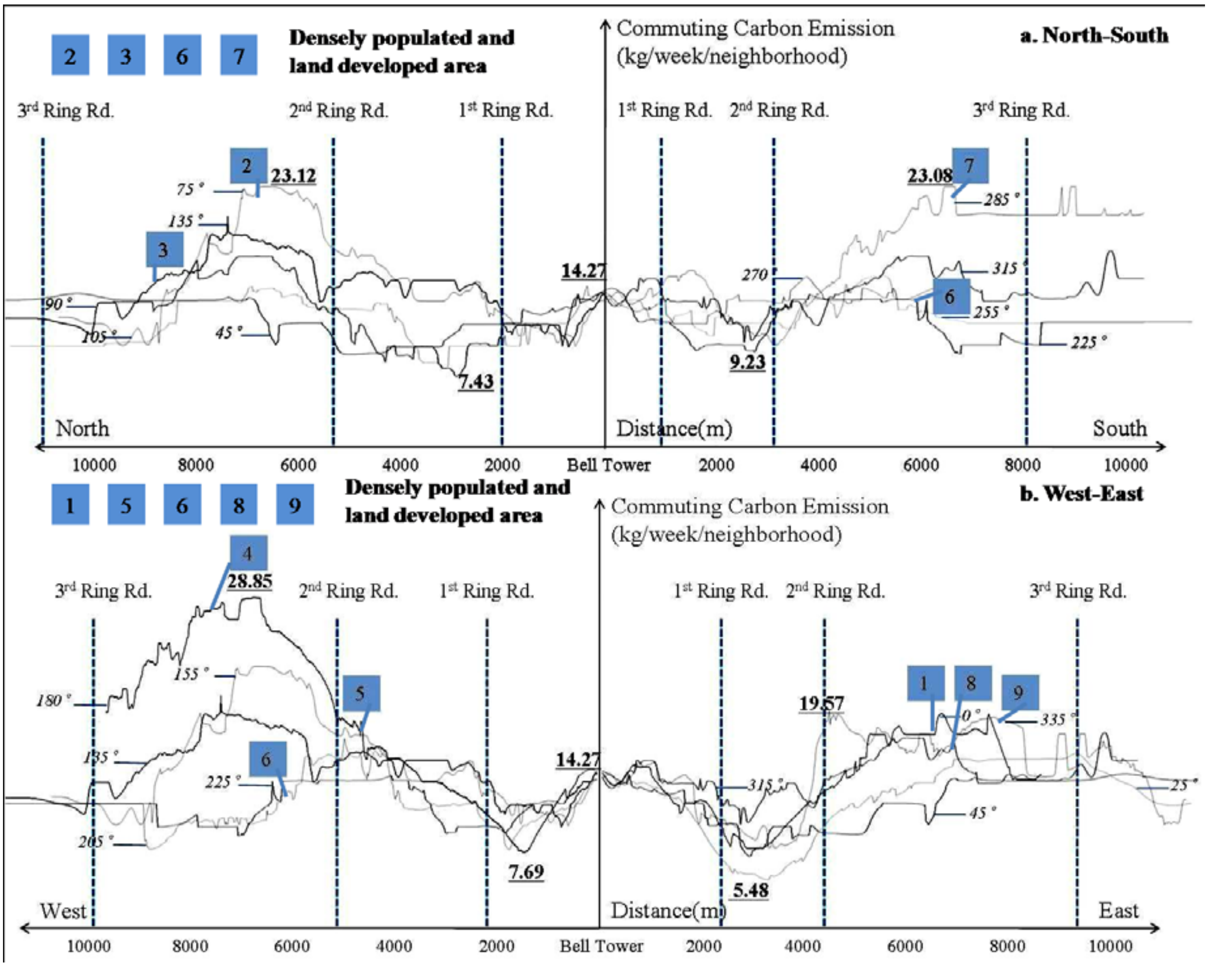
3.0 Results & Discussion

Explain your actual findings, including figures, illustrations and tables. Make comments on the results as they are presented, but save broader generalizations and conclusions for later. Discuss the importance of your findings, in light of the overall study aims. Synthesize what has (and has not) been learned about the problem and identify existing gaps. Recommend areas for further work.

3.1 Spatial pattern

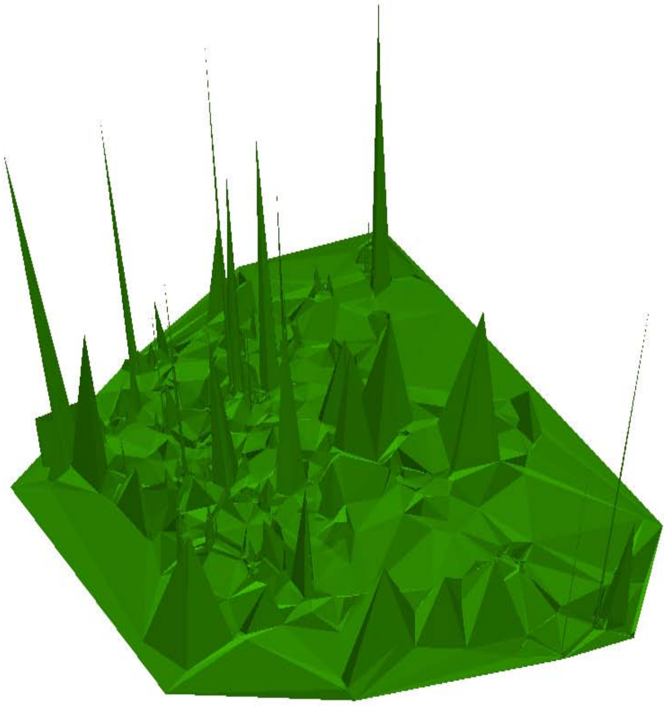
The values of carbon emission varied among the residential areas examined. By aggregating data according to the ring roads, it was found that households lived in the outer ring area had the highest carbon emission values. Households in the inner and middle belts of the city had high and low emission values. But on average the inner and middle city households emitted much less than those in the outer suburb. This shows a similar pattern with that demonstrated in some western cities (e.g. Melbourne in Australia).

Figure 3 Spatial distribution of CO_2 emission in Xi'an, cross section diagrams along the east-west and north-south directions



CO2 emission generated by commuting in Bangalore does not show similar regularities in spatial distribution as that shown by data in Xi'an. There are numerous clusters that exhibit extremely high emission volumes over the Greater Bangalore region. The fluctuations in emission volume seems more drastic, though a number of locations in the eastern (right hand side) half of the diagram show similar extreme values (Figure 4).

Figure 4 A TIN model representing CO_2 emission in Greater Bangalore



3.2 Mode of travel to work/school

The proportion of family members commuting to work by zero carbon modes (i.e. walking or cycling) is significantly higher in Xi'an across all the three members surveyed. In contrast, the proportion of member 1 commuting to work by car or motorbikes is significantly higher in Bangalore. This is true also to member 3. As to the use of bus or company shuttle, the proportion in Xi'an is slightly (by 3%) higher for member 1, 10% higher for member 2, but 9% lower for member 3 than that in Bangalore.

Table 4 Mode of travel to work by family members (%)

	Xi'an	Bangalore
Member 1		
Walking and cycling	51.9	11.9
Bus or company shuttle	28.2	25.6
Car or motorcycle	19.9	61.1
Missing data		1.4
Total	100	100
Member 2		
Walking and cycling	51.7	20.5
Bus or company shuttle	32.2	21.2
Car or motorcycle	16.1	15.1
Missing data		43.2
Total	100	100
Member 3		
Walking and cycling	45.9	25.9
Bus or company shuttle	44.3	53.4

Car or motorcycle	9.8	18.4
Missing data		2.3
Total	100	100

As to the shopping trips, More than 50% of the household in Xi'an use public transport for shopping trips. This is more than double of the proportion observed among Bangalore households that also use public transport. In contrast, more than 50% of the Bangalore households use car or motorbikes for their shopping trips, while in Xi'an only 31% of the families drove for shopping trips. About 20% of the households walked or cycled for their shopping trips in both cases.

Table 5 Mode of travel for shopping trips

	Xi'an	Bangalore
Walking and cycling	18.4	21.3
Bus or company shuttle	50.4	22.2
Car or motorcycle	31.2	50.9
Missing data		5.6
Total	100	100

Corresponding to the large proportion of the sample households that drove to work, 1101 households reported the use of petrol for commuting in Bangalore. This accounts for 56% of the total sample. In contrast, only 133 out of the 1200 samples in Xi'an consumed petrol. However, among the households that consume petrol for commuting, Xi'an shows an average level of consumption (149 liter per month) much higher than that in Bangalore (45 liter per month). Indeed, in Bangalore, there are more than 200 sample households that consume less than 10 liter of petrol per month!

Table 6 Petrol consumption in Xi'an and Bangalore

	Xi'an		Bangalore	
	Those who drive to work	All samples	Those who drive to work	All samples
Min	7	0	1	0
Max	1500	1500	2600	2600
Average	149	23	45	25
Median	100	0	25	5
No. of samples > 10 liter	132		894	
No. of samples with petrol consumption	133		1101	
Total sample	1200		1967	

3.3 The urban built environment

Table 7 shows that sample households live in very different housing between Xi'an and Bangalore. More than 96% of the sample households in Xi'an live in walk-up or high-rise residential buildings. In Bangalore, majority of the sample households live in single storey houses (41%) or walk-up residential blocks (42%). The proportion of sample households living in detached houses is significantly larger than that recorded in Xi'an (15% vs 0.3%).

Table 7 Proportion of sample households in different housing types

	Xi'an	Bangalore
Single storey	3.2	41
Walk-up (2-6 storey)	64	42
High-rise (> 6 storey)	32.5	2
Detached	0.3	15

Both Xi'an and Bangalore show the same trend that larger proportion of sample households live in newer houses (Table 8). There is 12% more sample households in Xi'an living in houses built post-1990 than that in Bangalore.

Table 8 Percentage of sample households living in housing built in different time

	Xi'an	Bangalore
Housing built before 1980	7	10
Housing built in the 1980s	11	20
Housing built in the 1990s	33	30
Housing built in the 2000s	49	40

In terms of orientation of houses, majority (73.3%) of the sample households in Xi'an have their major rooms facing the south. There are 9.5% of the households facing the north, 7.4% facing the east, and 6.8% facing the west. The rest of the houses (about 3% in total) face other directions. A large proportion (45%) of the sample households surveyed in Bangalore has their major rooms facing the east. A quarter of the sample households have their major rooms facing the north. 17% of the households face west, and 13% face the south.

The size of houses varies from 10 sq m to 420 sq m, with an average at 91 sq m in Xi'an (Table 9). In Bangalore, the range is from 3.34 sq m to 1486.4 sq m, with an average size at 135.45 sq m.

Table 9 Size of housing

	Xi'an (sq m)	Bangalore (sq ft)
Min	10	36 (3.34 sq m)
Max	420	16000 (1486.4 sq m)
Average	91	1458 (135.45 sq m)

As to the ownership structure, there are 34.2% of the sample households in Xi'an live in market housing; 43.7% live in work-unit housing, 6.6% live in affordable public housing, 2.5% live in government-subsidized rental housing 2.5%, 3.3% live in self-built housing, 0.6% old city housing; and 9.1% live in other types (such as rented housing from market). In Bangalore, 21% of the sample households live in houses provided by or bought from BDA (Bangalore Development Authority); 25% live in public housing; 9% in market housing; 2% live in market housing but with subsidies; and a large proportion (43%) live in other housing forms such as self-built housing.

At precinct level, 25% of the sample households in Xi'an have access to 10 different types of services and facilities in Xi'an, while the same measurement in Bangalore reads 9% only (Table 10). On the other end of the scale, 12% of the sample households have access to only 1 type of service or facility, but in Xi'an the percentage is 1.8%. The accumulated percentages indicate that a relatively smaller proportion of the sample households in Xi'an have poor access to services and facilities. For example, the proportion of households that have 5 or less service/facility types within their 500 meter radius is 21%; but in Bangalore the same measurement is 48%. Clearly, in the immediate built environment of the sample households, samples in Xi'an have better access to services and facilities than their counterparts in Bangalore.

Table 10 Proportion of sample households with different level of access[1] to services and facilities

No. of services/facilities types	Xi'an	Bangalore
1	1.8	12
2	2.1 (3.9)	8 (20)
3	4.8 (8.7)	7 (27)
4	5.1 (13.8)	9 (36)
5	7.4 (21.2)	12 (48)
6	8.6 (29.8)	9 (57)
7	10.1 (39.9)	14 (71)
8	16.2 (56.1)	11 (82)
9	17.4 (73.5)	9 (91)
10	25 (98.5)	9 (100)
Total	98.5%[2]	100

Numbers in brackets are accumulated percentages.

[1]The level of access is measured by availability of services and facilities within 500 meters radius from residence.

[2]About 1.5% of the sample households indicate that there is no services or facilities within 500 meters from their residence.

At neighborhood level, there is a large proportion of sample households in Bangalore not surrounded by a mix of job opportunities. 44% of the sample households note that only one type of economic activity is operating within 1 km radius from their residence. Another 29% claim that there are 2 types of economic activities within the 1 km zone. Only 0.5% of the sample households are surrounded by 7 economic activities or more, but together with the sample households that are surrounded by 6 economic activity types the percentage is still smaller than 2%. In contrast, almost 20% of the sample households in Xi'an are surrounded by a rich mix of economic activities (6 and more). The cumulative percentage of sample households that are surrounded by 2 activity types and less is 29%, presenting another sharp contrast with the Bangalore situation (73%) (Table 11).

Table 11 Proportion of sample households with different level of access[1] to jobs

No. of services/facilities types	Xi'an	Bangalore
1	12.4	44.0
2	16.7 (29.1)	29.3 (73.3)
3	18.4 (47.5)	14.2 (87.5)
4	17.3 (64.8)	7.7 (95.2)
5	14 (78.8)	2.9 (98.1)
6	13.8 (92.6)	1.4 (99.5)
7	5.1 (97.7)	0.5 (100)
Total	97.7[2]	100

Numbers in brackets are accumulated percentages.

[1]The level of access is measured by availability of job establishments within 1 km radius from residence.

[2]About 2.3% of the sample households indicate that there is no job establishment within 1 km from their residence.

On a larger scale, the mix of economic activities within the 1-5km belt from residence seems richer in Xi'an than that in Bangalore. More than three quarter of the samples in Bangalore claim that there are only 3 or less economic activity types inside the belt between 1-5 km radius from their residence (Table 12). The same measurement in Xi'an includes barely a quarter of the samples. On the other hand, about 40% of the sample households in Xi'an note that there are 6 or more economic activity types in the 1-5km belt. But in Bangalore only 7% of the sample households surrounded by 6 or more economic activity types.

Table 12 Proportion of sample households with different level of access[1] to jobs 1-5 km belt

No. of services/facilities types	Xi'an	Bangalore
1	6.8	34
2	7.4 (14.2)	21 (55)
3	10.2 (24.4)	21 (76)
4	16.7 (41.1)	10 (86)
5	16.1 (57.2)	7 (93)
6	22.6 (79.8)	4 (97)
7	17.3 (97.1)	3 (100)
Total	97.1[2]	100

Numbers in brackets are accumulated percentages.
[1]The level of access is measured by availability of job establishments inside the 1-5 km belt from residence.
[2]About 2.9% of the sample households indicate that there is no job establishment within the 1-5 km belt from their residence.

3.4 The households

3.4.1 Household size

About 48% of the sample households in Bangalore are 4-person households (Table 13). 20% are 5-person households, and 15% are 3-person households. The 6 and 7-person households account for 7% and 3% respectively. There is one extremely large household with 33 persons living under one roof.

Table 13 Household size, Bangalore

No. of people in household	No. of samples	% of total	No. of people in household	No. of samples	% of total
1	0	0.00	11	3	0.16
2	20	1.08	12	5	0.27
3	286	15.38	13	3	0.16
4	902	48.49	14	4	0.22
5	378	20.32	15	3	0.16
6	146	7.85	16	1	0.05
7	56	3.01	17	3	0.16
8	25	1.34	21	1	0.05
9	14	0.75	33	1	0.05
10	9	0.48			

In Xi'an 60.1% of the sample households are 3-person families. 17.8% are 2-person families, and 10% are 4-person families. The 5-person households account for 7.1% of the total sample, while 1-person families account for 3.1%. About 2% of the samples are families with 6-8 persons.

3.4.2 Income

The sample household annual income in Bangalore ranges from Indian Rs 24000 (about $392 USD) to Indian Rs 24000000 (about $392798 USD), with an average at Indian Rs 425814 (about $6969 USD), and median value at Indian Rs 240000 (about $3928 USD).

Income data about Xi'an show that about 38% of the sample households earn Renminbi Yuan 1000-3000 ($154 – $462 USD) per month; 34% earn Renminbi Yuan 3001 – 5000 ($462.1 - $769 USD) per month; 17% earn Renminbi Yuan 5001-10000 ($769.1 - $1538 USD). There are 0.4% of the sample households claim that they earn Renminbi Yuan 40000 ($6153 USD) per month.

Table 14 reports the distribution of sample households among the income bands used in the Xi'an survey. 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 is 5% more samples that earned USD $833 and less in Bangalore than that in Xi'an.

Table 14 Distribution of households in monthly income bands

RMB	USD $	Indian Rs	Xi'an		Bangalore	
			%	acc %	%	acc %
<1000	<167	<10250	7		24.71	
1001-3000	168-500	10251-30690	38	45	42.15	66.85
3001-5000	501-833	30691-51129	34	79	17.74	84.60
5001-10000	834-1667	51130-102320	17	96	9.00	93.59
10001-20000	1668-3333	102321-204580	3	99	2.49	96.09
20001-40000	3334-6667	204581-409220	0.99	100	0.97	97.05
>40000	>6667	>409220	0.01	100	0.46	97.50
missing					2.50	100.00

3.5 Regression results

3.5.1 Xi'an

Four regression models are calibrated for Xi'an, using total household CO2 emission (ETotal), CO2 emission generated by commuting (Ecommuting), CO2 emission associated with electricity consumption (Eelectricity) and CO2 emission associated with gas consumption (Egas) as dependent variables. The independent variables include the built environment variables such as housing attributes and neighborhood attributes, household variables such as family size and income, car ownership, use of appliances, and attitude towards the environment. The model outcomes reveal that the aggregate CO2 emission by household can be moderately explained by the above variables in Xi'an. When the emission volume is disaggregated, CO2 emission by commuting can be well explained by the variables, but emission associated with electricity and gas is poorly explained by the variables.

Table 15 reports the model summary of the aggregate household CO2 emission. The independent variables explain about 47% of the variations of the dependent variable – total CO2 emission by household.

Table 15 Model summary for household aggregate CO_2 emission, Xi'an

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.686[a]	.470	.458	.42714

a. Predictors: (Constant), Hdirection_W, LElectApp, Htype2_3, Hdirection_E, LPrecinct500, EviAttitude, LHousehdSize, Htype1_3, Carowner, Htype2_7, LHage, LNeighbhd1km, LIncome, Htype2_2, LHsize, LCommunity5km, Hdirection_S

Ten independent variables are significant in the model. They are Lprecinct500m, Lneighborhd1km, Lcommunity5km, Lincome, LhouseholdSize, Carowner, LElectApp, HType1_3, HType2_2, and Hdirection_E (Table 16). All the independent variables, except LNeighborhd1km and Hdirection_E, show positive relationship with the aggregate household CO_2 emission. In other words, sample households with richer variety of services and facilities within the 500 m radius from home, richer mix of economic activities in the 1-5 km belt from home, higher income, larger family size, car, more electric appliances, and those living in high-rise apartment or work-unit housing are associated with higher CO_2 emission. Samples with richer mix of economic activities within 1 km radius from home, and those with major rooms facing the east are associated with lower aggregate emission.

It may be more obvious for some of the above relationships to be explained than that for others. A richer mix of services, facilities and job varieties shows spatial variation in their impact on household emission. More services and facilities in the immediate vicinity do not necessarily reduce work-related commuting trip, nor do economies activities in the far away belt (1-5 km from home). On the opposite, a richer mix of services and facilities in the immediate vicinity is possibly related to the economic status of a household through a premium of the residence with a prestigious location. This set of variables will be further explored in the commuting CO_2 model.

Table 16 Summary statistics for household aggregate CO_2 emission, Xi'an

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.359	.219		28.978	.000
	LHsize	.024	.051	.016	.465	.642
	LHage	-.006	.059	-.003	-.094	.925
	LPrecinct500	.197	.046	.134	4.241	.000
	LNeighbhd1km	-.302	.036	-.289	-8.395	.000
	LCommunity5km	.187	.045	.151	4.147	.000
	LIncome	.213	.051	.131	4.203	.000
	LHousehdSize	.106	.045	.065	2.374	.018
	Carowner	.693	.041	.487	17.052	.000
	LElectApp	.323	.051	.190	6.361	.000
	EviAttitude	.030	.039	.021	.761	.447

	Htype1_3	.080	.035	.065	2.245	.025
	Htype2_2	.128	.037	.110	3.425	.001
	Htype2_3	-.015	.063	-.007	-.238	.812
	Htype2_7	-.082	.060	-.041	-1.363	.173
	Hdirection_E	-.194	.079	-.085	-2.446	.015
	Hdirection_S	-.078	.055	-.057	-1.408	.160
	Hdirection_W	-.108	.078	-.049	-1.394	.164

a. Dependent Variable: LEtotalNOH

Table 17 report the model summary of household CO2 emission generated by commuting trips. All work-related commuting trips are included in the calculation, regardless it is by car, bus, company shuttle bus, and/or taxi. A model with strong prediction power is produced, in which 72.7% of the variation of the dependent variable can be explained.

Table 17 Model summary for household CO2 emission generated by commuting, Xi'an

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.853[a]	.727	.719	.80672

a. Predictors: (Constant), Hdirection_W, Htype2_7, LHousehdSize, Htype2_4, Htype2_5, LNeighbhd1km, Carowner, Htype2_3, EviAttitude, Hdirection_E, LHage, Htype1_2, LElectApp, LPrecinct500, LIncome, Htype2_2, LHsize, LCommunity5km, Hdirection_S

Nine independent variables are significant in the model. They are Lprecinct500m, Lneighborhd1km, Lincome, Carowner, LElectApp, EnviAttitude, HType2_2, HType2_3, and HType2_7 (Table 18). Four of the nine independent variables, i.e., Lprecinct500m, Lincome, Carowner, and LElectApp show positive relationship with household CO2 emission generated by commuting. In other words, sample households with richer variety of services and facilities within the 500 m radius from home, higher income, car, and more electric appliances are associated with higher commuting emission. The other five show inverse relationships with the dependent variable. That is, samples with richer mix of economic activities within 1 km radius from home, an environment friendly attitude, and those who live in work-unit housing, affordable public housing, and other housing types (e.g. rental housing on market) are associated with lower commuting related emission.

Table 18 Summary statistics for household CO2 emission generated by commuting, Xi'an

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.828	.426		6.639	.000
	LHsize	.088	.096	.024	.921	.358
	LHage	.092	.113	.022	.807	.420
	LPrecinct500	.182	.090	.048	2.010	.045

LNeighbhd1km	-.154	.074	-.055	-2.065	.039
LCommunity5km	.075	.089	.024	.848	.397
LIncome	.441	.100	.103	4.401	.000
LHousehdSize	-.112	.079	-.029	-1.413	.158
Carowner	2.792	.079	.755	35.144	.000
LElectApp	.552	.103	.120	5.349	.000
EviAttitude	-.188	.078	-.050	-2.413	.016
Htype1_2	-.089	.069	-.028	-1.282	.200
Htype2_2	-.219	.075	-.071	-2.936	.003
Htype2_3	-.297	.125	-.050	-2.368	.018
Htype2_4	.390	.287	.029	1.360	.174
Htype2_5	.223	.217	.021	1.030	.303
Htype2_7	-.329	.118	-.063	-2.776	.006
Hdirection_E	.047	.157	.008	.302	.763
Hdirection_S	-.045	.106	-.013	-.424	.672
Hdirection_W	-.068	.151	-.012	-.450	.653

a. Dependent Variable: LEcommuting

Table 19 reports the model summary of CO2 emission associated with gas consumption. The model does not have a strong prediction power. Only 25% of the variations of the dependent variable can be explained by the independent variables.

Table 19 Model summary of CO2 emission generated by gas consumption, Xi'an

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.505[a]	.255	.233	.49319

a. Predictors: (Constant), Hdirection_W, Carowner, Htype2_3, LPrecinct500, LHousehdSize, Hdirection_E, Htype2_7, EviAttitude, LHage, Htype1_3, LElectApp, LNeighbhd1km, LIncome, Htype2_2, LHsize, LCommunity5km, Hdirection_S

Though the explaining power is weak, the model still gives insight to understand the relationships between variables. Nine independent variables are significant in the model. They are LHage, Carowner, LElectApp, HType1_3, HType2_3, HType2_7, Hdirection_S, Hdirection_E, and Hdirection_W (Table 20). Three of the nine independent variables, i.e., Carowner, LElectApp and HType1_3 show positive relationship with the household CO2 emission associated with gas consumption. In other words, sample households with a car, more electric appliances and those live in high-rise apartment buildings are associated with higher CO2 emission. The other six show inverse relationships with the dependent variable. That is, samples households that live in older buildings, affordable public housing, and rental housing, and those in houses with major rooms not facing the north are associated with lower commuting related emission.

Table 20 Summary statistics for household CO2 emission generated by gas consumption, Xi'an

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.837	.306		19.050	.000
	LHsize	.012	.072	.008	.174	.862
	LHage	-.155	.077	-.094	-2.003	.046
	LPrecinct500	-.035	.064	-.024	-.542	.588
	LNeighbhd1km	-.016	.048	-.016	-.341	.734
	LCommunity5km	-.056	.062	-.045	-.913	.362
	LIncome	.081	.069	.050	1.183	.237
	LHousehdSize	.074	.059	.047	1.257	.209
	Carowner	.132	.052	.098	2.516	.012
	LElectApp	.333	.070	.197	4.787	.000
	EviAttitude	-.018	.051	-.013	-.349	.727
	Htype1_3	.164	.046	.138	3.538	.000
	Htype2_2	.045	.049	.040	.923	.356
	Htype2_3	-.133	.079	-.065	-1.688	.092
	Htype2_7	-.744	.085	-.344	-8.746	.000
	Hdirection_E	-.479	.107	-.214	-4.485	.000
	Hdirection_S	-.268	.077	-.202	-3.474	.001
	Hdirection_W	-.206	.101	-.102	-2.037	.042

a. Dependent Variable: LEgas

Table 21 reports the model summary of CO2 emission associate with electricity consumption. The explanation power of the independent variables is comparable to that in the model for emission associated with gas consumption, with about 22% of the variations explained.

Table 21 Model summary of CO2 emission generated by electricity consumption, Xi'an

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.473[a]	.224	.206	.51441

a. Predictors: (Constant), Hdirection_W, LNeighbhd1km, Htype2_3, LHousehdSize, Htype2_4, Htype2_5, Hdirection_E, Carowner, EviAttitude, Htype2_7, LHage, Htype1_2, LElectApp, LPrecinct500, LIncome, Htype2_2, LHsize, LCommunity5km, Hdirection_S, Htype1_3

Eight independent variables are significant in the model. They are Lprecinct500m, Lneighborhd1km, Lcommunity5km, Lincome, Carowner, LElectApp, HType2_2, and HType2_7 (Table 22). All the independent variables, except LNeighborhd1km, show positive relationship with the electricity-related household CO2 emission. In other words, sample households with richer variety of services and facilities within the 500 m radius from home, richer mix of economic activities in the 1-5 km belt from home, higher income, car, more electric appliances, and those living in work-unit housing or rental housing are associated with higher CO2 emission. Samples with richer mix of economic activities within 1 km radius from home are associated with lower electricity related emission.

Table 22 Summary statistics of CO2 emission generated by electricity consumption, Xi'an

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	6.045	.251		24.116	.000
	LHsize	.001	.054	.001	.015	.988
	LHage	.017	.063	.011	.269	.788
	LPrecinct500	.153	.050	.110	3.049	.002
	LNeighbhd1km	-.307	.041	-.299	-7.531	.000
	LCommunity5km	.210	.050	.175	4.211	.000
	LIncome	.178	.056	.113	3.180	.002
	LHousehdSize	.041	.046	.028	.899	.369
	Carowner	.183	.046	.130	4.028	.000
	LElectApp	.391	.054	.252	7.269	.000
1	EviAttitude	.007	.045	.005	.151	.880
	Htype1_2	-.066	.110	-.055	-.601	.548
	Htype1_3	.033	.113	.026	.289	.773
	Htype2_2	.236	.043	.202	5.453	.000
	Htype2_3	.084	.074	.036	1.130	.259
	Htype2_4	.229	.147	.052	1.564	.118
	Htype2_5	.144	.113	.040	1.274	.203
	Htype2_7	.117	.067	.060	1.740	.082
	Hdirection_E	-.050	.087	-.023	-.575	.565
	Hdirection_S	.023	.061	.017	.371	.711
	Hdirection_W	-.012	.085	-.006	-.142	.887

a. Dependent Variable: LEelectricity

3.5.2 Bangalore

Table 23 reports the model summary of aggregate household CO2 emission. The model does not have a strong prediction power. Only 36.7% of the variations of the dependent variable can be explained by the independent variables.

Table 23 Model summary of aggregate household CO2 emission, Bangalore

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.606[a]	.367	.353	.43760

a. Predictors: (Constant), Hdirection_W, LN1km, LHsize, LHage, EviAttitude, Htype2_5, ElectApp, LHousehdSize, Carowner, Hdirection_E, Htype1_2, LIncome, Htype2_3, Htype1_4, LPricinct500, Htype2_2, Hdirection_S, LCommunity1500

Though the prediction power is weak, the model still gives insight to understand the relationships between the dependent and independent variables. Seven independent variables are significant in the model. They are LHsize, LIncome, LHousehdSize, Carowner, ElectApp, HType2_2, and Hdirection_E (Table 24). Except HType2_2, all the other six independent variables show positive relationship with the aggregate household CO_2 emission. In other words, sample households with a larger house, higher income, larger family, car, more electric appliances and those with major rooms facing the east are associated with higher CO_2 emission. Sample households that live in public housing show an inverse relationship with the aggregate emission volume. That is, sample households that live in public housing are associated with lower CO_2 emission.

Table 24 Summary statistics of aggregate household CO2 emission, Bangalore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	3.660	.263		13.899	.000
	LHsize	.118	.027	.130	4.394	.000
	LHage	.047	.038	.035	1.235	.217
	LPricinct500	.020	.028	.025	.720	.472
	LN1km	.046	.043	.045	1.069	.285
	LCommunity1500	.073	.039	.083	1.861	.063
	LIncome	.232	.018	.393	13.065	.000
	LHousehdSize	.131	.062	.062	2.127	.034
	Carowner	.156	.039	.118	4.011	.000
1	ElectApp	.224	.032	.205	6.987	.000
	EviAttitude	-.033	.037	-.026	-.893	.372
	Htype1_2	-.005	.035	-.005	-.153	.879
	Htype1_4	.029	.046	.021	.648	.517
	Htype2_2	-.155	.047	-.116	-3.294	.001
	Htype2_3	.125	.065	.061	1.923	.055
	Htype2_5	-.048	.040	-.044	-1.198	.231
	Hdirection_E	.159	.054	.097	2.919	.004
	Hdirection_S	.036	.039	.033	.918	.359
	Hdirection_W	.019	.050	.013	.386	.700

a. Dependent Variable: LETotalNEW

Table 25 report the model summary of household CO_2 emission generated by commuting trips. All work-related commuting trips are included in the calculation, regardless it is by car, bus, company shuttle bus, and/or taxi. A model with very weak prediction power is produced, in which only 14% of the variation of the dependent variable can be explained.

Table 25 Model summary for household CO2 emission generated by commuting, Bangalore

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.375[a]	.140	.123	1.21355

a. Predictors: (Constant), Hdirection_W, LN1km, LHsize, EviAttitude, LHage, Htype2_5, ElectApp, LHousehdSize, Carowner, Hdirection_E, Htype1_2, LIncome, Htype2_3, Htype1_4, LPricinct500, Htype2_2, Hdirection_S, LCommunity1500

Four independent variables are significant in the model. They are LHsize, Lincome, Carowner, and ElectApp (Table 26). All the four variables show positive relationship with household CO2 emission generated by commuting. In other words, sample households with a larger house, higher income, car, and more electric appliances are associated with higher commuting emission.

Table 26 Summary statistics for CO2 emission generated by commuting, Bangalore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	-.021	.685		-.030	.976
	LHsize	.167	.068	.081	2.456	.014
	LHage	.009	.101	.003	.093	.926
	LPricinct500	-.033	.076	-.017	-.438	.662
	LN1km	.142	.112	.059	1.266	.206
	LCommunity1500	-.020	.104	-.010	-.196	.845
	LIncome	.406	.047	.292	8.687	.000
	LHousehdSize	-.045	.159	-.009	-.282	.778
	Carowner	.317	.103	.100	3.069	.002
1	ElectApp	.174	.085	.067	2.039	.042
	EviAttitude	.051	.097	.017	.527	.598
	Htype1_2	-.066	.092	-.025	-.716	.474
	Htype1_4	.181	.119	.054	1.526	.127
	Htype2_2	-.004	.122	-.001	-.030	.976
	Htype2_3	.115	.171	.024	.670	.503
	Htype2_5	-.006	.107	-.002	-.052	.958
	Hdirection_E	.022	.141	.006	.158	.874
	Hdirection_S	.162	.103	.062	1.577	.115
	Hdirection_W	.213	.133	.060	1.607	.108

a. Dependent Variable: LECTotal

CO_2 emission associated with gas consumption cannot be model by regression analysis because a large number of observations (1499) are sharing the same value (500.6232). As such, those essential assumptions underlying the OLS model cannot be met.

Table 27 reports the model summary of CO_2 emission associated with electricity consumption. The model does not have a strong prediction power. Only 34% of the variations in CO_2 emission can be explained by the independent variables.

Table 27 Model summary for CO_2 emission associated with electricity consumption, Bangalore

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.582[a]	.339	.323	.57376

a. Predictors: (Constant), Hdirection_W, LIncome, Htype2_2, EviAttitude, LHage, ElectApp, LHousehdSize, Carowner, Htype2_3, Hdirection_E, Htype1_2, LNeighbhd1km, LHsize, Htype1_4, Hdirection_S, LCommunity1500, Htype2_5, LPricinct500

Although the prediction power is very limited, there are 11 variables that are statistically significant in explaining the variations of CO_2 emission associate with electricity consumption. They are Hsize, Neighbhd1km, Community1500, income, household size, carowner, ElectApp, HType1_4, HType2_2, HType2_3, and Hdirection_E. Seven of the 11 independent variables show positive relationship with the dependent variable. This suggests that sample households with a larger house, more variety of job mixes within the 1 km radius, higher income, larger family, car, more electric appliances, and with major rooms facing the east are associated with higher CO_2 emission associated with electricity use. Four of the variables, i.e., Community1500, HType1_4, HType2_2, and HType2_3, are associated with lower CO_2 emission. In other words, households living in detached or town houses, public housing, and housing other than BDA, market or subsidized market housing tend to have lower level of CO_2 emission associated with electricity consumption.

Table 28 Summary statistics for CO_2 emission associated with electricity consumption, Bangalore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.727	.357		7.630	.000
	LHsize	.079	.035	.072	2.273	.023
	LHage	.068	.050	.041	1.347	.178
	LPricinct500	.017	.056	.016	.300	.764
	LNeighbhd1km	.189	.054	.190	3.481	.001
	LCommunity1500	-.079	.044	-.070	-1.812	.070
	LIncome	.215	.024	.285	8.874	.000
	LHousehdSize	.488	.077	.196	6.322	.000
	Carowner	.142	.053	.084	2.689	.007
	ElectApp	.288	.044	.206	6.621	.000
	EviAttitude	-.017	.050	-.010	-.337	.736

Htype1_2	-.034	.048	-.024	-.709	.478
Htype1_4	-.219	.061	-.124	-3.568	.000
Htype2_2	-.225	.064	-.130	-3.487	.001
Htype2_3	.003	.088	.001	.039	.969
Htype2_5	-.230	.055	-.165	-4.164	.000
Hdirection_E	.146	.071	.072	2.049	.041
Hdirection_S	-.009	.052	-.006	-.164	.869
Hdirection_W	.064	.068	.033	.935	.350

a. Dependent Variable: LEelectricityKgYear

3.5.3 Summary

Table 29 summarizes the performance of independent variables in the seven models calibrated for Xi'an and Bangalore. Clearly, car ownership and the use of electric appliances show positive influences on CO2 emission in all the seven models. Income is a significant factor standing out in six models for a positive impact on CO2 emission. The precinct and neighborhood environment, as measured by the level of mix of services, facilities and job activities, is a significant consideration in explaining the emission levels in Xi'an. But the sign of relationship is interesting. Households with richer mix of services and facilities in their immediate vicinity are associated with higher emission; while those with a richer mix of employment within a 1 km radius from home are associated with a lower level of CO2 emission in both commuting and electricity consumption. In Bangalore, the size of housing shows a positive influence on the emission level.

Another observation is that residents in public housing estates have strong relevance to the CO2 emission estimation. This factor entered five of the seven models. However, the different signs show that its influence varies by type of activity or energy use.

Table 29 Summary of the models for Xi'an and Bangalore

	Xi'an				Bangalore		
	Total emission	Emission by com'ting	Emission by gas use	Emission by elect use	Total emission	Emission by com'ting	Emission by elect use
R^2	0.47	0.727	0.255	0.224	0.367	0.14	0.339
H size					P	P	P
H age			N				
Precinct	P	P		P			
Neighhd	N	N		N			P
MacZ	P			P			N
Income	P	P		P	P	P	P
F size	P				P		P
Own car	P	P	P	P	P	P	P
ElectApp	P	P	P	P	P	P	P
EviAtti'd		N					
High-rise	P		P				
Detach							N
Public H	P	N		P	N		N
MarketH		N	N				N
RentalH		N	N	P			

H FaceE	N		N		P		P
H FaceS			N				
H FaceW			N				

Note: P indicates a significant positive relationship between the independent variable and the dependent variable; N indicates a negative relationship.

4.0 Conclusions

Restate the study aims or key questions and summarize your findings

This project tackles a core issue in sustainable development research, i.e., carbon emission control (Low et al. 2005), by examining the impact of family characteristics, housing stocks, and the neighborhood environment on household carbon emission. The idea of reducing energy use and household carbon emission via modifying land-use mix, transportation arrangements and population density is novel and complementary to the technology-oriented efforts (e.g. development of energy-saving products, use of renewable energy sources). This project develops and implements a conceptual and methodological innovation using two case study cities that provides distinctive but comparable contexts to study energy use behavior and urban planning policies.

The main findings of the research include

1. Unique spatial patterns. A concentric ring pattern is discernible in the case of Xi'an, waving downward from the inner city then upward towards the outer ring. In Bangalore, the high level emission households are distributed sporadically, mixing up with low emission households in multiple clusters all over the space;

2. Distinctive modes of commuting. More than half (52%) of the households in Xi'an show that family members walk or cycle to work, while in Bangalore more than 60% of the family head (i.e. member 1) drive to work. The proportion of households that use motor vehicles, whether motorbikes or cars, is higher in Bangalore than Xi'an. However, among the households that use motor vehicles, the average level of petrol consumption in Xi'an (149 liter per month) is higher than that in Bangalore (45 liter per month);

3. Distinctive housing. 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 that in Bangalore; and the unit size of housing is smaller but less varied in Xi'an as compared to that in Bangalore.

4. Different neighborhood environment. Households in Xi'an are more likely to be surrounded by a richer mix of services, facilities and economic activities 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%). On the other end of the scale, 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. On a neighborhood scale (i.e., within 1 km radius from home), more than 50% of the sample households in Xi'an are surrounded by four or more economic activity types; while in Bangalore the same measurement is about 12%. In terms of households that locate in an environment with limited access to jobs, about 30% of the samples in Xi'an are surrounded by two or one economic activity types, while in Bangalore the percentage is as high as 73%. This same pattern is true for an even larger zone (about 1-5 km from home) centered on households.

5. Distinctive family characteristics. Families in Xi'an are smaller but richer 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 six-persons or more, but in Bangalore about 13% of the samples have six members or more.

6. Modernization as a key drive towards high emission. Findings in both cities suggest that modernization, as represented by motorization, use of electric appliances, and higher income, are associated with higher carbon emission. The factors such as ownership of motor vehicles and electric appliances as well as higher income are consistently associated with higher carbon emission in the statistical models.

7. The 1 km zone as a planning unit to reduce carbon emission. A rich mix of economic activities within the 1 km radius from home is associated with low household carbon emission. This is confirmed by both the aggregate household emission model and the commuting related emission model in Xi'an. A related finding is that a rich mix of services and facilities in the immediate vicinity of a household is associated with higher emission from the household. If services and facilities represented the level of job mix, the provision of more job varieties within the immediate zone from home may be associated more with the prestigious location rather than a potential balance between residence and jobs.

Urban planning policies, via their influence upon land-use and thus the mix of services, facilities and jobs, have always had an impact upon energy consumption in cities. New visions and guidelines to guide/regulate urban development are emerging. These visions and guidelines include conceptual ideas such as 'networked cities' (in Perth see Curtis 2006) and 'city of cities' (in Sydney, see Searle 2006) as well as planning policy to change spatial parameters such as land-use mix (via 'new urbanism'), population density (via 'urban consolidation' and 'compact cities'), and public transportation (via 'transit-oriented development'). By providing findings on the association between carbon emission and key determinants this research may enable a more informed choice by planning agencies between these different visions, and in turn provide confidence in the articulation of policy designed to reshape land use patterns.

5.0 Future Directions

The planning parameters especially in terms of activity mix display a significant relationship with household carbon emission. Future studies need to quantify land-use allocated to different economic activities, the building spaces associated with each land-use types, and the jobs associated with the building spaces. These efforts will lead to an enquiry of household carbon emission and the determinants within given micro urban environments. The findings will contribute to understanding of the mechanisms that regulate household energy use and carbon emission, thus lead to planning innovations about the creation of low carbon urban neighborhoods.

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Follow a standard format when citing your references

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Appendix

I. <u>Conferences/Symposia/Workshops</u>
Agenda/Programme (including title, date and venue)
Participants list (comprising contact details of each participant, including organisation, address, phone number, fax number, and email address)

1. The 2011 International Seminar on Low Carbon Cities, Xian, China, October 31 – November 2, 2011, Chang'an University Transportation Research Mansion, sixth floor Conference Room

Table AI1-1 *Agenda/Programme of workshop in Xi’an*

DATE	TIME	ACTIVITIES	VENUE
30. Oct. 2011		Participants Arrived	Jinshi International Hotel
		Dinner	Jinshi International Hotel
31. Oct. 2011	9:00~12:20	Project team meeting	Transportation Technology Building of Chang'an University, 601 Conference meeting room
	12:20~15:00	Lunch Break	Jintang Restaurant
	15:00~18:20	Seminar (open to public)*	Transportation Technology Building of Chang'an University, 601 Conference meeting room
	19:00~20:00	Dinner	Jintang Restaurant
01. Nov. 2011	8:00~13:00	Cultural tour	Terracotta Warriors and Horses of Qinshihuang Mausoleum
	13:00~15:00	Lunch	mutton foam bun of Xi'an Lao Sun family
	15:30~17:30	Inner city tour	Xi'an City Wall
	18:00~19:00	Dinner	Grains Restaurant
	19:00~21:30	Night Tour	Big Wild Goose Pagoda、Qu Jiang New City

02. Nov. 2011	9:00~12:00	Project team meeting	Transportation Technology Building of Chang'an University， 601 Conference meeting room
	12:00~13:00	Lunch	Jintang Restaurant
	Afternoon	All Participants will leave Xi'an	

- Speakers are listed below

Sun Sheng Han, Professor, Melbourne University, Australia

T.V. Ramachandra, Professor, Indian Institute of Science, India

Nicholas Low, Professor, Melbourne University, Australia

Bo Qin, Associate Professor, Renmin University of China, China

Ningrui Du, Professor, Wuhan University, China

Yuanqing Wang, Professor, Chang'an University School of Highway, China

Table AI1-2 *Participants list in Xi'an workshop*

Sl.No.	Name	Address	Email	Mobile No.	Signature
1.	Yang Hu	Shaanxi Urban and Rural Planning Design Institute, China	ghy@sxsghy.cn	029-83227016	
2.	Zhang Peng	Xi 'an Urban Planning Design and Research Institute, China	xianhuihua@163.net	029-84799822	
3.	Yan Shaole	Xi 'an Urban Planning Design and Research Institute, China	xianhuihua@163.net	029-84799822	
4.	Zhu Hui	Xi 'an Public Transportation Corporation, China			
5.	Li Zhongshan	Xi 'an Public Transportation Corporation, China	lzs310@126.com		
6.	Wang Xijun	Feng Wei New Area Administrative Committee, Xi'an, China		029-88868315	
7.	Niu Guohong	Xi 'an Municipal			

		Design Institute, China		137720998 06	
8.	Zhang Qihuan	Xi 'an Municipal Design Institute, China	xmedri@163.com	86-29-88402326	
9.	Sun Sheng Han	Faculty of architecture, Building and Planning, The University of Melbourne-Australia	sshan@unimelb.edu.au	+614124425 78	
10	Guo Lu	Chang'an University Xi'an, China	april0402gl@sina.com	+861389192 7783	
11	Bo Qin	Renin University of China, Beijing-100872	qinbo@vip.sina.com		
12	Qi Bin	Renin University of China, Beijing-100872			
13	Wang Li	Chang'an University Xi'an, China	573986825@qq.com	+861599177 0245	
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15	Zheng Mengmeng	Chang'an University Xi'an, China	250757864@qq.com	+861510924 2318	
16	Liu Zhijie	Chang'an University Xi'an, China	531983654@qq.com		
17	Yao Zhigang	Chang'an University Xi'an, China			
18	Quan Jianyou	Chang'an University Xi'an, China			

2. Low Carbon Cities: 2012 Bangalore Workshop, 13-14th April 2012, Rustom Choksi Hall, Indian Institute of Science, Bangalore, India

Table AI2-1 *Agenda/Programme of workshop in Bangalore*

Date and Time	Details
13 April 2012, 9.30 – 11.30 AM	Inauguration & Key speakers presentations*
1130 – 1200 hours	Tea

1200 – 1300 AM	Interactive session with stakeholders and media
1300 – 1430 hours	Lunch
3 PM to 4 PM	Progress review (international team)
4 PM to 4 30 PM	Tea
4 30 PM to 6 PM	Next phase of project –discussion
7 00 PM	Dinner
14th April 2012, 7 30 AM – 4 00 PM	Field visit and participants interactions/discussions

* Inauguration & Key speakers presentations:

Sun Sheng Han, Faculty of Architecture, Building and Planning, The University of Melbourne, Australia sshan@unimelb.edu.au, **Conceptual framework and methodology: Role of for urban spatial parameters on greenhouse gas (GHG) emission**
T.V. Ramachandra, Energy & wetlands Research Group Centre for Ecological Sciences Indian Institute of Science cestvr@ces.iisc.ernet.in**, Carbon Footprint of Greater Bangalore**
Yuanqing Wang, Chang'an Unervisity Xi'an China. wyq21@vip.sina.com**, Urban spatial parameters on greenhouse gas (GHG) emission -Xi'an case study**
Bo Qin, Renmin University of China, Beijing, 100872 qinbo@vip.sina.com, **Low Carbon Beijing**

Table AI2-2 *Participants list in Bangalore workshop*

Sl.No.	Name	Address	Email	Mobile No.
1.	Harsha K	FOV, IIIT-B, Electronic city, Bangalore	harsha@fieldsofview.in	9986214125
2.	Dr. B K Chakrapani	Vijaya College, Bangalore	b.k.chakrapani@gmail.com	9448088013
3.	Dr. Shobha S. V	St Joseph's college	svsbkc@gmail.com	9448111487
4.	Megha Prakash	Current Science	Prakash.megha@gmail.com	9880334369
5.	Sandipan Saraig	Waste Wise Trust	Sandipan.sarangi@gmail.com	9742872640
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8.	Aafiya Sidrath	KK High School	meccamedina19@gmail.com	9740716770
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10	Bindhu	KK High School	moon55@gmail.com	9945518123
11	Allirani	KK High School	vp.allirani@gmail.com	9901159949

12	Jay Kumar	BGVS, IISC	jaykumarhs@gmail.com	9620464215
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14	Shreeya Verma	CAOS, IISC	shreeyaverma@gmail.com	9611190299
15	Shashikala Y	V.V.Pura College Bangalore	-	8553778431
16	Sun Sheng Han	Faculty of architecture, Building and Planning, The University of Melbourne-Australia	sshan@unimelb.edu.au	+61412442578
17	Yuanqing Wang	Chang'an University X'ian, China	wyq21@vip.sina.com	13609296368
18	Guole	Chang'an University X'ian, China	april0402gl@sina.com	
19	Bo Qin	Renim University of China, Beijing-100872	qinbo@vip.sina.com	
20	Qi Bin	Renim University of China, Beijing-100872		
21	Bharath H. Aithal	Energy & Wetlands Research Group, CES, IISc	bharath@ces.iisc.ernet.in	
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24	Dr. Uttam Kumar	Energy & Wetlands Research Group, CES, IISc	uttam@ces.iisc.ernet.in	
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27	Anindita Dasgupta	Energy & Wetlands Research Group, CES, IISc	Anindita_dasgupta@ces.iisc.ernet.in	
28	Gouri Kulkarni	Energy & Wetlands Research Group, CES, IISc	gouri@ces.iisc.ernet.in	
29	Vishnu Bajpai	Energy & Wetlands Research Group,	bajpai@ces.iisc.ernet.in	

		CES, IISc		
30	T.V. Ramachandra	Energy & Wetlands Research Group, CES, IISc	cestvr@ces.iisc.ernet.in	

3. 2013 Low Carbon Cities Beijing Workshop, 13-16th January 2013, Renmin University, Beijing, China

Table AI3-1 *Agenda/Programme of workshop in Beijing*

DATE	TIME	ARRANGEMENT	PLACE
Jan. 13th, 2013		Participants Arrived	Xianjin Hotel of Renmin University
Jan. 14th, 2013	9:30~12:30	Project team meeting	Conference room 320, Qiushi Building of Renmin University
	12:30~14:00	Lunch	Conference room 320, Qiushi Building of Renmin University
	14:00~17:30	Policy workshop*	Room 216, Qiushi Building of Renmin University
	18:00~20:00	Dinner	Huixianju Restaurant
Jan. 15th, 2013	9:30~12:30	Project team meeting	Conference room 320, Qiushi Building of Renmin University
	12:30~13:00	Lunch	Kungfu Fast-food
	14:00~15:00	Field trip	City Planning Exhibition Hall, Jingshan Park
Jan. 16th, 2013	8:00~12:00	Seminar（Students）	Conference room 320, Qiushi Building of Renmin University
	12:00~14:00	Lunch	Fast Food
	14:00~18:30	Field trip	Dashanzi Art District
	18:30~19:00	Dinner	Farewell Dinner

*Speakers include

Sun Sheng Han, Faculty of Architecture, Building and Planning, The University of Melbourne, Australia sshan@unimelb.edu.au

T.V. Ramachandra, Energy & wetlands Research Group Centre for Ecological Sciences Indian Institute of Science cestvr@ces.iisc.ernet.in

Yuanqing Wang, Chang'an Unervisity Xi'an China. wyq21@vip.sina.com

Bo Qin, Renmin University of China, Beijing, 100872 qinbo@vip.sina.com
Ray Green, Faculty of Architecture, Building and Planning, The University of Melbourne, Australia rigreen@unimelb.edu.au

Table AI3-2 *Participants list in Beijing workshop*

name	organisation	address	phone number	fax number	email adress
Sun Sheng Han	University of Melbourne	Parkville VIC 3010	61 3 8344 7055		sshan@unimelb.edu.au
Ray Green	University of Melbourne	Parkville VIC 3010			
Mark Wang	University of Melbourne	Parkville VIC 3010			
Ramachandra T.V.	Indian Institute of Science	Bangalore 560 012, India	91-080-23600985	91-080-23601428	cestvr@ces.iisc.ernet.in
Bajpai Vishnu	Indian Institute of Science	Bangalore 560 012, India			bajpai@ces.iisc.ernet.in
Wang Yuanqing	Chang'an University	Middle Section of Nan Erhuan Road, Xi'an, Shanxi Province, P.R.China			wyq21@vip.sina.com
Guo Lu	Chang'an University	Middle Section of Nan Erhuan Road, Xi'an, Shanxi Province, P.R.China			
Zheng Mengmeng	Chang'an University	Middle Section of Nan Erhuan Road, Xi'an, Shanxi Province, P.R.China			

Zeng Jun	Chang'an University	Middle Section of Nan Erhuan Road, Xi'an, Shanxi Province, P.R.China			
Liu Zhijie	Chang'an University	Middle Section of Nan Erhuan Road, Xi'an, Shanxi Province, P.R.China			
Du Ningrui	Wuhan University	Luo-jia-shan, Wuchang, Wuhan, Hubei Province, P.R.China			
Huang Jingnan	Wuhan University	Luo-jia-shan, Wuchang, Wuhan, Hubei Province, P.R.China			huangjn73@hotmail.com
Li Xue	Wuhan University	Luo-jia-shan, Wuchang, Wuhan, Hubei Province, P.R.China			

Li Yuling	Wuhan University	Luo-jia-shan, Wuchang, Wuhan, Hubei Province, P.R.China			
Yang Shangguang	East China University of Science and Technology	China Meilong Road 130, Shanghai,P.R.China			sgyang@ecust.edu.cn
Liu Lin	East China University of Science and Technology	China Meilong Road 130, Shanghai,P.R.China			
Li Ze	Tianjin University	92 Weijin Road, Nankai District, Tianjin, P.R.China	86-022-27404491	86-022-27890420	
Zhang Tianjie	Tianjin University	92 Weijin Road, Nankai District, Tianjin, P.R.China	86-022-27404491	86-022-27890420	
Qin Bo	Renmin University of China	No. 59 Zhongguancun Street, Haidian District Beijing,P.R.China	86-13683373538	86-10-62514875	qinbo@vip.sina.com

Tian Hui	Renmin University of China	No. 59 Zhongguancun Street, Haidian District Beijing,P.R. China	86-18810383259	86-10-62514875	tianhui_252493119@qq.com
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Wang Yajie	Beijing Municipal Commission of Urban Planning	60,South Lishi Road,Beijing,P.R.China	86-10-88073568		

Cheng Xiaoduo	Heilongjiang University	No.74 Xuefu Road,Nanga ng district,Haer bin,Heilongj iang Province,P. R.China	86-13936623399		chxdok@126.co m

II. <u>Funding sources outside the APN</u>
A list of agencies, institutions, organisations (governmental, inter-governmental and/or non-governmental), that provided any in-kind support and co-funding for the project and the amount(s) awarded. If possible, please provide an estimate amount.

1. Bangalore Funding sources outside the APN

Table AII-1 Funding sources outside APN, Bangalore

Organization	Contribution
Indian Institute of Science	1. Subsidized auditorium and guest house facilities for workshop participants 2. Knowledge sharing with project partners 3. Salary and research grant for collaborating investigator from Indian Institute of Science 4. Salary of research scholars (Bharath, Durga Madhab Mahapatra)
The Ministry of Environment and Forests, Government of India	Infrastructure support for collaborating investigator from Indian Institute of Science
The Ministry of Science and Technology (DST), Government of India	Infrastructure support for Geoinformatics lab (computers and GIS software) for collaborating investigator from Indian Institute of Science

2. Beijing Funding sources outside the APN

Table AII-2 Funding sources outside APN, Beijing

Organization	Contribution
National Natural Science Foundation of China	Provide research founding RMB30,000-40,000
Beijing Municipal Commission of Education	Provide research founding RMB 20,000
Beijing Municipal Commission of Urban Planning	providing supports in questionnaires survey

3. Xian Funding sources outside the APN

Table AII-3 Funding sources outside APN, Xi'an

Organization	Contribution
National Natural Science Foundation in China	1. Salary and research grant for collaborating investigator from Chang'an University 2. Salary of research scholars(young scientists)

4. Melbourne Funding sources outside the APN

Table AII-1 Funding sources outside APN, Melbourne

Organization	Contribution
The University of Melbourne	1. Salary for the leading researcher 2. Computer, GIS software and stationery
Australia Research Council	3. Accommodation for participants from Shanghai and Heilongjiang for the Beijing low carbon workshop 4. One part-time research assistant
Australian Centre for Governance and Management of Urban Transport (GAMUT)	5. Travel support to meet with project team members before commencement of project in Wuhan May 2010.

III. List of Young Scientists

Include brief detail (full name, involvement in the project activity) and contact detail (name of institution/country and email address) of your scientists involved in the project. Also include short message from the young scientists about his/her involvement in the project and how it helps develop/build his capacity and the knowledge he gained.

1. List of young scientists Bangalore

Table AIII-1 List of young scientists, Bangalore

Name & Address	Work done	Conferences
Vishnu Bajpai Energy Wetland research Group, TE-15, Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012, INDIA e-mail: bajpai@ces.iisc.ernet.in	Epidata design for storing data, Compilation of data, Spatial and Statistical analysis of data , Zone wise analysis and spatial pattern of CO_2 emission from each household due to electricity consumption in different wards of Bangalore, Analysis of socioeconomic factor affecting CO_2 emission in Bangalore.	**1.** Title of Talk: Carbon dioxide emission due to electricity consumption in the residential sector of Greater Bangalore Conference: Lake 2012: Conservation and Management of Wetland Ecosystem , 6th-8th Nov 2012. Venue: School Of Environment Science, Mahatma Gandhi University Kottayam Kerala. **2.** Title of Talk: Carbon dioxide emission due to

		electricity consumption in the residential sector of Greater Bangalore. Conference: Role of spatial parameter in greenhouse gas emissions.14-16 Jan 2013. Venue: Renmin University, Beijing China.
Gouri Kulkarni, Energy & Wetlands Research Group, TE15, Centre for Ecological Sciences, Indian Institute of Science, Bangalore-560 001, INDIA. E-mail: gouri@ces.iisc.ernet.in	Data Collection: Collected the information on Carbon footprint through the questionnaire with the help of student volunteers across the all the zone. Duration: August-December 2011. Compilation of Data: 1750 questionnaire. Data Analyses: Statistical Analysis: Plotted the graphs for overall and zone-wise frequency distribution. Effects of socio-economic factors (Education, household size, income) on CO_2 emission from household (Commuting and Inside house). Assessed the role of socioeconomic factors such as income, education, occupation and household size on the generation and composition of solid waste.	Presented paper on "Carbon footprint of municipal solid waste in Greater Bangalore" in Biennial symposium - Lake 2012: National Conference on Conservation and Management of Wetland Ecosystems, November 06-08, 2012, School of Environmental Sciences, Mahatma Gandhi University, Kottayam, Kerala.
Supriya Guruprasad, Energy & Wetlands Research Group, TE15, Centre for Ecological Sciences, Indian Institute of Science, Bangalore- 560 001, INDIA. E-mail:	Data compilation with Ms.Gouri Kulkarni of 450 households	
Alli Rani, K K English High School	Household survey of 250 households	
M A Khan, Principal, K K English School	Organised the orientation programme for student volunteers to take part in household survey of 250	

	households with Ms.Alli Rani	
Bharath H. Aithal, Research Scholar Energy & Wetlands Research Group, TE15, Centre for Ecological Sciences, Indian Institute of Science, Bangalore-560 001, INDIA. E-mail: Bharath@ces.iisc.ernet.in	Spatial analysis, statistical analysis of data	
Durga Madhab Mahapatra, Research Scholar Energy & Wetlands Research Group, TE15, Centre for Ecological Sciences, Indian Institute of Science, Bangalore-560 001, INDIA. E-mail: durgamadhab@ces.iisc.ernet.in	Field experiments	

Benefits:

1) Capacity building of young researchers in the strategies for sample household survey, data analysis and an opportunity to interact with lead researchers during the workshop and conference
2) Publications in peer reviewed journals

2. List of young scientists Beijing

Table AIII-2 List of young scientists, Beijing

full name	Work done	how it helps
Shao Ran Renmin University of China	Literature review, discussion on the research design, completing her master thesis	learn the softwares like SPSS and arcgis, improve the ability of collecting and analyzing data, cultivate the capacity of linking theory with practice and using model to analysis data. Her thesis won the Best Master Thesis of Renmin University of China

Yang Xiaotian Renmin University of China	Discussion on the questionnaire， collecting data, modeling analysis main elements affecting carbon emission and complete the master essay	learn the softwares like SPSS and arcgis, improve the ability of collect and analysis data, cultivate the capacity of linking theory with practice and using model to analysis data. Her master essay won the Best Thesis in the School of Public Administration and Policy in Renmin University of China.
Tian Hui Renmin University of China tianhui_252493119@qq.com	use a model to analysis main elements affecting carbon emission from neighborhood and complete the master essay	learn the softwares like SPSS and arcgis, improve the ability of collect and analysis data, cultivate the capacity of linking theory with practice and using model to analysis data.
Qi Bin Renmin University of China qibin0718@126.com	Questionnaires survey，collect data, use a model to analysis main elements affecting carbon emission from building and complete the bachelor essay	learn the softwares like SPSS and arcgis, improve the ability of collect and analysis data, cultivate the capacity of linking theory with practice and using model to analysis data. The master essay was one of the best essaies in Renmin University of China.
Li Weixi Renmin University of China liweixi19@126.com	send questionnaires，collect data， some preliminary analysis	learn the softwares like SPSS and arcgis, improve the ability of collect and analysis data
Miao Fenfen Renmin University of China miaook_123@126.com	send questionnaires，collect data	learn the softwares like SPSS and arcgis, improve the ability of collect data

3. List of young scientists Xian

Table AIII-3 List of young scientists, Xi’an

Name & Address	Work done	**Conferences**
Wang Jing, BRT Research Center ,Traffic Engineering Research Institute, Chang’an University, Xi’an 710064,CHINA E-mail: 909907978@qq.com	Organized students to take part in the “Spatial Planning & Low-carbon Xi’an” survey of 1373 questionnaires. Made preliminary statistical analysis. Studied on the calculation	

	model of the carbon emission.	
Guo Lu, BRT Research Center ,Traffic Engineering Research Institute, Chang'an University, Xi'an 710064,CHINA E-mail: 330332415@qq.com	Collected the information of Xi'an on social economics, population, land use, etc. Made an in-depth analysis of the samples of survey Wang Jing conducted: Plotted the graphs for family attributes and made the spatial analysis of carbon emissions. Explored the effects of factors on family commute carbon emissions.	Title of Talk: Urban spatial parameters on greenhouse gas (GHG) emission -Xi'an case study. Conference: 12,April, 2012. Venue: Indian Institute of Science, Bangalore , INDIA.
Liu Zhijie, BRT Research Center ,Traffic Engineering Research Institute, Chang'an University, Xi'an 710064,CHINA E-mail: 531983654@qq.com	Data compilation of the survey and made analysis: Effects of internal attributes (income, car ownership, occupation, etc.) of family and external attributes (network density, employment density, etc.) of family on the family commute carbon emissions of different family size. Combined the data and the Xi'an urban transportation planning model.	
Zheng Mengmeng, BRT Research Center ,Traffic Engineering Research Institute, Chang'an University, Xi'an 710064,CHINA E-mail:250757864@qq.com	Organized students to take part in the "Spatial Planning & Low-carbon Xi'an" survey of 1501 questionnaires. Data spatial analysis: the spatial autocorrelation analysis and hot spot analysis of the family commute carbon emissions. Draft the third and fourth part of the book about the carbon emissions on Xi'an.	Title of Talk: The Discussion of Factors Which Influence Family Commuter Traffic Carbon Emissions. Conference: Role of spatial parameter in greenhouse gas emissions.14-16 Jan 2013. Venue: Renmin University, Beijing China.
Gao Yanan, BRT Research Center ,Traffic Engineering Research Institute, Chang'an University, Xi'an 710064,CHINA E-mail: 676842171@qq.com	Data collection, analysis the characteristic of carbon emissions of typical neighborhoods: effects of family attributes and travel characteristics on family carbon emissions.	

	Draft the fifth and sixth part of the book about the carbon emissions on Xi'an.	
Wu Zhouhao, BRT Research Center ,Traffic Engineering Research Institute, Chang'an University, Xi'an 710064,CHINA E-mail: 354095014@qq.com	Technical support for Spatial analysis :ArcGIS geographic analysis package, CUBE transport planning package.	
Zen Jun, BRT Research Center ,Traffic Engineering Research Institute, Chang'an University, Xi'an 710064,CHINA E-mail: 895631170@qq.com	Assisted the survey conducted by Zheng Mengmeng , Draft the first and second part of the book on the carbon emissions about Xi'an.	Title of Talk: Study of Urban Travel Carbon Emission Based on the Life-cycle Analysis. Conference: Role of spatial parameter in greenhouse gas emissions.14-16 Jan 2013. Venue: Renmin University, Beijing China.
Liu Yuanyuan, BRT Research Center ,Traffic Engineering Research Institute, Chang'an University, Xi'an 710064,CHINA E-mail: 404033967@qq.com	Spot-surveying, interpretation of the data form all the survey, integration of the various parts of the book.	
An Rui, BRT Research Center ,Traffic Engineering Research Institute, Chang'an University, Xi'an 710064,CHINA E-mail: 853733064@qq.com	Assisted and participated in the carbon emissions survey of four typical neighborhoods in Xi'an, analyzed the relationship between these factors (population, environment, travel characteristic,)and commute trips.	
Huang Xinran, BRT Research Center ,Traffic Engineering Research Institute, Chang'an University, Xi'an 710064,CHINA E-mail: 489653249@qq.com	Organized students to take part in the "Spatial Planning & Low-carbon Xi'an" survey of four neighborhoods, collected the information on the four neighborhoods.	

Benefits:

1) Capacity building of young researchers in the project is the improvement of the ability of data analysis and the training of writing skills, and the access to handling various problems during all over the process.
2) Five of them have completed their directed research on the project and two of them have completed undergraduate graduation thesis.

4. List of young scientists in Melbourne

Table AIII-4 List of young scientists, Melbourne

Full name	Work done	How it helped
Xin Yang ABP UniMelb x.yang@student.unimelb.edu.au	Model calibration	Acquired skills about the application of SPSS in data transformation, management, statistical diagnostics, and regression modeling
Delong Sun ABP UniMelb d.sun@student.unimelb.edu.au	Variable coding	Acquired skills about data extraction, coding and graphical presentation of data using MS Excel.
Yina Sima ABP UniMelb ysima@unimelb.edu.au	Literature search	Acquired knowledge on low carbon cities research

Glossary of Terms
Include list of acronyms and abbreviations

In the Appendix section, the report may also include:
Actual data or access to data used in the study
Abstracts, Power Point Slides of conference/symposia/workshop presentations
Conference/symposium/workshop reports

The final project report must follow the template outlined in this document. Use Calibri font size 12 for all the headings and font size 11 for the text.

The report is to be submitted **one month before the end the Contract Period** in the following formats:

1. By airmail to the address below:
   a. **Soft Copy – 2 CD-ROMS**, appropriately labeled and covered using the design and information on the cover page of the Report Template
   b. **Hard Copy – 2 bound copies** appropriately labeled and covered using the design and information on the cover page of the Report Template

   Dr. Linda Stevenson
   APN Executive Science Officer
   APN Secretariat
   4F East Building
   1-5-2 Wakinohama Kaigan Dori
   Chuo-Ku, Kobe 651-0073 JAPAN

2. By e-mail and addressed to Dr. Stevenson (lastevenson@apn-gcr.org) and Taniya Koswatta (tkoswatta@apn-gcr.org).
   Kindly note that our server can also receive attachments of up to 8MB file size. In case that the final project report file size exceeds 8MB please try any of the following options:

   a. For a file size of more than 8MB but less than 10MB please send the report to our Gmail account at apngcr@gmail.com and notify us in our APN account so we could check for it immediately.
   b. For a larger file size please try the following:
      - Upload on your institution's ftp server and provide to us the download details (i.e. IP address, login details, etc)
      - Send through any of the free file hosting available in the internet. Please note that these free file hosting save your files for a limited number of days so it is very important to notify us immediately. Some of these are the following:
        - http://www.filefactory.com/
        - http://www.mediafire.com/
        - http://www.yousendit.com/
3. A separate **CD** containing other project outputs (i.e. publications, photos, etc)