Volume 4, No. 4 (2016)

International Review for Spatial Planning and Sustainable Development

SPSD Press from 2010

SPSD Press from 2010

International Review for Spatial Planning and Sustainable Development

For investigation regarding the impact of planning policy on spatial planning implementation, International Community of Spatial Planning and Sustainable Development (SPSD) seeks to learn from researchers in an integrated multidisciplinary platform that reflects a variety of perspectives—such as economic development, social equality, and ecological protection—with a view to achieving a sustainable urban form.

This international journal attempts to provide insights into the achievement of a sustainable urban form, through spatial planning and implementation; here, we focus on planning experiences at the levels of local cities and some metropolitan areas in the world, particularly in Asian countries. Submissions are expected from multidisciplinary viewpoints encompassing land-use patterns, housing development, transportation, green design, and agricultural and ecological systems.

IRSPSD INTERNATIONAL
ISSN 2187-3666 (Online)

International Review for Spatial Planning and Sustainable Development
https://www.jstage.jst.go.jp/browse/irspsd
http://spsdpress.jimdo.com/volumes/
http://dspace.lib.kanazawa-u.ac.jp/dspace/bulletin/irspsd

International Review for Spatial Planning and Sustainable Development

Volume 4, No. 4, 2016

SPSD Press from 2010

International Review for Spatial Planning and Sustainable Development

SPSD Press from 2010

International Review for Spatial Planning and Sustainable Development, Volume 4 No.4, 2016

Content

Special Issue on "Urban and Regional Sustainability in China"

International review for spatial planning and sustainable development, Vol.4 No.4 (2016), 1-3
ISSN: 2187-3666 (online)
DOI: http://dx.doi.org/10.14246/irspsd.4.4_1

Editorial introduction

Special Issue on "Urban and Regional Sustainability in China"

Guest Editors:

Feng Zhen[1]* and Jen Te Pai[2]

1 School of Architecture and Urban Planning, Nanjing University

2 Department of Land Economics, National Chengchi University

** Corresponding Author, Email: zhenfeng@nju.edu.cn*

Received: May 30, 2016; Accepted: June 30, 2016

Since 2000, China has entered into a new phase, which takes economic transformation and sustainable development as an important strategy for national, regional and urban development. Many scholars have discussed the pathways of globalization, innovation and development in China (Dicken, 1998; Wei, Y. H. D., 2007). Recently, with the rapid development and application of ICTs (Information and Communication Technologies), internet-dependent cities, resident mobility and social sustainability are also become hot topics in China (Zhen, Wang, & Wei, 2015). Therefore, this special issue addresses these four key issues: innovation, greening, mobility and sustainability.

The Chinese central government has vigorously promoted the development of low-carbon industry. The first paper, written by Wang, Liu, and Tan (2016), verifies the effectiveness of policies and measures to reduce carbon emissions, which partially offset the incremental carbon emissions produced by required industrial production. However, the authors also highlight that the effectiveness of local government efforts to reduce emissions is still insufficient, which induces the ongoing growth of the total amount of carbon emissions. The paper also reveals that there is a huge gap between the actual development of low-carbon industries and real industrial development. Most of the regions in China still face difficulties in reducing carbon emissions and improving urban livability.

Under the strategy of "internet plus" and mass innovation, traditional manufacturing cities in China are undergoing profound changes. Taking Shenzhen as a typical representative city, the second paper, by Fernandez, Puel, and Renaud (2016) analyzes the role of the local Shanzhai community (made up of entrepreneurs and companies historically based on the strategy of imitating high-end products) and the international manufacturing community in open innovation. Based on the built conceptual framework of open innovation, the authors conclude that the establishment of an innovation ecosystem for the Shenzhen electronics cluster was mainly promoted by open-source innovation. Although Shanzhai brings completely negative effects on open innovation and the upgrading of an electronics cluster, it is worth acknowledging that the open-source innovation driven by the manufacturing community can support and accelerate the modernization of declining industrial sectors. This open innovation is associated with the specific economic and industrial environment in Shenzhen. However, the open innovation paradigm is still an emerging approach for changes in technology and manufacturing cultures that are rooted in special territories.

Considering the new mobility paradigm in an information era, the third paper, by Xi, Zhen, and Chang (2016) argued that analysis on elemental flows should turn into the space of flows, which could be treated as the coupling of technologies, activities, socio-economic factors and physical environments. Based on this argument, the authors proposed a systematic measurement of the urban space of flows by evaluating spatial mobility from technological accessibilities, the intensity of activity and the spatial activeness. These theoretical methods are then used for extracting the topological structure of Nanjing City into the nodes of place, the route of flows, the boundary of flows, the functional zones and the network of flows. This topological structure implies the interaction between elemental flows and physical space, which provides a new approach to understanding the mixed morphology of urban space instead of the traditional space of places. According to the topological structure of urban space of flows, more attention should be given to those places with lower spatial mobility (such as new built districts with few residential activities) and those places with over crowed activities.

The fourth paper, by Wei, Z. et al. (2016) explores the evolution of housing estates and their social sustainability in China, using a case study of Guangzhou. The study finds that the housing reform which dramatically changed the supply side of housing from government to market-based, could be used to solve the shortage of housing conundrum and also could give rise to the improvement of living environments. The findings of this research indicate that the living environment of gated communities is indeed better than work-unit neighborhoods, but the social relations within the work-unit compounds are more harmonious.

China has become the largest tourist-generating country in the world (UNWTO, 2015), however, there is limited research on Chinese tourism, especially of student tourism. In the fifth paper, Xu, Brown, and Long (2016) discuss socio-cultural and indirect political influences on the tourist experiences and aspirations of Chinese students of tourism, based on a survey of Chinese students studying tourism management, using a free-elicitation technique. The result suggests that Chinese students produce a big potential market for European tourism. For their motivation, this study reveals that for Chinese youth, past travel experiences did not seem to be linked with a tendency to revisit the same place, but rather encourages interest in wider exploration.

Sustainability is a very broad and complex topic. Especially in China, there are many fields worthy of further exploration. This special issue addressed only a few topics regarding urban and regional sustainability. I hope more research about Chinese sustainability can be explored in future studies, based on the body of research presented in this special issue.

REFERENCES

Dicken, P. (1998). *Global Shift: Transforming the World Economy*. New York, NY: Guilford Publications.

Fernandez, V., Puel, G., & Renaud, C. (2016). "The Open Innovation Paradigm: From Outsourcing to Open-Sourcing in Shenzhen, China". *International Review for Spatial Planning and Sustainable Development, 4*(4), 27-41. doi: http://dx.doi.org/10.14246/irspsd.4.4_27

Wang, L., Liu, X., & Tan, M. (2016). "Regional Differences of the Driving Factors and Decoupling Effect of Carbon Emissions: Evidence from China's Pollution-Intensive Industry". *International Review for Spatial Planning and Sustainable Development*, *4*(4), 4-26. doi: http://dx.doi.org/10.14246/irspsd.4.4_4

Wei, Y. H. D. (2007). "Regional Development in China: Transitional Institutions, Embedded Globalization, and Hybrid Economies". *Eurasian Geography and Economics*, *48*(1), 16-36.

Wei, Z., Wang, B., Chen, T., & Lin, Y. (2016). "Community Development in Urban Guangzhou since 1980: A Social Sustainability Perspective". *International Review for Spatial Planning and Sustainable Development*, *4*(4), 58-68. doi: http://dx.doi.org/10.14246/irspsd.4.4_58

Xi, G., Zhen, F., & Chang, E. (2016). "Measuring Urban Space of Flows in Information Era: Empirical Evidence from Nanjing, China". *International Review for Spatial Planning and Sustainable Development*, *4*(4), 42-57. doi: http://dx.doi.org/10.14246/irspsd.4.4_42

Xu, F., Brown, L., & Long, P. (2016). "Travel Experiences and Aspirations: A Case Study from Chinese Youth". *International Review for Spatial Planning and Sustainable Development*, *4*(4), 69-87. doi: http://dx.doi.org/10.14246/irspsd.4.4_69

Zhen, F., Wang, B., & Wei, Z. (2015). "The Rise of the Internet City in China: Production and Consumption of Internet Information". *Urban Studies*, *52*(13), 2313-2329.

International review for spatial planning and sustainable development, Vol.4 No.4 (2016), 4-26
ISSN: 2187-3666 (online)
DOI: http://dx.doi.org/10.14246/irspsd.4.4_4

Regional Differences of the Driving Factors and Decoupling Effect of Carbon Emissions

Evidence from China's Pollution-Intensive Industry

Lafang Wang [1*] , Xia Liu[1] and Meimei Tan[1]
1 School of Economics and Trade, Hunan University
** Corresponding Author, Email: lfwang@hnu.edu.cn*

Received: May 01, 2016; Accepted: June 15, 2016

Key words: Pollution-intensive industry, CO_2 emissions, Completed decomposition technique, Decoupling analysis, Reduction potential

Abstract: The completed decomposition model combined with the decoupling index is used to analyze the contribution of each factor which influences energy-related CO_2 emission in 15 regions over the period 2000-2012. The results show that the major factors that influence CO_2 emission in areas are industrial output effect and energy intensity effect, followed by the industrial structure effect, while the energy structure and energy emission intensity have a smaller effect. Moreover, a reduction potential model is implemented in order to investigate the emission reduction potential of regions and sub-industrial sectors. It is found that although most governments showed great enthusiasm in promoting emission reduction, most regions present no decoupling effect. It indicates that emission reduction efforts have not always proven effective till now, therefore, most regions, including Beijing, have great energy saving and emission reduction potential.

1. INTRODUCTION

The Chinese Government has promised a CO_2 intensity target of 40%-45% reduction by year 2020 compared to 2005 levels, but the situation of its carbon emission ranking first in the world makes this task difficult to fulfil. How to implement the emission reduction policies at the industry level is key to realize this target. At present, China's economic growth is still in the pattern of growth led by manufacturing. So, although China has taken important measures to reduce its carbon emission, a sustainable high growth rate of manufacturing, especially of pollution-intensive ones, is still the main driving force of the rapid growth in CO_2 emissions.

Chinese natural resources are unevenly distributed and there have been big economic development differences in regions, which lead to an obvious regional difference in carbon emissions (Liu, Z. et al., 2010; Xiong et al., 2012). Many studies have focused on China's energy-related CO_2 emissions and some important opinions have been gained from the existing literature regarding the driving factors of CO_2 emissions (Wang, C., Chen, & Zou, 2005; Xu, Xu, & Hu, 2011). Unfortunately, there are very few studies with respect to the driving factors of CO_2 emission from a regional perspective (Li, Song, & Liu, 2014; Wei, Ni, & Du, 2012; Yi et al., 2011). Hardly any comparison of CO_2 emissions at the regional level from the perspective of pollution-intensive industries has been done. Therefore, it is necessary to investigate the driving forces of CO_2 emissions in the pollution-intensive industries and realize a deeper understanding of how CO_2 emissions related to pollution-intensive industries have evolved in regions. To achieve this goal, the proper approach needs to decompose the CO_2 emissions into the possible factors that affect such emissions. In this way, we can get a deeper understanding of the strengths and weaknesses of each region regarding their emission performance.

There are a variety of methods that can be used to decompose the CO_2 emissions, such as Structural decomposition analysis (SDA), IPAT equation, Divisia index decomposition analysis (Divisia IDA), and Laspeyres index decomposition analysis (Laspeyres IDA). The SDA method has been used in many studies (Tukker & Dietzenbacher, 2013; Wiedmann, 2009). However, it is based on an environmentally extended input-output table which is published every five years. Although the interval of data for four years can be calculated, it is built on a series of assumptions, the reliability is not high, and the economic development situation changes very fast. Therefore, SDA cannot fit the needs of research. For the IPAT equation, it is mainly used to analyze the impact of human activities on the environment, which reflects the influence of population, output and technology on CO_2 emissions (Dietz & Rosa, 1994; Ehrlich & Holdren, 1971). The IPAT equation does not take other factors such as the energy use into account. Divisia IDA and Laspeyres IDA use the index concept in decomposition (Hoekstra & Van den Bergh, 2003), which has been used in many studies on CO_2 emissions' decomposition due to the abundant availability of data. Although it has been proved by Ang (2004) and Greening et al. (1997) that there is a stronger theoretical basis in Divisia IDA than that in Laspeyres IDA, because there is a large residual term after decomposition in the traditional Laspeyres IDA, the Laspeyres IDA does have some advantages compared with others (Diakoulaki & Mandaraka, 2007; Xu, Xu, & Hu, 2011). Sun (1998) improved the Laspeyres IDA, modifying it into a complete decomposition technique, which eliminates the un-decomposed residual term, and makes the results more accurate. According to these advantages and disadvantages of above decomposition methods, this research employs the complete decomposition technique to decompose the CO_2 emissions.

The decomposition of carbon emissions can reflect the impact of each factor on carbon emissions, and tell us which factors determine the change of CO_2 emissions in different regions of China's pollution-intensive industries over the examined time. However, the degree of decomposition analysis is not sufficient for full examination of changes that took place in each area and sub-sector separately, and cannot show: (1) what reduction efforts have been done contributing to the maximum decline of the CO_2 emissions in each region? (2) Is there a regional difference in the relationship between development and emission reduction? (3) What is the reduction potential of CO_2 emissions of the pollution-intensive industries and how high can this be?

To answer the question (1) and (2), the proper approach is to try to determine the decoupling process of industrial growth from the CO_2 emissions level and to realize the joint exploitation of the factors identified in the complete decomposition analysis. This decoupling was proposed by OECD in 2002 firstly (Organization for Economic Co-operation and Development, 2002). As an important concept for integrating economy and environment (Enevoldsen, Ryelund, & Andersen, 2007; Wang, W. et al., 2013), it breaks the relationship between environmental damage and economic wealth, or the relationship between environmental pressure and economic performance. The decoupling theory has been widely used in many studies. The main methods adopted were the comprehensive analysis of variation method, the decoupling index method, the elastic analysis, the decoupling analysis method which is based on a complete decomposition technique, the statistical analysis method, the econometric analysis method and the differential regression coefficient method (Zhong et al., 2010). Among them, the decoupling index method is more widely applied. The decoupling index method and the elastic analysis are mainly focused on studying the relationship between economic growth and CO_2 emissions and they do not take other influence factors into account; the econometric analysis method and the differential regression coefficient method have high demand in data. Considering the availability of data and the purpose of this paper, we will choose the decoupling analysis method which is based on complete decomposition technique as a tool.

The third question implies an assessment of the gap between the optimal value and the real value of emission reduction. Although sample areas are regions of China, they show big differences in their levels of industrial development and industrial structure. Moreover, other obvious distinctions such as the availability of natural resources and the historical attachment to particular industrial activities make assessment a rather important task.

The remainder of this paper is organized as follows: Section 2 introduces the definition of pollution-intensive industries. Section 3 presents the methodology and the data. Section 4 provides the result and discussion. Section 5 contains concluding remarks.

2. DEFINITION OF POLLUTON-INTENSIVE INDUSTRY

According to the existing literature, pollution-intensive industries are generally considered to be those who produce large amounts of pollutants in the process of production or sales, but there is no consistent definition in current academia for this kind of industry, and also no uniform standard to define it. The current way of definition can be roughly divided into the following categories:

a) Calculating the index of pollution emission uses multiple indicators, such as industrial wastewater, waste gas and solid waste. And then the industry can be divided into high, middle, low pollution industries and cleaning industry (Liu, Q., Wang, & Li, 2012). The advantage of this method is that it can distinguish whether the industry is polluting industry or not, but it cannot distinguish the industry pollution types.
b) Judging by the degree or scale of pollution or contamination uses a single indicator, such as emissions scale or emissions intensity. Generally, the emissions scale is the sum of different kinds of pollutants. However, this method does not take the different properties of each pollutant into account.

From what has been mentioned above, in this paper, we take those two aspects into account when we define the pollution-intensive industries.

Step 1: Classify the type of pollutant. To achieve this, two indicators, including the emission intensity and emission scale, are constructed. Their calculation formula can be expressed as follows:

$$EI_{ij} = \frac{XE_{ij}}{X_i} \tag{1}$$

$$ES_{ij} = \frac{XE_{ij}}{ET} \tag{2}$$

where EI_{ij} and ES_{ij} denote the emission intensity and the emission scale of *j* pollutant in industry *i*; XE_{ij} denotes the j^{th} pollutant emission quantities of the i^{th} industry; X_i is the industrial production of the i^{th} industry; while ET is the total industrial added value. Using the relevant data of 2010, EI_{ij} and ES_{ij} can be calculated.

Step 2: Calculate the pollutant index of each type. The pollutants are divided into three categories: water pollutant which is measured by wastewater emissions, gas pollutant which is measured by the emission of SO_2, dust and smoke dust, and solid waste which is measured by solid waste emissions. Based on Equation (1) and Equation (2), the normalization process is shown as follows:

$$\overline{EI_{ij}} = \frac{EI_{ij} - \min(EI_{ij})}{\max(EI_{ij}) - \min(EI_{ij})} \tag{3}$$

$$\overline{ES_{ij}} = \frac{ES_{ij} - \min(ES_{ij})}{\max(ES_{ij}) - \min(ES_{ij})} \tag{4}$$

Based on Equation (3) and (4), the pollution index I_{ij} (where *j* is waste air, waste water and solid waste, respectively) of industry *i* can be calculated as illustrated in Equation (5):

$$I_{ij} = (\overline{EI_{ij}} * \overline{ES_{ij}})^{1/2} \tag{5}$$

Table 1, below, summarizes the results of these three kinds of pollution indexes. Correspondingly, the pollution-intensity industry is sorted into three groups including high-water-pollution industry, high-gas-pollution industry and high-solid-waste pollution industry.

The scope of this paper is to analyse the decoupling process of industrial growth from the CO_2 emissions level in the pollution-intensive industries. As the high carbon emissions industry generally belongs to the high-gas-pollution industry, we chose the pollution-intensive industry according only to the result of high-gas-pollution industries. As shown in *Table 1*, there are seven typical high-gas-pollution industries, including electricity, heat production and supply, non-metallic mineral products industry, ferrous metal smelting and rolling industry, chemical materials and chemical products manufacturing, paper and paper products industry, non-ferrous metal smelting and rolling industry, and petroleum processing and coking and nuclear fuel processing.

All the data of high-pollution industries that Section 3 requires are calculated from these seven industries.

Table 1. The categories of pollution-intensive industry

Industry	Waste air	Waste water	Solid waste
Production and Supply of Electric Power and Heat Power	1.0000	0.1602	0.4144

Manufacture of Non-metallic Mineral Products	0.5195	0.0400	0.0445
Manufacture and Processing of Ferrous Metals	0.2622	0.1254	0.2587
Manufacture of Chemical Raw Material and Chemical Products	0.1349	0.3598	0.1015
Manufacture of Paper and Paper Products	0.1270	1.0000	0.0351
Manufacture and Processing of Non-ferrous Metals	0.1151	0.0418	0.0811
Processing of Petroleum, Coking, Processing of Nucleus Fuel	0.1129	0.1002	0.0317
Mining and Washing of Coal	0.0521	0.1779	0.2848
Manufacture of Textile	0.0396	0.3725	0.0067
Mining of Non-ferrous Metal Ores	0.0391	0.1612	0.7383
Manufacture of Beverage	0.0350	0.2018	0.0149
Manufacture of Chemical Fibre	0.0348	0.1536	0.0100
Mining and Processing of Non-metal Ores	0.0308	0.0331	0.0495
Manufacture of Foods	0.0297	0.1291	0.0096
Mining of Ferrous Metal Ores	0.0292	0.0482	0.6402
Processing of Food from Agricultural Products	0.0284	0.1926	0.0174
Processing of Timbers, Manufacture of Wood, Rattan, Palm and Straw Products	0.0211	0.0114	0.0037
Manufacture of Medicines	0.0206	0.1222	0.0057
Manufacture of Rubber	0.0132	0.0204	0.0027
Manufacture of General Purpose Machinery	0.0116	0.0094	0.0045
Mining of Other Ores N.E.C	0.0113	0.0000	0.0195
Production and Distribution of Gas	0.0112	0.0075	0.0022
Extraction of Petroleum and Natural Gas	0.0086	0.0261	0.0031
Manufacture of Special Purpose Machinery	0.0082	0.0107	0.0021
Manufacture of Metal Products	0.0075	0.0498	0.0038
Manufacture of Transport Equipment	0.0067	0.0189	0.0034
Manufacture of Plastic	0.0059	0.0053	0.0008
Manufacture of Leather, Fur, Feather and its Products	0.0043	0.0789	0.0012
Manufacture of Tobacco	0.0032	0.0054	0.0007
Manufacture of Textile Wearing Apparel, Footwear and Caps	0.0028	0.0237	0.0006
Manufacture of Artwork, Other Manufacture N.E.C	0.0026	0.0052	0.0006
Recycling and Disposal of Waste	0.0017	0.0034	0.0020
Manufacture of Electrical Machinery and Equipment	0.0013	0.0000	0.0003
Printing, Reproduction of Recording Media	0.0010	0.0038	0.0002
Manufacture of Furniture	0.0010	0.0051	0.0003
Production and Distribution of Water	0.0007	0.2383	0.0009
Manufacture of Measuring Instrument and Machinery for Cultural Activity and Office Work	0.0001	0.0126	0.0005
Manufacture of Communication, Computer and Other Electronic Equipment	0.0000	0.0305	0.0008
Manufacture of Articles for Culture, Education and Sport Activity	0.0000	0.0018	0.0000

3. METHODOLOGY

3.1 Complete decomposition technique

The residuals decomposition method of the complete decomposition technique is based on the principle of "jointly created and equally distributed" (Sun, 1998). For example, the target variable Z can be decomposed as Equation (6):

$$Z = \prod_{i=1}^{n} x_i \tag{6}$$

where X_i denotes the i^{th} factor of target variable Z, n denotes the number of factors. Z_t and Z_0 denote the target variable in year t and in base year, therefore, Z_t and Z_0 is the sum of X_{it} (i.e. $X_{it} = X_{i0} + \Delta X_i$) and X_{i0}, respectively. Then the change in target variable recorded in time t in comparison with their level in a base year t=0 can be expressed as follows:

$$\Delta Z = Z_t - Z_0 = \prod_{i=1}^{n} x_{it} - \prod_{i=1}^{n} x_{i0} = \prod_{i=1}^{n} (x_{i0} + \Delta x_i) - \prod_{i=1}^{n} x_{i0} \tag{7}$$

In this paper, n=5, thus ΔZ can be shown as Equation (8):

$$\Delta Z = Z_t - Z_0 = \prod_{i=1}^{5} x_{it} - \prod_{i=1}^{5} x_{i0} = \prod_{i=1}^{5} (x_{i0} + \Delta x_i) - \prod_{i=1}^{5} x_{i0} \tag{8}$$

From Equation (8), we can see that ΔZ can be divided into two parts. The first part is the first item, which reflects the change of ΔZ resulting from the individual factor change. This is also the only part of the traditional LMDI model. The second part is the rest and reflects the change caused by multiple factors.

According to the principle of the complete decomposition technique, the value in the second part should be assigned to each of the corresponding factors (Sun, 1998), and then we can obtain the contribution of each factor to the target variable, which is shown as Equation (9):

$$\begin{aligned} X_{i-effect} = & \sum_{i=1}^{5} \frac{Z_0}{x_{i0}} \cdot \Delta x_i + \frac{1}{2} \sum_{i \neq j} \frac{Z_0}{x_{i0} \cdot x_{j0}} \cdot \Delta x_i \cdot \Delta x_j \\ & + \frac{1}{3} \sum_{i \neq j \neq k} \frac{Z_0}{x_{i0} \cdot x_{j0} \cdot x_{k0}} \cdot \Delta x_i \cdot \Delta x_j \cdot \Delta x_k \\ & + \frac{1}{4} \sum_{i \neq j \neq k \neq m} \frac{Z_0}{x_{i0} \cdot x_{j0} \cdot x_{k0} \cdot x_{m0}} \cdot \Delta x_i \cdot \Delta x_j \cdot \Delta x_k \cdot \Delta x_m \\ & + \frac{1}{5} \sum_{i \neq j \neq k \neq m \neq r} \frac{Z_0}{x_{i0} \cdot x_{j0} \cdot x_{k0} \cdot x_{m0} \cdot x_{r0}} \cdot \Delta x_i \cdot \Delta x_j \cdot \Delta x_k \cdot \Delta x_m \cdot \Delta x_r \end{aligned} \tag{9}$$

In this paper, the target variable Z is CO_2 emission C_{kt}, thus, C_{kt} can be decomposed as follows:

$$C_{kt}=\sum_{j=1}^{5}C_{jkt}=\sum_{i=1}^{7}P_{kt}\frac{P_{ikt}}{P_{kt}}\cdot\frac{E_{ikt}}{P_{ikt}}\cdot\sum_{j=1}^{5}\frac{E_{jkt}}{E_{kt}}\cdot\frac{C_{jkt}}{E_{jkt}}=\sum_{i=1}^{7}P_{kt}\cdot PS_{ikt}\cdot EI_{ikt}\cdot\sum_{j=1}^{5}ES_{jkt}\cdot EF_{jkt} \tag{10}$$

where C_{kt} denotes the total CO_2 emission of *k* region in year *t*. It also can be expressed as the total CO_2 emission of *k* region resulting from the consumption of five types of energy. C_{jkt} is the total CO_2 emission of the j^{th} energy of *k* region in year *t*. PS_{ikt} reflects the output shares of sector *i* in *k* region (i.e. P_{ikt}) within the total industry output of *k* region (i.e. P_{kt}) in year *t*. EI_{ikt} reflects the change in the ratio of energy consumption of sector *i* in *k* region (i.e. E_{ikt}) to the total produced value of sector *i* in *k* region (i.e. P_{ikt}). ES_{jkt} reflects the change in the share of energy forms in the total energy consumption of the pollution-intensive industry in *k* region. EF_{jkt} is the CO_2 emission of industrial energy use in *k* region.

The change in CO_2 emission ΔC_{kt} during the period of [0, *t*] can be shown in Equation (11):

$$\begin{aligned}\Delta C_{kt}&=C_{kt}-C_{k0}\\&=\sum_i P_{kt}\cdot PS_{ikt}\cdot EI_{ikt}\cdot\sum_j ES_{jkt}\cdot EF_{jkt}-\sum_i P_{k0}\cdot PS_{ik0}\cdot EI_{ik0}\cdot\sum_j ES_{jk0}\cdot F_{jk0}\end{aligned} \tag{11}$$

Combing Equation (9), the changes in CO_2 emission ΔC_{kt} during the period of [0, *t*] can be decomposed into five parts as shown in Equation (12):

$$\Delta C_{kt}=P_{kt}^{eff}+PS_{kt}^{eff}+EI_{kt}^{eff}+ES_{kt}^{eff}+EF_{kt}^{eff} \tag{12}$$

where P_{kt}^{eff} is the industrial output effect, reflecting CO_2 emission changes of *k* region resulting from output changes in pollution-intensive industries; PS_{kt}^{eff} is the industrial structural effect, reflecting CO_2 emission changes of *k* region resulting from structural changes in pollution-intensive industries; EI_{kt}^{eff} is energy intensity effect, reflecting CO_2 emission changes of *k* region resulting from energy intensity; ES_{kt}^{eff} is energy structural effect, reflecting CO_2 emission changes of *k* region resulting from the changes of the energy structure in pollution-intensive industries; EF_{kt}^{eff} is energy source emission intensity effect, reflecting CO_2 emission changes of *k* region resulting from the changes of energy emission intensity in pollution-intensive industries.

The value of ΔC_{kt} in equation (12) is an absolute value (*kt* CO_2). In order to better reflect the change in carbon emissions, the absolute value can be converted into the relative value (%) which is shown as a percentage:

$$dM_{kt}=\frac{M_{kt}^{eff}\cdot dC_{k}}{C_{k0}} \tag{13}$$

Here $dC_{kt}=\frac{\Delta C_{kt}}{C_{k0}}$, $M_{kt}^{eff}=P_{kt}^{eff}, PS_{kt}^{eff}, EI_{kt}^{eff}, ES_{kt}^{eff}, EF_{kt}^{eff}$, respectively.

3.2 Decoupling analysis method

In reference to the definition given by Diakoulaki and Mandaraka (2007), the emission reduction is actually the result of all actions inducing a decline in the CO_2 emission of industrial production, such as optimizing the industrial structure, improving energy efficiency, and increasing the usage ratio of clean energy. These efforts correspond to the industrial structural effect PS_{kt}^{eff} , energy intensity effect EI_{kt}^{eff} , energy structure effect ES_{kt}^{eff} and energy source emission intensity effect EF_{kt}^{eff} . Therefore, for the government of region *k*, all the effort they made in year *t* (ΔF_{kt}) can be expressed as the sum of these four effect factors, that is:

$$\Delta F_{kt} = PS_{kt}^{eff} + EI_{kt}^{eff} + ES_{kt}^{eff} + EF_{kt}^{eff} \tag{14}$$

Generally, when talking about low-carbon economies, this refers to an economy which is in the decoupling process between economic growth and greenhouse gas emissions, that is, the growth speed of the economy is faster than that of the CO_2 emission intensity (Guo, 2010). According to the decoupling theory, the decoupling index is measured by the ratio of environmental pressures to economic driving forces such as economic activities (Diakoulaki & Mandaraka, 2007). The value of ΔF_{kt} may take a negative sign if the sum of these four factors resulting in emission reduction. Therefore, the decoupling index (D_{kt}) can be expressed as Equation (15):

$$D_{kt} = \begin{cases} -\Delta F_{kt} / P_{kt}^{eff}, & P_{kt}^{eff} > 0 \\ (\Delta F_{kt} - P_{kt}^{eff}) / P_{kt}^{eff}, & P_{kt}^{eff} < 0 \end{cases} \tag{15}$$
$$= D_{PS} + D_{EI} + D_{ES} + D_{EF}$$

where D_{PS} indicates the industrial-structure decoupling index, D_{EI} indicates the energy-intensity decoupling index, D_{ES} is the energy-structure decoupling index, and D_{EF} reflects the energy-emissions-intensity decoupling index.

According to the above analysis, there are three values in this decoupling index D_{kt} :

a) If $D_{kt} \leq 0$, it reflects no decoupling efforts. That is to say, emission reduction policies miss the mark or the policies have no effect. So the CO_2 emission still increases fast alongside the development of the economy.
b) If $0 < D_{kt} < 1$, it means there is a weak decoupling efforts. This case suggests that the emission reduction policies have a certain effect, CO_2 emission is now slowing, but the reduction volume is less than the increase of emission caused by the development of the economy. Therefore, the total CO_2 emission is still increasing.
c) If $D_{kt} \geq 1$, it means there are strong decoupling efforts. It reflects that the emission reduction policies have an obvious effect in the reduction of CO_2 emission and lead to a larger volume reduction of CO_2 emission than the new growth resulting from the development of the economy.

3.3 Reduction potential

The above reflects the government's carbon emissions reduction efforts, but it cannot reflect the reduction potential of the CO_2 emissions of pollution-intensive industries.

The reduction potential is the likelihood that emissions can be reduced. Emission reduction potential of each region can be represented as follows:

$$I_k = (1 - \frac{CE_{\min}}{CE_k}) * 100 \quad (16)$$

where $CE_{\min}$ reflects the minimum of the carbon emission intensity among all samples; CE_k is the carbon emission intensity of the region *k*. Equation (16) implies that the carbon intensity of all areas will be close to the minimum value. The emission reduction potential of the lowest carbon emissions intensity of the region is zero, and the rest of the region varies from 0 to 100. The bigger the *I*, the bigger the emission reduction potential.

3.4 Data description

In this paper, the data comes from various issues of the statistical yearbook of provinces and cities. The industrial output was calculated at constant 2000 prices. Carbon emissions are the total emission of five energies used by seven high-pollution industries. Because the original data of energy consumption is in physical quantities, we convert the physical quantities to standard statistics firstly, and then use the standard coal consumption coefficient to calculate the total emission of each type of energy (*Table 2*). This method is more reasonable and accurate compared with the emission of end-use energy consumption. It needs every kind of energy consumption data of the seven pollution-intensive industries in regions, but the data in the statistical yearbook of some provinces is not complete. Therefore, this paper picks up fifteen typical provinces and cities as the subjects of study, including Beijing, Tianjin, Shanxi, Inner Mongolia, Liaoning, Jilin, Anhui, Fujian, Jiangxi, Henan, Hubei, Chongqing, Gansu, Ningxia and Xinjiang. The energy is composed of coal, coke, gasoline, diesel and electricity.

Table 2. The standard coal coefficient and carbon emissions coefficient of four energies

Energy	Standard coal coefficient (kgce/kg)	Carbon emission coefficient (tCO2/toe)	Energy	Standard coal Coefficient (kgce/kg)	Carbon emission coefficient (tCO2/toe)
Raw coal	0.7143	2.769	Gasoline	1.4714	2.029
Coke	0.971	3.314	Diesel	1.4571	2.168

The standard coal coefficient is referenced from "General principles for calculation of total production energy consumption" (GB/T2589-2008), and the carbon emission coefficient of energy, except electricity, is calculated in reference to the IPCC Carbon Emission Calculation Formula (2006 edition). The carbon emissions coefficient of electricity is not fixed because the power generation technology in cities and provinces is different. Therefore, we calculate the carbon emissions coefficient of electricity in reference to the method of Fu (2011). The standard coal coefficient and carbon emission coefficient of five energies are shown in *Table 2* and *Table 3*.

Table 3. Carbon emission coefficient of electricity in ten provinces and cities: 2000-2012 (tCO_2/toe)

	BJ	TJ	LN	JL	FJ	SX	NMG	HN
2000	7.04	7.54	7.85	6.67	3.97	8.3	8.06	8.33
2001	7.03	7.39	7.7	6.35	3.65	8.14	8.03	8.09
2002	7.00	7.39	7.72	6.79	4.42	8.11	7.99	7.99

2003	6.87	7.37	7.6	7.18	5.16	8.08	7.83	8.01
2004	7.01	7.28	7.49	6.87	5.76	7.98	7.47	8.71
2005	6.9	7.23	7.4	6.56	4.61	7.91	7.08	7.72
2006	6.66	7.19	7.42	6.99	4.55	7.63	7.51	7.44
2007	6.49	7.12	7.18	6.74	4.91	7.48	7.38	7.16
2008	6.21	7.16	6.98	6.4	4.78	7.14	7.24	6.89
2009	5.96	7.05	6.92	6.02	5.11	7.21	6.97	6.75
2010	5.79	6.83	6.5	5.52	4.43	7.02	6.63	6.66
2011	5.77	6.82	6.52	5.85	5.43	7.02	6.6	6.65
2012	5.35	6.75	6.17	5.59	4.5	6.85	6.43	6.37
	HB	AH	JX	CQ	GS	NX	XJ	
2000	4.07	7.71	6.35	6.77	4.72	7.45	8.28	
2001	4.44	7.62	6.26	6.91	5.04	7.57	7.73	
2002	4.54	7.48	6.1	6.54	5.44	7.56	7.64	
2003	4.13	7.93	6.98	6.42	5.93	7.34	7.91	
2004	2.97	7.53	7.04	6.27	5.48	7.27	8.00	
2005	2.85	7.44	6.8	6.31	5.03	7.3	8.27	
2006	3.29	7.41	6.28	6.67	5.17	7.26	8.12	
2007	2.87	7.2	6.49	5.99	5.07	7.16	7.63	
2008	2.3	6.98	6.11	5.4	4.93	6.98	7.53	
2009	2.51	6.8	6.16	5.42	4.5	6.84	7.34	
2010	2.68	6.72	5.93	5.31	4.81	6.7	6.81	
2011	3.11	6.77	6.32	5.52	4.76	6.8	6.96	
2012	2.62	6.56	5.44	2.44	4.73	6.52	6.47	

Data resource: China Electric Power Yearbook from 2001 to 2012

Abbreviation note: BJ: Beijing City, TJ: Tianjin City, SX: Shanxi Province, NMG: Inner Mongolia Autonomous Region, LN: Liaoning Province, JL: Jilin Province, AH: Anhui Province, FJ: Fujian Province, JX: Jiangxi Province, HN: Henan Province, HB: Hubei Province, QC: Chongqing City, GS: Gansu Province, NX: The Ningxia Hui Autonomous Region, and XJ: Xinjiang Uygur Autonomous Region.

The other data used in this paper are presented in *Table 4*-*Table 6*, below. Specifically, *Table 4* shows total energy consumption in high-pollution industries and the consumption ratio of five energies. It can be seen that during the period 2000-2012, coal, accounting for 76% of total energy consumption, is the principal energy in all regions. The total energy consumption in each region is rising, and the average growth rate is 310%. Among them, the highest growth rate of energy consumption is Xinjiang (729%), while the smallest one is Beijing (35%).

Table 4. Total energy consumption in high-pollution industries and the five energy consumption ratios for the years 2000-2012

Regions	Year	Raw coal	Coke	Gasoline	Diesel	Electricity	Total (10^7ktoe)
BJ	2000	36%	46%	1%	1%	16%	929
	2012	83%	0%	0%	1%	15%	1258
TJ	2000	48%	30%	1%	2%	19%	429
	2012	32%	46%	0%	1%	21%	1815
SX	2000	85%	11%	0%	0%	4%	8224
	2012	82%	12%	0%	0%	6%	22567
NMG	2000	86%	7%	0%	1%	6%	3165
	2012	86%	6%	0%	0%	8%	23295
LN	2000	79%	13%	0%	0%	7%	6223
	2012	69%	21%	0%	1%	9%	14573

JL	2000	84%	7%	0%	0%	8%	2141
	2012	83%	10%	0%	0%	7%	6192
AH	2000	82%	11%	0%	0%	6%	2069
	2012	82%	10%	0%	0%	8%	9461
FJ	2000	82%	6%	0%	2%	10%	1338
	2012	77%	9%	0%	1%	13%	5879
JX	2000	71%	16%	0%	1%	13%	1268
	2012	69%	20%	0%	0%	11%	4281
HN	2000	85%	7%	0%	0%	8%	5166
	2012	89%	0%	0%	0%	11%	16483
HB	2000	83%	0%	0%	1%	16%	2048
	2012	83%	0%	0%	0%	17%	5936
CQ	2000	75%	14%	0%	0%	10%	955
	2012	71%	11%	0%	1%	17%	2503
GS	2000	73%	12%	0%	0%	14%	1426
	2012	72%	12%	0%	0%	16%	5401
NX	2000	80%	5%	0%	0%	15%	719
	2012	84%	2%	0%	0%	14%	5317
XJ	2000	87%	5%	1%	1%	6%	1103
	2012	79%	10%	0%	0%	11%	9148

Table 5 denotes total output in high-pollution industries and the share of sub-sectors. The growth rate of output in high-pollution industries presents significant differences in both their reference values in 2000, as well as in their development with time. The maximum growth rate is Shanxi with a rate of 2300%, while the minimum one is Beijing with a rate of 214%. For most regions, Chemical, ferrous metals and electric and heat power are the main sectors which account for more than 50% in output, but the new increasing areas of the economy in some regions have transformed chemical to non-metals and non-ferrous metals during the period 2000-2012.

Table 6 presents the energy intensities of the high-pollution industries and of seven sub-sectors calculated based on the data of *Table 4* and *Table 5*. With the exception of Xinjiang and Ningxia having increased energy intensity, all other regions present a decreasing trend. The maximum energy intensity is Shanxi, although it has decreased 88.9% from 2000 to 2012. The minimum one is Tianjin. At a sector level, the maximum sector is electric and heat power, which is larger than other sub-sectors, followed by petroleum, non-metals, ferrous metals, chemical and paper, and the minimum is non-ferrous metals, but the gap between sectors is small.

Table 5. Total output in high pollution industries and the share of sub-sectors for the years 2000-2012

Region	Year	Paper	Petroleum	Chemical	Non-metallic	Ferrous	Non-ferrous	Electric	Total
BJ	2000	2%	34%	17%	12%	23%	1%	10%	768
	2012	1%	18%	7%	9%	3%	2%	60%	2416
TJ	2000	4%	19%	28%	6%	29%	6%	9%	705
	2012	3%	3%	17%	4%	53%	10%	10%	4935
SX	2000	1%	12%	15%	8%	32%	13%	20%	129
	2012	0%	20%	9%	5%	37%	7%	22%	3096
NMG	2000	2%	7%	11%	6%	37%	9%	27%	377
	2012	1%	6%	17%	9%	22%	21%	23%	3909
LN	2000	1%	33%	15%	9%	24%	6%	12%	2073
	2012	2%	23%	15%	18%	28%	6%	9%	9896
JL	2000	3%	7%	48%	9%	13%	3%	16%	555
	2012	3%	4%	31%	27%	17%	3%	16%	3245
AH	2000	4%	15%	20%	14%	19%	13%	17%	578
	2012	3%	4%	17%	17%	21%	16%	23%	3613
FJ	2000	12%	13%	15%	20%	11%	6%	24%	701
	2012	9%	9%	13%	23%	19%	9%	19%	3739
JX	2000	3%	19%	13%	12%	18%	17%	17%	401

	2012	2%	3%	9%	9%	6%	21%	48%	2932
HN	2000	7%	10%	16%	22%	10%	12%	23%	1381
	2012	5%	6%	14%	27%	15%	19%	14%	7370
HB	2000	5%	16%	19%	16%	23%	6%	16%	1034
	2012	4%	6%	24%	17%	26%	8%	15%	5418
CQ	2000	3%	1%	27%	19%	20%	11%	18%	273
	2012	5%	2%	21%	20%	20%	14%	17%	1936
GS	2000	1%	22%	15%	8%	10%	25%	19%	519
	2012	0%	26%	8%	7%	18%	25%	16%	2349
NX	2000	6%	4%	31%	6%	8%	23%	21%	133
	2012	2%	22%	13%	6%	11%	18%	29%	727
XJ	2000	2%	53%	6%	10%	11%	4%	13%	292
	2012	1%	41%	12%	8%	15%	11%	16%	1242

Abbreviation notes: Paper: Manufacture of Paper and Paper Products; Petroleum: Processing of Petroleum, Coking, Processing of Nucleus Fuel; Chemical: Manufacture of Chemical Raw Material and Chemical Products; Non-metallic: Manufacture of Non-metallic Mineral Products; Ferrous: Manufacture and Processing of Ferrous Metals; Non-ferrous: Manufacture and Processing of Non-ferrous Metals; Electric: Production and Supply of Electric Power and Heat Power. Total: the total of all high pollution industries.

Table 6. Energy intensities in high pollution industries and in seven sub-sectors for the years 2000-2012

Region	Year	Paper	Petroleum	Chemical	Non-metallic	Ferrous	Non-ferrous	Electric	Total
BJ	2000	0.5	0.1	0.4	2.1	3.2	0.2	0.7	1.2
	2012	0.2	0.0	0.2	0.1	0.1	0.0	0.3	0.5
TJ	2000	0.6	0.1	0.6	1.2	1.1	0.4	0.1	0.6
	2012	0.2	0.0	0.2	0.2	0.4	0.0	0.1	0.3
SX	2000	10.3	43.2	7.8	8.9	5.7	1.6	17.2	63.8
	2012	0.9	5.8	2.0	1.6	1.7	1.6	5.2	7.1
NMG	2000	2.1	7.4	6.0	5.6	3.7	1.5	19.8	8.4
	2012	0.2	4.8	1.7	2.1	1.4	0.3	8.3	5.7
LN	2000	2.8	0.3	1.0	2.3	4.6	1.1	11.0	3.0
	2012	0.2	0.1	0.2	0.4	1.1	0.2	3.3	1.5
JL	2000	3.2	0.1	0.4	3.0	2.3	1.5	17.6	3.9
	2012	0.5	0.1	0.2	0.6	1.0	0.4	5.0	1.7
AH	2000	1.3	0.9	2.1	3.5	3.3	0.4	11.1	3.6
	2012	0.3	0.1	0.5	0.9	0.7	0.0	2.6	2.4
FJ	2000	0.8	0.0	2.0	1.7	1.6	0.3	4.1	1.9
	2012	0.2	0.0	0.3	0.5	0.6	0.1	2.0	1.6
JX	2000	2.7	0.4	2.3	5.1	3.5	0.6	7.9	3.2
	2012	0.2	0.0	0.1	4.1	1.0	0.0	0.2	1.6
HN	2000	1.4	1.3	3.2	2.4	3.0	1.6	8.5	3.7
	2012	0.3	2.0	0.5	0.2	0.2	0.2	3.3	2.2
HB	2000	0.8	0.0	1.9	2.2	1.0	0.7	6.2	2.0
	2012	0.2	0.0	0.5	0.5	0.2	0.1	1.5	1.2
CQ	2000	1.0	0.8	1.4	4.4	2.6	0.4	9.1	3.5
	2012	0.5	1.0	0.5	0.7	0.6	0.2	1.7	1.4
GS	2000	1.5	0.2	1.9	3.6	5.6	1.6	6.1	2.7
	2012	0.7	0.1	1.0	1.5	1.5	0.6	3.5	2.2
NX	2000	2.8	3.6	3.3	6.4	5.1	1.3	13.8	5.4
	2012	2.1	1.1	2.1	1.7	1.2	0.9	6.0	7.4
XJ	2000	3.4	1.0	2.1	5.9	2.7	1.2	16.1	3.8
	2012	1.2	1.1	2.4	1.9	1.8	0.9	6.2	6.0

4. RESULTS AND DISCUSSION

4.1 Analysis of energy-related CO_2 emissions from high-pollution industrial sectors

The direct (due to fuel consumption) and indirect (because of industrial electricity consumption) contribution of CO_2 emissions of the high-pollution industrial sectors in China's industrial sectors rose between 2000 and 2012 from 82.86% to 87.53% (*Figure 1*). In 2000, the amount of carbon emissions of polluting industries exceeded 100 million tons in Liaoning and Shanxi, Tianjin is the smallest with only 8.72 million tons. But in 2012, there are nine provinces, the two largest regions are Inner Mongolia and Shanxi, reaching up to 455 million tons and 444 million tons, respectively, followed by Liaoning, 307 million tons, and Beijing, the smallest with only 22.16 million tons. CO_2 emissions of the 15 regions increased, the fastest growth rate is in Xinjiang (713%), while the growth rate of Beijing is only 6.5%. The reasons explaining these changes in energy-related CO_2 emissions will be investigated through the complete decomposition analysis presented in the following section.

Figure 1. Energy-related CO_2 emissions from high-pollution industrial sectors (ten thousand ton)

4.2 Decomposition of changes in CO_2 emissions in high-pollution industrial sectors

As can be seen from *Table 7*, each driving factor has a different impact on CO_2 emissions in these fifteen regions. The main factors are the industrial output effect (P_{kt}^{eff}) and energy intensity effect (EI_{kt}^{eff}), followed by the industry structural effect (PS_{kt}^{eff}), while the energy structural effect (ES_{kt}^{eff}) and energy emission intensity effect (EF_{kt}^{eff}) make a small contribution to CO_2 emission. Furthermore, industrial output effect is a constant positive, which not only means that the industrial output effect results in the continual increase of energy-related CO_2 emissions over the period 2000-2012, but also indicates that energy saving and emission reduction in high-pollution industries may pay a price by enacting output growth deceleration. The energy intensity effect in most regions is negative in most years over the period 2000-2012, indicating that energy intensity effect plays a key role in decreasing the regional CO_2 emissions. With the exception of a few regions having positive effects, the industry structural effect mainly plays a negative role, indicating that the optimization of the industrial structure has a negative impact on the increase of emissions. The energy structure effect is unbalanced, which is related to endowment elements that vary in regions.

Although the whole energy consumption relative to GDP drops obviously, China's coal-dominated energy structure have not changed drastically. In addition, we can also see that energy emission intensity mainly contributes negatively to CO_2 emission, but in some areas shows positive effects. It is worth mentioning that although the energy structure effect makes a small contribution to CO_2 emission, if China cannot gradually reduce the proportion of coal consumption, the negative effect brought on by the energy intensity effect would be offset by the positive effect brought on by the energy structure effect.

Table 7. The components of the complete decomposition analysis

Region	Year	P_{kt}^{eff}	PS_{kt}^{eff}	EI_{kt}^{eff}	ES_{kt}^{eff}	EF_{kt}^{eff}	ΔC_{kt}
BJ	2000-2006	1155.8	169.0	-716.5	-378.8	-56.7	172.8
	2006-2012	725.4	175.2	-877.9	215.0	-196.7	41.0
TJ	2000-2006	994.1	146.3	-228.7	43.8	-47.9	907.6
	2006-2012	1678.7	194.2	-1077.6	133.8	-86.9	842.2
SX	2000-2006	5406.0	1134.7	-6329.3	85.3	-190.3	106.4
	2006-2012	12357.2	225.9	-5531.8	1810.3	-602.9	8258.6
NMG	2000-2006	6321.8	-97.6	-2321.7	1027.5	-244.7	4685.3
	2006-2012	9849.3	-1547.3	-2551.7	230.3	-856.1	5124.4
LN	2000-2006	4204.7	654.9	-924.2	65.5	-200.0	3801.0
	2006-2012	5139.2	-1509.2	-1098.2	350.5	-657.5	2224.9
JL	2000-2006	1956.8	625.4	-886.2	-390.2	60.2	1366.1
	2006-2012	2769.8	-835.2	-1967.3	92.5	-279.7	-219.8
AH	2000-2006	1042.7	59.8	529.2	-1051.7	4.1	584.1
	2006-2012	2832.7	542.3	-3593.3	1643.2	-242.9	1182.1
	2000-2012	3689.3	1462.2	-2853.9	581.5	-718.5	2160.4
FJ	2000-2006	1256.4	177.1	-431.9	168.5	124.8	1294.9
	2006-2012	1858.8	-572.5	-201.7	78.8	-13.2	1150.2
JX	2000-2006	1131.4	-126.9	-302.0	-205.1	-260.12	491.3
	2006-2012	2970.3	3520.94	-1207.51	175.23	3.3	-4612.5
HN	2000-2006	5026.9	-652.8	-995.1	503.6	-453.4	3429.2
	2006-2012	4473.8	-2249.3	-805.7	495.7	-598.2	1316.3
HB	2000-2006	1788.6	188.4	-573.2	-414.4	-279.3	710.1
	2006-2012	1767.0	-412.6	-2209.6	316.1	-213.5	-752.7
CQ	2000-2006	959.8	-60.0	-435.2	147.4	-12.1	599.9
	2006-2012	1356.4	-31.7	-681.9	250.4	-366.9	526.2
GS	2000-2006	1339.7	-555.3	-192.8	-24.0	115.1	682.7
	2006-2012	2117.8	516.4	-980.2	227.1	-192.4	1688.6
NX	2000-2006	1309.8	13.9	-587.5	99.3	-35.3	800.2
	2006-2012	1739.6	-4.2	-24.9	-191.9	-192.9	1325.8
XJ	2000-2006	997.6	-155.9	150.5	-88.5	-21.2	882.5
	2006-2012	1639.3	336.6	-236.3	100.6	-418.0	1422.1

The impact of each single factor is illustrated in the following remarks.

Industrial output effect (see Figure 2): the output effect is the critical driving factor in the growth of energy-related CO_2 emissions influencing carbon emissions changes, reflecting the corresponding growth of industrial output in 15 regions. In most regions, the contribution amounts to 60%-70%. Tianjin shows the highest impact (180.8%), followed by Inner Mongolia and Ningxia. Among the leading industries contributing to the rise in the industrial output, chemical, ferrous metals, and the electric industry are predominant in these regions (see *Table 5*). The output of these three sub-sectors averagely amount to about 60% of the high pollution industries. Among them, ferrous metals and the electric industry are the largest energy consumers of the seven sub-sectors. Conversely, Liaoning and Anhui present the lowest influence in accordance with the declining role of high pollution industries in their economies.

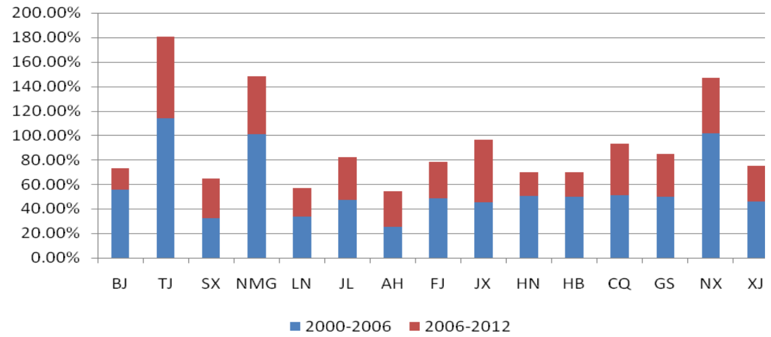

Figure 2. Percent change in pollution-intensive industrial CO_2 emissions due to the output effect

Industrial structure effect (*Figure 3*): From the perspective of absolute amount, in the period 2000-2012, the industrial structure effect mainly has a positive effect in Jiangxi and Tianjin, in that the share of high CO_2 emission industries such as ferrous metal, electric and other industries are growing rapidly, leading to the rapid growth of CO_2 emissions. Unfortunately, no dramatic changes take place in typical regions toward the reduction in number of the energy intensive sectors. Although Inner Mongolia, Henan and Chongqing present a negative industrial structure effect, it does not show great shifts in regional industrial activities, but a slight decline of energy intensive sectors. Simultaneously, the proportion of low CO_2 emissions industries in these regions is increasing. Industrial structure, therefore, helps to reduce CO_2 emissions and plays a negative effect. Tianjin, Beijing, Anhui and Shanxi show an opposite trend with the rapid growth of its heavy industries, thus acquiring its overall industrial development.

Energy intensity effect (*Figure 4*): the energy intensity effect also plays a key role in inhibiting carbon emissions increase. Results show that in 15 regions, energy efficiency improvements are higher in the seven energy intensive industries than other industries, especially in the ferrous metals and chemical industries. Tianjin, Beijing, Shanxi and Inner Mongolia have great absolute amounts of this effect, and the energy intensities of these regions show a sharp drop of about 70%, 52%, 51% and 49%, respectively. The only exception toward improving energy efficiency is recorded in Xinjiang, exhibiting energy intensity increase, especially in the ferrous metals, electric and chemical industries.

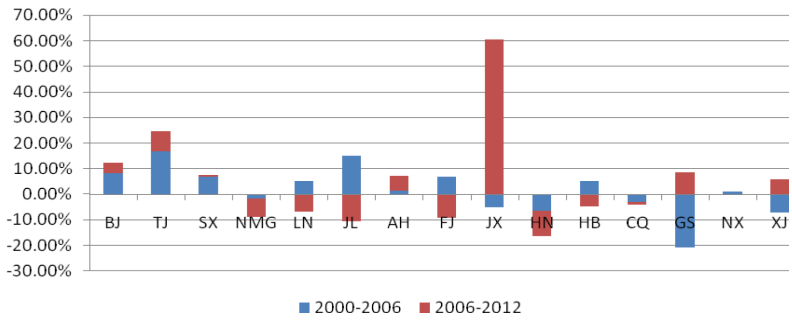

Figure 3. Percent change in pollution-intensive industrial CO_2 emissions due to the industrial structure effect

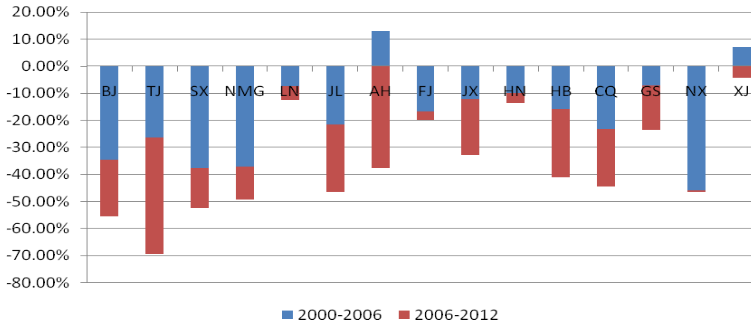

Figure 4. Percent change in pollution-intensive industrial CO_2 emissions due to the energy intensity effect

Energy structural effects (*Figure 5*): this effect is generally less than 10%. It is dominated by the energy consumption structure of China, and it reflects that China's fuel switching from coal and oil to natural gas is not obvious, the primary energy type of consumption is still coal. The energy structure in Tianjin, Inner Mongolia and Chongqing, plays a significant positive role, indicating that the adjustment of energy in these areas promotes the carbon emissions increase. The energy structure in Beijing, Anhui, Jilin and Hubei, shows a negative effect. In addition to a positive shift from coal and oil towards natural gas, they further increase the use of biomass and of combined electricity in energy intensive industries.

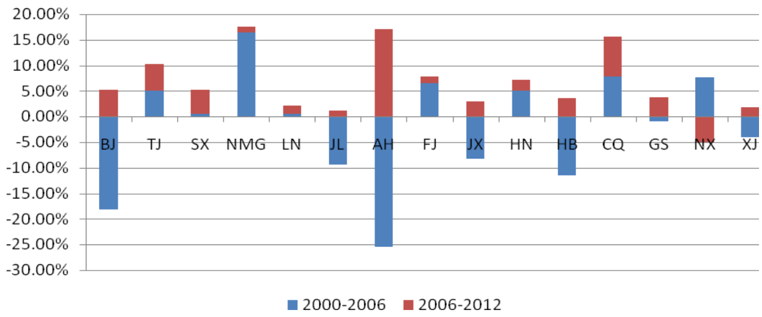

Figure 5. Percent change in pollution-intensive industrial CO_2 emissions due to the energy structure effect

Energy emission intensity effect (*Figure 6*): the effect of energy emissions intensity on carbon emissions is relatively small and negative as a whole, showing that the effect of energy emission intensity on carbon emissions plays a slightly inhibitory role in most regions. It reflects that the gradual implementations of energy-saving policies improve the energy efficiency and decrease the energy intensity in most regions with growing shares of natural gas or renewable energies. Fujian province is the only area showing a rising effect.

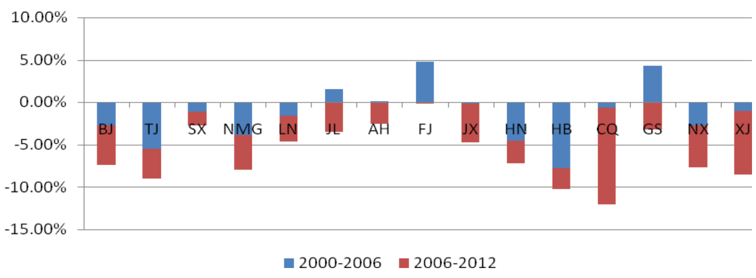

Figure 6. Percent change in pollution-intensive industrial CO_2 emissions due to the energy emission intensity effect

4.3 Analysis of reduction efforts

Figure 7 presents the emission reduction efforts made during the period 2000-2006 and 2006-2012. It can be observed that the emission reduction measures of 15 regions are basically effective in two periods. The top three are Beijing, Tianjin and Fujian. In the period 2006-2012, their efforts lead to a total emission reduction of about 17%-39%. In the other twelve areas the respective percentage is below 10%. Among them, Shanxi's reduction effort lead to an accumulated decrease of 17093.6×10^4 ton (i.e. -3.8%) CO_2 emissions during the period 2000-2012.

It should be noted that this does not mean the efforts in the 15 areas are sufficient. In Beijing, the efforts made in the period 2006-2012 have compensated for a small part of the negative changes of the others. On the one hand, that might be the reason that the marginal cost of further reducing energy intensity or of increasing the share of cleaner energy forms for Beijing's fuel mix is high. On the other hand, in this period, not all the energy intensity of pollution-intensive industries declined in Beijing. The growth rate of the oil industry and electricity industry reached 127% and 63%, respectively, which makes the overall energy intensity fail to curb the increase of carbon emissions.

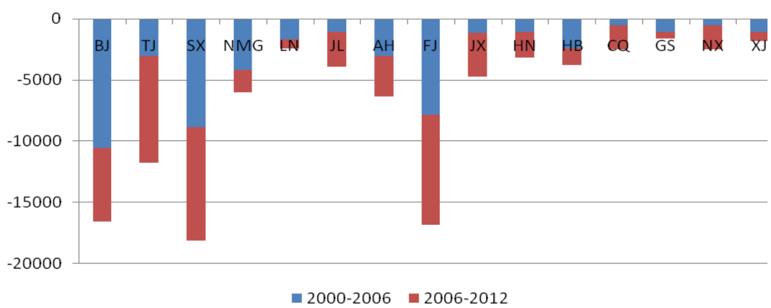

Figure 7. Absolute change in pollution-intensive industrial CO_2 emissions associated with emission reduction effort

Figures 1 to *7* reveal significant points. For example, Beijing, despite its impressive efforts, failed to decrease carbon emissions below the 2000 level, conversely emissions exhibited an increase of 13%. Similarly, with a total increase of 140%, Tianjin showed great initiatives in promoting CO_2 emission reduction measures. This indicates that we cannot assess the effort of government's performance only based on the change of the amount of CO_2 emissions.

4.4 Analysis of decoupling index

Figures 8 and *9* show the decoupling index calculated for the 15 regions under consideration, together with the distribution of four efforts. It indicates that among the four decoupling indexes, the biggest contributor to the total decoupling index is energy intensity, followed by industry structure and energy structure, while energy emission intensity is the smallest contributor.

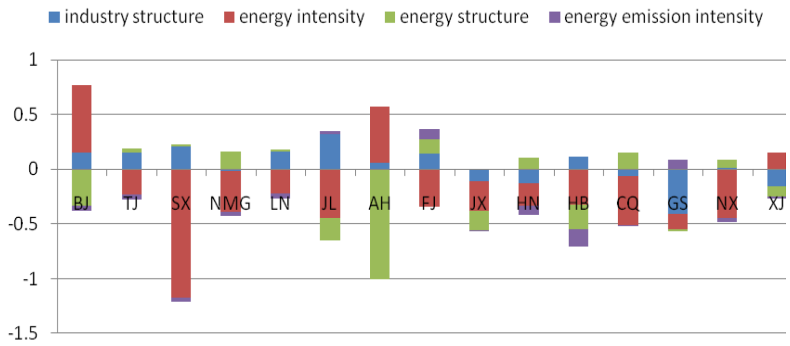

Figure 8. The decoupling index of high pollution industries of 15 regions in the period 2000-2006

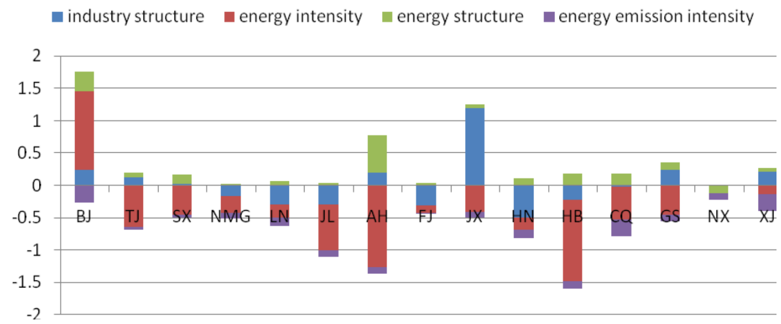

Figure 9. The decoupling index of high pollution industries of 15 regions in the period 2006-2012

According to the decoupling index, in the period 2006-2012, the 15 regions can be divided into three categories:

Regions with a strong decoupling index (*D*>1), including Beijing: The decoupling index of Beijing's pollution-intensive industries has changed from 0.39 in the period 2000-2006 to 1.48 in the period 2006-2012. From *Figures 1* and *7*, we find that the regions with a strong decoupling index is mainly due to the larger decoupling index of energy intensity, indicating that carbon emission reductions due to energy intensity reduction are greater than the increase resulting from industrial growth. At the same time, among the

15 regions, Beijing presents a low and positive industrial output effect, which indicates that its decoupling procession goes along with the stabilization of energy-intensive industries' production and with shifts toward other sectors. Of course, the fuel switches in utilities in Beijing is also a very important cause.

Regions with a weak decoupling effect ($0<D<1$), including Jiangxi, indicate that carbon emission reductions owing to government efforts in their pollution-intensive industries have compensated for a large part of the increases caused by industrial growth. Energy intensity is still the decisive factor to make Jiangxi weak in decoupling, while other factors play a minor role. The industrial structure of Jiangxi plays a negative role in the total decoupling index because the ratio of high pollution industry output to regional output increased during 2000-2012, thus making carbon emissions increased.

Regions with no decoupling effect ($D<0$) included all regions except Beijing and Jiangxi. Results show that in most regions the carbon emissions reduction measures failed to inhibit the increase of carbon emissions and the industrial output effect on carbon emissions played a positive and dominant role. In fact, the emission reduction measures of these regions are basically effective, but it does not suffice.

4.5 Analysis of reduction potential

The above reflects the government's carbon emissions reduction efforts. The results can be used to determine policy priorities for improving the decoupling effectiveness in 15 regions. For example, for regions with no decoupling effect, the possibilities to further reduce energy intensities should be reconsidered. Although most of the 15 regions present no decoupling effect, most governments show great enthusiasm in promoting CO_2 emission reduction. So, what can the reduction potential of CO_2 emissions for the pollution-intensive industries be?

Table 8 shows the carbon emission intensity of 15 regions. In the period 2000-2012, the carbon emissions intensity of Tianjin is the minimum, namely, Tianjin will serve as a target region, and the carbon emissions intensity of other regions will gradually converge to Tianjin. The results in descending order are listed in *Table 9*.

Table 8. The carbon emissions intensity of pollution-intensive industries in the period 2000-2012

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average
BJ	2.7	2.5	3.5	3.3	3.3	3.3	2.8	2.5	2.1	1.9	1.1	1	0.9	2.4
TJ	1.2	1.4	1.2	1.7	0.8	1.2	1.4	1.4	1.2	1.2	0.9	0.8	0.8	1.2
SX	25.4	28.0	31.4	30.9	26.8	25.4	24.3	22.7	19.7	19	17.2	16	14.7	23.2
NMG	16.6	15.8	17.3	17.1	17.9	17.7	16.1	14.9	14.3	12.5	11.2	12.5	11.4	15
LN	6.1	5.6	5.5	5.9	5.7	5.5	5.1	4.7	4	3.5	3.7	3.4	3.1	4.8
JL	7.4	6.9	6.9	6.7	5.8	7.1	6.7	5.5	5.5	4.8	4.5	3.9	3.8	5.8
AH	7.2	8.2	7.2	8.6	8.9	7.8	7.5	7.2	7.1	6.7	6	5.5	5.1	7.2
FJ	3.7	3.5	3.8	3.3	4.6	4.1	4	4.2	3.9	3.7	3.2	3.4	2.9	3.7
JX	6.2	5.7	5.4	6.1	6.6	5.7	5.5	5.1	4.4	4	3.7	3.6	2.9	5
HN	7.2	7.1	6.6	6.4	7.6	7	6.9	6.5	5.8	5.1	4.7	4.4	4	6.1
HB	3.5	3.3	3.5	3.5	3.8	4.6	4.2	3.4	2.8	2.6	2.4	2.2	1.9	3.2
CQ	6.9	6.3	5.8	5.8	5.1	4.9	5	4.8	4	3.6	3.1	3.1	2.4	4.7
GS	5.2	2.2	5.0	5.2	6.2	6	5.6	5.5	5.3	4.5	4.6	4.6	4.2	4.9

NX	9.7	9.0	9.8	9.5	12.8	12.1	12.1	12.3	10.8	10.9	12.3	14.9	12.9	11.5
XJ	7.4	7.0	7.6	7.7	8.6	8.7	10	10.6	11	12.6	13.4	14.8	15.9	10.4
Total	6.3	5.9	6.0	6.4	7	7.2	7.2	6.9	6.6	6.4	6	6.1	5.8	6.4

Results show that in addition to Tianjin, emission reduction potentials of other areas are greater than 50, indicating that the energy efficiency of pollution-intensive industries in most areas is low. In general, the carbon emissions intensity has a close relationship with energy efficiency, namely, high energy efficiency means low carbon emissions intensity. Therefore, excepting Tianjin, the 14 regions with low energy efficiency have great energy-saving potential in future.

Table 9. The carbon emissions potential of pollution-intensive industries in the period 2000-2012

Region	Potential	Ranking	Region	Potential	Ranking	Region	Potential	Ranking
SX	94.98	1	Total	81.91	6	LN	75.53	11
NMG	92.25	2	HN	80.96	7	CQ	75.09	12
NX	89.84	3	JL	79.94	8	FJ	68.65	13
XJ	88.83	4	JX	76.65	9	HB	63.71	14
AH	83.74	5	GS	76.41	10	BJ	50.88	15

Although all regions have a large emissions reduction potential, the potentials are varied and there exist large gaps. Shanxi, with the greatest reduction potential, reaches up to 94.98, and the larger five main areas are Inner Mongolia, Ningxia, Xinjiang, Anhui and Henan, all above 80. The emission reduction potential of Beijing is relatively low. Due to the limitation of marginal cost and technical factors, further emission reduction in Beijing is more difficult than areas with high carbon emission intensity.

In general, the reduction potentials of the eastern area rank relatively far down the list, are small and are below the national average, such as Beijing, Tianjin and Fujian, while the central and eastern areas show great reduction potential, such as Shanxi, Inner Mongolia, Ningxia, Xinjiang and other regions. Moreover, in the eastern area, the emission reduction potentials of Jilin and Liaoning are relatively higher than other regions of this area. It is because these two regions are the representatives of the old industrial bases and the heavy industry output makes up a large proportion of total output. The emission reduction potentials of the western areas of Chongqing rank down the list probably in that the energy intensity is low and continues to decline, thus gradually improving the energy efficiency.

The regional reduction potentials of seven industries are shown in *Table 10*, including the rankings in the brackets. From *Table 10*, we know that the minimum of industrial carbon intensity concentrates on Beijing, Tianjin and Hubei, indicating that the energy use efficiency and output efficiency of these areas are relatively high. However, the reduction potentials of seven industries in Shanxi, Inner Mongolia, Henan, Ningxia, Xinjiang and other areas are relatively large. These areas are abundant in natural resources, lack energy savings and emission reduction motivation and have low energy efficiency. In addition, there are significant regional differences between the chemical and non-ferrous industries in reduction potential. Xinjiang (96.4) has the largest emission reduction potential in the chemical industry, the lowest, Tianjin, only 8.6. Shanxi (95.4) has the largest emission reduction potential in the non-ferrous industry, the lowest, Tianjin, only 13. However, the regional differences between the ferrous industry and electric industry is minor, especially in the electric industry where the emission reduction potentials of all regions are more than 97, indicating low energy efficiency in this industry. The reason is that more than 70% of power production is supplied by coal power generation with poor power generation technology and a small proportion of the use of clean energy generation, leading to low energy use efficiency and large emission reduction potential.

Comparing the industrial emission reduction potential with the national level, we found that the emission reduction potentials of the petroleum, ferrous and electric industries are basically higher than the national level.

Table 10. The regional emissions reduction potential of pollution-intensive industries and ranking in the period 2000-2012

Region	Paper	Petroleum	Chemical	Non-metallic	Ferrous	Non-ferrous	Electric
BJ	1.7(15)	71.4(13)	0	31.7(15)	73.6(14)	0	97.3(14)
TJ	0	38.4(14)	8.6(15)	0	62.2(15)	13.0(15)	0
SX	89.9(1)	99.9(1)	95.3(2)	83.44(1)	93.4(1)	95.4(1)	99.1(4)
NMG	79.2(6)	99.7(3)	95.2(3)	83.38(3)	84.8(8)	93.9(2)	99.2(3)
LN	81.2(4)	89.5(10)	65.5(13)	55.4(11)	87.5(5)	81.3(6)	98.3(8)
JL	79.5(5)	78.3(12)	27.9(14)	74.7(6)	81.9(11)	85.1(8)	98.9(5)
AH	69.5(9)	84.0(11)	85.8(7)	79.16(5)	86.1(7)	40.2(12)	98.8(6)
FJ	42.0(14)	10.2(15)	79.6(8)	49.5(13)	77.0(12)	33.6(14)	96.9(15)
JX	68.2(10)	92.3(9)	75.9(10)	73.9(7)	86.2(6)	62.8(11)	98.0(10)
HN	70.6(8)	99.1(5)	87.7(5)	41.8(14)	84.6(9)	93.5(3)	98.1(9)
HB	48.3(13)	0	86.1(6)	50.4(12)	0	76.2(10)	97.5(13)
CQ	74.5(7)	99.2(4)	70.7(12)	67.1(9)	74.6(13)	43.4(13)	97.9(11)
GS	68.1(11)	93.6(8)	74.8(11)	72.9(8)	91.9(3)	86.1(5)	97.8(12)
NX	88.7(2)	99.8(2)	89.4(4)	83.39(2)	84.5(10)	83.1(9)	99.3(2)
XJ	86.1(3)	98.9(6)	96.4(1)	82.5(4)	93.3(2)	91.7(4)	99.4(1)
Total	59.2(12)	98.8(7)	77.6(9)	57.0(10)	88.3(4)	85.2(7)	98.5(7)

5. CONCLUSIONS

This paper focuses on the pollution-intensive industries and examines energy related to CO_2 emissions in 15 regions in China. The sample time period starts in 2000, just before China entered the World Trade Organization (WTO), and ends in 2012, so, all necessary data are available. The year 2006 is a turning point to assess whether the emission reduction measures affect emission trends and their key factors.

In fact, the CO_2 emissions in most areas of China continue their upward trend. The complete decomposition analysis tries to explain this trend. At the same time, in order to comparatively assess the effectiveness of areas in reducing CO_2 emissions in terms of various measures, this paper also focuses on their ability and degree in decoupling industrial growth from their upward trend in CO_2 emissions. Finally, this paper assesses the reduction potential of CO_2 emissions in pollution-intensive industries to end the analysis.

According to the analysis of driving factors and the decoupling index above, we know that the largest driving factors of carbon emissions are the industrial output effect and energy intensity effect, thus the emission reduction efforts should focus on these two aspects. Energy intensity decreases can be effective in reducing carbon emissions through improving energy efficiency, strengthening technological innovation, increasing investment on advanced energy saving technology R&D and learning from other regions with lower energy intensity to improve their energy efficiency.

The industrial output effect shows that industry development will inevitably lead to carbon emissions increase, and finding a balance between industrial development and carbon emissions becomes a key point in energy saving in the case of industry development. Although the governments in each region have taken efforts to reduce carbon emission, the effectiveness of emission reduction has regional differences, and not all efforts are effective.

The energy structure and energy emission intensity basically play a negative role in the total decoupling index, which goes along with carbon reduction measures, thus it is necessary to optimize energy structure and energy emission intensity. Energy structural optimization can be done by reducing fossil energy consumption and increasing clean energy consumption; China has abundant hydropower, wind energy, solar energy in clean energy endowment, while the technology of use and development is not mature, thus the premise of completing emission reduction targets is to improve technology. Moreover, in this paper we only consider five types of energy which are of high carbon emission intensity and cannot reflect regional energy structure optimization. All the energy emission intensities are fixed, except electricity, and optimizing the energy emission intensity can lower the energy emission intensity of electricity, which can be done by improving power generation technology and increasing clean power generation.

The output of high pollution industries occupies a certain proportion in regional total output. Therefore, changing development mode, adjusting industrial structure and upgrading industry may be helpful to carbon emission reductions. The output ratio and energy intensity are large in electric, ferrous metals and chemical industries, thus the focal point of industry development transition and industrial structure adjustment should be put on these three sub-sectors.

Most of the regions, including Beijing, have great energy-saving and emission-reduction potential. Therefore, the optimization and adjustment of high energy consuming and high polluting industries is the key to energy conservation and emission reduction.

ACKNOWLEDGEMENT

The authors thank the anonymous reviewers and editors for their insightful comments and suggestions. The authors are responsible for any errors in this paper. The authors also gratefully acknowledge support from the Chinese Ministry of Education Humanities and Social Science Youth Fund (Grant No. 15YJC790083) and the Natural Science Foundation of Hunan Province of China (Grant No. 14JJ3058).

REFERENCES

Ang, B. W. (2004). "Decomposition Analysis for Policymaking in Energy:: Which Is the Preferred Method?". *Energy Policy*, *32*(9), 1131-1139.

Diakoulaki, D., & Mandaraka, M. (2007). "Decomposition Analysis for Assessing the Progress in Decoupling Industrial Growth from Co 2 Emissions in the Eu Manufacturing Sector". *Energy Economics*, *29*(4), 636-664.

Dietz, T., & Rosa, E. A. (1994). "Rethinking the Environmental Impacts of Population, Affluence and Technology". *Human ecology review*, *1*, 277-300.

Ehrlich, P. R., & Holdren, J. P. (1971). "Impact of Population Growth". *Science, Technology & Human Values*, *171*(3977), 1212-1217.

Enevoldsen, M. K., Ryelund, A. V., & Andersen, M. S. (2007). "Decoupling of Industrial Energy Consumption and Co^2 Emissions in Energy-Intensive Industries in Scandinavia". *Energy Economics*, *29*(4), 665-692.

Fu, X. (2011). "Decoupling Progress Analysis and Compare Research between China Regional Industry Development and Co^2 Emission". Central South University, Hunan Province.

Greening, L. A., Davis, W. B., Schipper, L., & Khrushch, M. (1997). "Comparison of Six Decomposition Methods: Application to Aggregate Energy Intensity for Manufacturing in 10 Oecd Countries". *Energy Economics*, *19*(3), 375-390.

Guo, C. (2010). "An Analysis of the Increase of Co^2 Emission in China - Based on Sda Technique". *China Industrial Economics*, *12*, 47-56.

Hoekstra, R., & Van den Bergh, J. C. (2003). "Comparing Structural Decomposition Analysis and Index". *Energy Economics*, *25*(1), 39-64.

Li, F., Song, Z., & Liu, W. (2014). "China's Energy Consumption under the Global Economic Crisis: Decomposition and Sectoral Analysis". *Energy Policy*, *64*, 193-202.

Liu, Q., Wang, Q., & Li, P. (2012). "Regional Distribution Changes of Pollution-Intensive Industries in China". *Ecological Economy*, *1*, 107-112.

Liu, Z., Wang, A., Yu, W., & Li, M. (2010). "Research on China Regional Carbon Emission". *Acta Geoscientica Sinica*, *31*(5), 727-732.

Organization for Economic Co-operation and Development. (2002). *Indications to Measure Decoupling of Environmental Pressure and Economic Growth*. Paris: OECD.

Sun, J. W. (1998). "Changes in Energy Consumption and Energy Intensity: A Complete Decomposition Model". *Energy Economics*, *20*(1), 85-100.

Tukker, A., & Dietzenbacher, E. (2013). "Global Multiregional Input–Output Frameworks: An Introduction and Outlook". *Economic Systems Research*, *25*(1), 1-19.

Wang, C., Chen, J., & Zou, J. (2005). "Decomposition of Energy-Related Co^2 Emission in China: 1957–2000". *Energy*, *30*(1), 73-83.

Wang, W., Liu, R., Zhang, M., & Li, H. (2013). "Decomposing the Decoupling of Energy-Related Co 2 Emissions and Economic Growth in Jiangsu Province". *Energy for Sustainable Development*, *17*(1), 62-71.

Wei, C., Ni, J., & Du, L. (2012). "Regional Allocation of Carbon Dioxide Abatement in China". *China Economic Review*, *23*(3), 552-565.

Wiedmann, T. (2009). "A Review of Recent Multi-Region Input–Output Models Used for Consumption-Based Emission and Resource Accounting". *Ecological Economics*, *69*(2), 211-222.

Xiong, Y. L., Zhang, Z. Q., Qu, J. S., Li, Y., Zeng, J. J., & Wang, Q. H. (2012). "Research on Characteristics of Provincial Co^2 Emissions from 2005-2009 in China". *Journal of Natural Resources*, *27*(10), 1767-1777.

Xu, Y., Xu, K., & Hu, Y. (2011). "Driving Factors and Decoupling Effect of Carbon Emissions: Evidence from China's Manufacturing Sector". *Statistical Research*, *28*(7), 55-61.

Yi, W. J., Zou, L. L., Guo, J., Wang, K., & Wei, Y. M. (2011). "How Can China Reach Its Co 2 Intensity Reduction Targets by 2020? A Regional Allocation Based on Equity and Development". *Energy Policy*, *39*(5), 2407-2415.

Zhong, T. Y., Huang, X. J., Han, L., & Wang, B. Y. (2010). "Review on the Research of Decoupling Analysis in the Field of Environments and Resource". *Journal of Natural Resources*, *25*(8), 1400-1412.

International review for spatial planning and sustainable development, Vol.4 No.4 (2016), 27-41
ISSN: 2187-3666 (online)
DOI: 4http://dx.doi.org/10.14246/irspsd.4.4_27

The Open Innovation Paradigm: from Outsourcing to Open-sourcing in Shenzhen, China

Valérie Fernandez[1], Gilles Puel[2*], Clément Renaud[1]
1 Telecom ParisTech, UMR I3
2 University de Toulouse, LEREPS
** Corresponding Author, Email: Gilles.Puel@univ-tlse2.fr*

Received: March 02, 2016; Accepted: May 30, 2016

Key words: Open innovation, New urban places, Makers, *shanzhai*, Shenzhen

Abstract: Having once been the headquarters of 'Made in China,' Shenzhen's industry is currently undergoing profound change. The appearance of new urban places for technological innovation is reviving the ageing industrial processes of this manufacturing city. It is supposed to transform Shenzhen into the Silicon Valley of hardware. Two groups, one local, the *shanzhai* community made up of entrepreneurs and companies historically based on a strategy of imitating high-end products, and the other, a more international maker community, are thought to be the main drivers of this change using values of 'open innovation'. The building of this ecosystem relies largely on practices associated with being open-source. Like in California, open innovation contributed to the creation of resources for the development of a vast high-tech industry. This ethnographic field study shows how, while both communities, the international makers and the *shanzhai*, draw on open innovation, they do not have the same values. For the *shanzhai*, open innovation means total deregulation and a kind of coopetition that poorly masks fierce competition. For the makers, open innovation does not entirely eliminate the classic tension between 'open' and 'closed' commons in the world of makers. These two communities still rarely collaborate.

1. INTRODUCTION

Having once been the headquarters of 'Made in China,' Shenzhen's industry is currently undergoing profound change. The appearance of new urban places for technological innovation is reviving the ageing industrial processes of this manufacturing city.

The new 'Made in China' plan, first suggested by experts (Li, 2014) and a few academics (Lindtner, 2014, 2015), is intended to transform Shenzhen into the Silicon Valley of hardware. Two groups, one local, the *shanzhai* [i] community made up of entrepreneurs and companies historically based on a strategy of imitating high-end products, and the other, a more international manufacturing community, are thought to be the main drivers of this change using values of 'open innovation' (Chesbrough & Bogers, 2014). This idea of rebooting 'Made in China' is widely present on the Internet and, of course, has the support of the Chinese government (as demonstrated in *Zhongguo Zhizao* 2025).

While both communities, the international makers and the *shanzhai*, draw on open innovation, they do not have the same goals or the same values. For the *shanzhai*, open innovation means total deregulation and a kind of coopetition that poorly masks fierce competition. For the makers (Anderson, 2012), open innovation does not entirely eliminate the classic tension between 'open' and 'closed' commons in the world of makers (Garnier, 2014). These two communities, while both located in Shenzhen because of the advantages the city offers, still rarely collaborate.

The present study analyzes the dynamics of innovation in these communities, which are situated in this territory and in 'third places' (such as the *shanzhai* cluster, manufacturing 'fablabs' and 'excubators'). Each of these places incorporates a facet of open innovation and extends the frontiers of the open innovation paradigm, all while reaffirming the situated nature of open innovation. The argument advanced here is that there is truly a geography of innovation, which means that the same concept of open innovation has different economic (and social) realities depending on the territory in which it is situated.

This study, based on extended field research, focuses primarily on describing the models of open innovation in the Shenzhen electronics cluster. The first section presents the concepts involved in open innovation and the second section, the relationship between open innovation and the business strategies and the characteristics of the society, the region, and the organizations involved. The third analyzes the electronics cluster's history and changes over time and the various models of open innovation places that have developed in Shenzhen. The article concludes with a more detailed discussion of our findings about the various configurations of groups working in innovation.

2. FRAMEWORK: THE BROAD PARADIGM OF OPEN INNOVATION

This research addresses the subject of open innovation, its models and its different variations over time and in different regions.

2.1 From open innovation to open source

The 'open innovation' paradigm described in the seminal work of Chesbrough (2003), referring to strategies of R&D coopetition, externalization and partnerships, gained currency among researchers at the turn of the millennium. Over the next ten years, the concept took on a broader meaning that was no longer limited to the market. It came to be understood as a combination of an innovation model based on cooperation between firms (compatible with a market economy and new economic models) and a societal model, embodied primarily in the open-source software movement and more generally the spirit of ODOSOS (Open Data, Open Source, Open Standards) (Chesbrough & Bogers, 2014; West et al., 2014).

This broadening of the open innovation paradigm occurred also within the "spatial turn" movement (Dale & Burrell, 2008; Van Marrewijk & Yanow, 2010; Warf & Arias, 2008), which examines issues through their anchoring in a given geographical space, the capital (spatial, social and cognitive) in those spaces (Bathelt, Malmberg, & Maskell, 2004), and 'third places' (Oldenburg, 1989).

2.2 Third places and open production: hacker spaces and ‘fablabs’

With the generalization of digital manufacturing equipment and networks for exchanging content, the appropriation of open production triggered by open-source has spread to hardware, now known as ‘open hardware.’ Rapid digital prototyping enabled bottom-up innovation, allowing the market to trigger industrial production and even financing processes based on participative funding platforms such as crowdfunding. In broader terms, these new trends, boosted by urban production spaces (‘fablabs’) (Gershenfeld, 2005) and technological experimentation (hacker spaces), can be seen as a form of technological re-appropriation by urban users. Beyond the industrial planning of smart cities, a “fab city” was envisioned as ‘a city where citizens could have access to a new array of infrastructures, including public ‘fablabs’ with close ties to private initiatives[ii]’.

2.3 New innovation ecosystems

Digital technologies, as networks and as production tools, and open hardware culture have helped expand the spaces of “innovation by doing”. They enable, accelerate and concretize initiatives in prototyping that involve co-construction and/or collaboration between different actors in the innovation process. For example with open hardware, the design and the functioning of each component are documented and available online. This facilitates skills transfer and sharing, and the reconfiguration of value chains among individuals and/or companies. The traditional image of the industrial cluster, envisaged as an ‘organized market’ (Kogut, 2000) within a territory of various actors who complement each other in the production chain, thus becomes enriched, as does the transfer and complementarity of skills (Dyer & Nobeoka, 2000; Nahapiet & Ghoshal, 1998). This traditional image of the cluster then gives way to new actors: to people and organisational configurations such as ‘third places’, on the frontier between market and non-market economies.

3. STUDY DESIGN

The innovation economy is built around the circulation of so-called intangible assets (ideas, designs, creative skills and so on.) that constitute the intellectual capital of economic actors (individuals, businesses and manufacturing) (Dumay & Cuganesan, 2011). Recent research using a relational view of economic actors (Bathelt & Glückler, 2011) has called into question econometric approaches (OECD, 2013) by showing the importance of non-economic activities in increasing businesses’ productivity (Corrado et al., 2014).

To analyze the dynamics of open innovation driven by spaces[iii] and ‘third places,’ this study therefore adopted a relational perspective. We consider that a given region’s ability to innovate is based on situated processes of creation and knowledge transfer and on its ability to bring together local actors as well as other actors with complementary activities outside the region.

This study examines both places, which are synapses of a physical and virtual network for the creation of intellectual capital, and the key actors in these places, as nodes of the network.

Fieldwork was done during two periods. In the first, from June to September 2012, a field study[iv] was conducted on *shanzhai* telephones and the geography of Shenzhen companies who had driven this mode of innovation based on reverse engineering. Conducted in partnership with China Unicom, the purpose of this first phase was to analyze the ecosystem of the *shanzhai* telephone, the business models of the companies who make these phones, the reasons for their success, their limitations, and the new dynamics at work in 2013 with the arrival of *shanzhai* smartphones.

Next, a period of desk research identified three meta-models of innovation places. The key places and actors in these meta-models were then identified by mapping the physical and relational spaces. This mapping sought to determine the emblematic character of the places for each model.

The first model identified a group of 'third places' mentioned in the relevant literature, namely co-working spaces, hackerspaces, and a hybrid of the previous two. These spaces are those of 'makers' with their media events, such as the Maker Faire and the Maker Carnival. As the analysis of these places has been discussed elsewhere (Renaud, Fernandez, & Puel, 2015), the present paper will only briefly touch on these aspects.

The second model identified was that of an incubator/accelerator for hardware startups (such as Seeed Studio and Hax). The main goal of organizations with this model is to support creation and business development in the open source environment. These places serve as bridges between the West and China.

The third meta-model identified was the cluster model with its various forms, such as the *shanzhai* where innovation is often confused with intellectual property violations. Examples are *Huaqiangbai*, the giant cluster of electronics suppliers and a synapse between the worlds of *shanzhai* and makers, and Bao'An, a creative cluster and an emblematic place for the proposed transformation of Shenzhen into the Silicon Valley of hardware.

These models were then tested in the second period of fieldwork of participatory observation from December 2014 to February 2015 in Shenzhen. For each of these places, fieldwork was conducted on site, including visits, an inventory of the objects and machines present, and interviews with the key actors of these places. Using the person-to-person method of the Chicago School (Blanchet & Gotman, 2007), we gradually validated or enriched our study design through interviewing these networks' key informants.

Twenty-seven key informants were interviewed in nine different places, covering all three models observed. For the clusters, which we consider here as one space, several different companies within them were interviewed. Participants were questioned about the place's value proposition and business model, the sociological profiles of users for models one and two, relations with local and international actors (institutions, users, competitors, etc.), the image of open source, and the actual practices of open source in their daily work context. These site visits were supplemented by meetings with several important people in the innovation ecosystem in China.[v]

4. ECOSYSTEM DYNAMICS IN SHENZHEN

The history of Shenzhen's territory has been marked by three periods. First, it was the 'factory' for Western countries that outsourced the manufacturing of their electronics. During this period, a cottage hardware industry was created in a culture of imitation and reverse engineering practices, which, over time, resulted in different expressions of creativity: recycling, re-invention, and agility. Small companies that conducted business among themselves and worked together informally increased their manufacturing capacities and capabilities in order to target specific market segments that were not addressed by Western companies. These small companies collaborated throughout the entire process of the electronics value chain (design, sourcing, assembly, production testing, packaging and distribution) through an open source culture. This culture was very informal at the beginning (in other words, the culture of this region), and was strengthened by the arrival of the Western open source culture. Gradually, these small companies developed their own expertise, particularly in designing new products, and also developed a culture and quality control promoted by Western open source.

Starting in the early 1980s, Western firms took advantage of major reforms in China (*gaige kaifant*) to relocate manufacturing and to outsource production to the Shenzhen area in the Pearl River Delta (Al, 2012; Richet & Ruffier, 2014). As this was China's first 'special economic zone' and was close to Hong Kong's legal and banking systems, it became an ideal location for electronics manufacturers (Margretta, 1998).

4.1 The Shanzhai Cluster

With the rapid growth of the components market in the 1990s, suppliers created standard components that were compatible with each other to accelerate their products' commercialization. The appearance of kits containing a set of parts and a manual (Chien & Wang, 2010) enabled a host of small manufacturers to produce countless models of mobile phones at low cost. These phones are known as *shanzhai* (Keane & Zhao, 2012; Liang, 2012), that is, midway between counterfeits and originals.

In the 1990s, some entrepreneurs took advantage of the city's geography, as it is close to Hong Kong and to parts suppliers, to counterfeit Nokia and Samsung handsets for the domestic market. The initial letters of Shenzhen (SZ) on the phones enabled them to circumvent national quality controls. Gradually, these phones came to be called *shanzhai* phones.

In 2004, the Taiwanese company MTK developed and sold its 'turnkey' processors at a low price, which 'democratized' telephone manufacturing. Gradually, as the *shanzhai* phone market grew, manufacturers turned away from simply copying others and started improving the materials and the features. In short, they realized they could innovate. They then acquired the capacity to make smartphones that were sold worldwide. Eighty million units, accounting for one-third of the phones made in China, were sold in 2011 (Liang, 2012). This *shanzhai* smartphone industry employed three million people in the Pearl Delta Region. In 2012, about 10,000 companies worked in this industry in the Shenzhen region (including approximately 2,000 phone manufacturers, 200 solution providers, 100 design firms, 1,500 national and regional buyers and 3,000 materials suppliers).

> "*Shanzhai* phone manufacturers understood the needs of modest communities and so they made cheaper phones. They were successful thanks to these small communities, even though the *shanzhai* phone industry has had some problems."[vi]

Extreme competition led *shanzhai* phone makers to want to differentiate themselves, and thus they adopted an iterative innovation model used by small production units around Shenzhen.

Shanzhai phone manufacturers followed a different strategy than that of major manufacturers. Of course, they were able to incorporate all the latest technologies (for example, MP4 and television) at a lower cost thanks to MTK processors. But above all, they were successful because they were able to target each community of consumers differently, their manufacturing cycle was shorter than the big brands (six weeks), and almost seasonally they adapted to market demand with agility and flexibility. *Shanzhai* manufacturers need neither patents nor essential technologies, as they get the latter from the ecosystem leader, MTK. However, coopetition is ruthless and when a success story such as Xiaomi emerges from the mass of startups, their growth strategy comes to resemble that of well-established manufacturers: creating proprietary distribution networks, increasing R&D, and 'rediscovering' intellectual property and its rights. In addition, research laboratories and telephone providers have developed thanks to support for innovation provided by the city of Shenzhen.

4.2 Huaqiangbei, the Suppliers Cluster

These clusters have grown thanks to the advantages of the Pearl Delta region: the international port of Hong Kong, half of all telephone factories in Dongguan, materials suppliers, distribution centres and sales platforms.

Products and components are sold in the Huaqiangbei district of Shenzhen, the world's largest electronics marketplace: a giant cluster consisting of a dense network of retailers and wholesalers. Huaqiangbei serves as a showcase both for international buyers and for the local industry, which it supplies with accessories, machines and components. In recent years, Huaqiangbei businesses have been feeling the effects of competition from the Internet and orders for equipment and components are mostly B2B. Mass producers of components have also set up marketing and sales services that directly rival retailers. These manufacturers' lack of technological expertise often prevents them from diversifying to more advanced technological fields.

Nick has worked in Huaqiangbei for several years as an exporter to India and Bangladesh:

> "Let me explain the *shanzhai* business. The manufacturers invest zero in research, absolutely nothing. First, they buy design from design houses that will provide them with the hardware design and the software. Then it is all about competing on prices. Who[ever] knows the right guy to get cheaper parts and components, who can save one on this and two on that, who has faster machines, that guy will win the market. They all use [the] same package, same model name even, same everything, but the parts are getting cheaper really quickly. If you have a new product coming out, I know that the price will usually go down very quickly in a few days."

Nick also explains the end of Huaqiangbei:

> "All the businesses in Huaqiangbei are family businesses. They don't do much work outside the family. Shanzhai manufacturers don't take part in anything else: they don't design, they don't sell. People just focus on executing what they know in a better or cheap[er] way. Now that manufacturers are getting in[to] sales and marketing as well, nobody knows how to continue."

The industrial economic downturn prompted China to jettison the labour-intensive model and instead to develop a more sophisticated manufacturing sector. The Chinese government announced a ten-year plan called Made in China 2025 (*Zhongguo Zhizao* 2025) to promote R&D initiatives and nurture high-tech industries. The Chinese Premier has been to Shenzhen to visit *Chaihuo*, the city's hackerspace, where he pledged to support these new innovators who are at the forefront of China's modernization (PRC, 2015).

While the government's discourse at national level is that of modernizing factories from the old Made in China era, at the local level, in Guangdong province in particular, we observed that these small factories, instead of evolving, are closing and are being replaced by large companies offering a range of integrated services including design, sales, marketing and production. More specifically, in the field of telephony, five companies now have 60% of the mobile phone market of Chinese brands (excluding foreign brands).

Table 1. Market shares of Chinese smartphone manufacturers for 2^{nd} and 3^{rd} quarter 2015[vii]

Companies	**2015/3**	**2015/2**
Huawei	18.7%	17.9%
Xiaomi	12.7%	14.0%
Lenovo	12.7%	12.5%
TCL	10.4%	9.7%
OPPO	8.7%	9.7%
Others	36.8%	36.2%

Source: Trendforce

5. MODELS OF PLACES AND INNOVATION IN SHENZHEN

The challenge for Shenzhen is to bring together the required skills in engineering, design and marketing, and existing manufacturing resources. Several hybrid models between the factory, the incubator, the co-working space, and the applied research centre have thus emerged around the city, resulting in highly innovative initiatives.

Figure 1. Map of the Makers' Ecosystem (source HaxLR8R, modified by the authors)

5.1 Bao'an District: a Creative Industrial Cluster

The Bao'an District is a cluster of factories specialized in manufacturing and assembling electronic products (Ng, 2011). Well-connected to transport networks and Shenzhen's underground subway, the Xixiang neighbourhood in Bao'an offers attractive rental rates for small businesses and a local government open to innovation proposals (Wang & Ju, 2010).

Although little research has been done on this area, this largely industrial district offers several interesting case studies such as the F518 cluster, located at the centre of the district. This creative cluster caters to a specific demand: the design and production of connected devices. Based on a strict recruitment of firms by sector to ensure that the cluster has a portfolio of complementary competences – including design, electronics assembly, marketing services, and packaging – this cluster run by the local government offers a single point of contact. From the idea to the sale, the cluster meets customers' demands not only for design but also production: "We work with the hundreds of factories in the area. In recent years we have learned to know them well, and there are too many to name them all," explained Huang Xi, the manager. With over twenty products designed and manufactured, this cluster is constantly growing and is currently having new offices built to house more firms.

The majority of companies in the F518 cluster are subcontractors established in the Bao'an district. The manager of the cluster of companies in F518 explains:

> "Let's say you want to make a phone. You can do everything at 518: industrial design (electronics), appearance. Any design can be made here. Then you can also do the packaging design. Once finished, you can also print in Bao'an... From idea to market, the businesses of 518 and the Bao'an district can do everything. This is what we call the supply chain model."

Thus, cluster F518 groups together subcontractors whose services are mainly for factories wanting to design their own goods.

5.2 From electronics design to production

Another typical example is that of electronics designers who are gradually turning to production to become Small Electronics Manufacturers (SEM). We analyzed two such young firms, Mixtile and Cubietech, located at the heart of Chegongmiao, the neighbourhood occupied by most electronics designers. Both develop open-source development boards based on ARM processors, which can easily be used to produce a prototype. The founders of Mixtile, Eric Dong and Martin Liu, said that they chose open source to be able to focus on quality: “Designing hardware products is difficult…. In traditional *shanzhai*, one has to move fast, very fast. Products are outdated immediately. With open source one can take more time and aim for quality, find good suppliers and develop a brand.” In the case of Cubieboard, Mike Lee agrees, “We can develop new models progressively. If necessary, we can add on or take off functionalities to meet our customers’ specific demands. Our Cubieboard 2 is used by a Singapore firm that designed a 3D printer.” Located in the Bao’an district, Cubitech has access to the manufacturing resources of the surrounding firms, but the relationships are not always good. The founders of Mixtile have the same problem, as they explained, “The factories are dirty places and we don’t want to go there. In fact, all the orders go via Internet.” Both firms want to become better known and to acquire more clients thanks to their open-source products. They thus want to propose manufacturing services based on modified versions of their products, as well as design and customization services. Open source provides them with an opportunity to orient production towards a quality approach, to counter the bad image of ‘Made in China,’ and also to avoid the terrible pressure of the rhythm of *shanzhai* products:

> “We have classmates in the *shanzhai* phone business, and it is very tough. For instance, he has to get his products out before August to make money, because the product lifecycle is 3 months maximum. If he doesn’t [have] success, then it will [go] bankrupt. So he is always running, rushing, working… This is very hard work, very tiring. You can make a lot of money, but it is very dangerous. For instance, for a phone costing 100 yuan the designer maybe just get[s] 5 yuan, so he needs to produce a lot to make money. If it is good and on time, he can have [a] big return on his investment. If not, he is finished. For guys in [the] *shanzhai* business, a deadline really means dead!”

Based on open sourcing, the value proposition for these companies is quality design, based on the agile method (designs are sent to production via the Internet) and meeting demand.

5.3 The incubator-factory: a step up from the ‘fablab’

The strong trend in information technology and innovation markets towards connected devices is naturally found in Shenzhen where resources abound. Several initiatives have sought to build bridges between the Californian innovation culture and Shenzhen’s resources.

One of these, Seeeds Studio, founded in 2008 by former Intel employee Eric Pan, makes hardware models for open-source projects. It has an assembly line, a warehouse for inventory, a prototyping laboratory, and produces electronic objects for small and medium-sized series. Projects are often started with crowdfunding and then presented to Seeeds Studio as a prototype. Seeeds then takes care of industrial design, production, and shipping the products throughout the world. This fast-growing firm with over 180 employees helps start-ups scale up production from 'ten to 10,000 units.' It is located in the industrial zone of Liuxiandong in the Nanshan district, close to electronics producers and assemblers. Since 2011, it has also had a space called Chaihuo in the Overseas Chinese Town cluster, one of Shenzhen's key areas for designers and easily accessible for visitors. Every year, the firm also heads the organization of Shenzhen's Maker Fair, now a forum for encounters between these new Chinese industrial innovation models and the global community of innovators. Moreover, Seeeds Studio recently opened offices in California to facilitate access to its services for start-ups in connected devices, whose number is growing exponentially.

Another organization bringing Californian start-up culture to Shenzhen is HAXLR8R, an incubator for hardware projects located at the heart of Shenzhen's electronics market. Founded in 2011 by a group of Californian investors, it has created a project-development methodology called Lean Hardware, based essentially on using resources in Shenzhen to build the supply chains of the start-ups that are supported by HAXLR8R. The incubation program lasting 111 days covers all important points from production to export regulations and marketing strategies. The majority of projects are launched in a campaign on crowdfunding websites. Projects are also launched on Demo Day in San Francisco to take advantage of the presence of California's media. The early results of this incubator are highly encouraging, since the start-up success rate is over 85%.

All of these places serve as nodes for an upstream funding network for the crowdfunding of open source projects and for producing small and medium series with a balanced cost model thanks to open sourcing. In fact, open sourcing enables companies to overcome certain problems: economies of scale vs economies of scope (the low-cost manufacturing of small production series is made possible by the reduced costs of design and manufacturing as a specific assembly of standard components is used); integration of production processes; and a better integration of the (re)design, production, and distribution phases.

6. DISCUSSION: INNOVATION MODELS GROUNDED IN THE LOCAL CONTEXT AND PROMOTED BY OPEN MANAGEMENT PROCESSES

The essential idea here is the role of open sourcing in the emergence of new value chains, driven by new kinds of 'fablabs' that manufacture in small and medium series. Open sourcing lowers the design and production costs and meets a variety of demands. It also enables an optimization of the design for agile production and re-designing due to the low cost of prototypes. Moreover, open sourcing facilitates the emergence of small companies specialized in complex electronic design (for the Internet of Things) for manufacturing distributed via the web.

The birth of the "maker movement" has raised new questions on not only the creation of physical objects and devices connected to the Internet, but also more broadly on their role and their status throughout the urban fabric. How can new industrial dynamics driven by innovation be integrated into regions with different histories and identities? The city of Shenzhen offers one example of the appearance of new models that have directly grown out of its history and its regional characteristics. Here, the city's industrial past (capital, workforce, basic knowledge and recent knowledge) served as a base for building and attracting communities of innovators and for connecting with another land of innovation, California.

In California, the high-tech industry benefited extensively from open-source technologies and open innovation. They significantly accelerated the development of start-ups that went on to become large firms, especially in the Internet. In the Shenzhen ecosystem, the *shanzhai* open innovation model was a catalyst for the rapid development of a distributed manufacturing fabric, alongside the classic industrial model. This *shanzhai* model of multiple small companies specialized in manufacturing has since served as a resource for the growth of a high-tech industry that in many respects echoes the Fab City project.[viii]

An important ingredient of the modernization of this industrial fabric making Shenzhen an innovative ecosystem has been open access to documentation on the technologies involved and their associated practices (open source). This documentation not only enables users to learn new, collaborative ways of working on a global scale, but also for manufacturers to guarantee the quality of their products validated by the user community and to benefit from this community as a marketing resource. Open innovation is at the centre of the modernization process because it accelerates business development and employee training. This culture of continuous learning and re-use of existing resources thus sometimes occurs in places that already exist, but which are now occupied by new actors who promote open innovation dynamics.

Thus, what is the 'maker' culture in China today? DIY has its places in the hackerspaces that emerged in Shenzhen, but everything happens around Seeeds Studio, the main physical 'enabler' and a physical third place helping U.S. do-it-yourselfers to manufacture and market their products. Seeeds Studio thus helps start-ups scale up to the level of industrial production.

This industrial network is also adept at *shanzhai* methods of absorbing/adapting/prototyping and testing new products very quickly. The *shanzhai* ecosystem became an innovative manufacturing system mainly because it bypasses the legal system of intellectual property. It is hardly surprising that this attitude toward copyright has received a favourable response in the maker movement.

Ultimately, the Chinese market blurs maker identity by contributing different qualities and values. For example, a 'pressy' button for phones financed by a crowdfunding campaign sold for $27 in October 2013. Three months later, a speed button was sold for $3; six months later, Xiaomi sold its version, Mikey, for $1, before Qihho gave the smart button to developers for free. Here, they copy, they lower prices, and end up giving products away for free hoping to create an ecosystem around themselves, similar to MTK in *Shanzhai* (Liang, 2012). In China, the externalities and the DIY ecosystem are different from those in the West. WPG Holdings, one of the largest electronics distributors in Asia, makes Chinese versions open source. They design cards for factories and for designers that will be integrated into phones, tablets, watches, computers, etc. In another example, ATU designs 130 cards per year, free of charge, because what they mainly sell are the components of these cards, allowing them to attract creative companies (but not always very rich or necessarily Western) in order to design new cards.

This new form of open innovation follows the tradition of the *shanzhai* ecosystem headed by MTK and is similar to Western open source innovation, but should not be confused with it; this story is not simply that of Western empowerment.

7. CONCLUSION

As a region of innovation, Shenzhen is organized around two spaces whose borders are today barely permeable:

-an historical industrial cluster made of a myriad of small-scale manufacturing companies that have gradually increased their manufacturing capacity and capabilities. Their agility has been nourished by an 'illegal' and 'informal' open source culture. They are beginning to seize opportunities enabled by 'legal' open source, although that has not led to a change in their culture; and

-the new urban form that is the heart of the system: the incubator or accelerator for start-ups that includes prototyping as well as production. It is certainly here that the makers come (as a middle-ground space (Simon, 2009)), but they are essentially Western makers. HAXLR8R, for example, recruits in Europe and San Francisco. The makers come here because Shenzhen is the 'fablab' of the world (it has the heritage of the manufacturing city, of Made in China, etc.) and also because they have access to local resources. Yet, there is hardly any interaction with local manufacturing communities, who are still marked by the copycat culture (see the emblematic story of the 'pressy' button) and who are still very far from the ideals of sharing and of a "do it with others" approach.

This case study of electronics manufacturing in the Shenzhen area shows that open innovation models can support and accelerate the modernization of declining industrial sectors when these models are based on the economy and the industrial characteristics of the region. By examining the various models of innovation observed, we found that all were based on pre-existing technical and economic circumstances that they used in new ways to grow their business. Hence, the Californian innovation model that underpinned the development of the Internet and the Shenzhen innovation model in the hardware field cannot be applied or reproduced elsewhere, for they are intrinsically bound to the territories in which they emerged. The open innovation paradigm remains an emerging concept for technological changes and changes in manufacturing cultures that are rooted in local territories.

ACKNOWLEDGEMENTS

This work was supported by the French National Research Agency (ANR) [183.775 euros].

REFERENCES

Al, S. (2012). *Factory Towns of South China: An Illustrated Guidebook*. Hongkong: HK University Press.

Anderson, C. (2012). *Makers: The New Industrial Revolution*. New York: Crown Business.

Bathelt, H., & Glückler, J. (2011). *The Relational Economy: Geographies of Knowing and Learning*. Oxford: Oxford University Press.

Bathelt, H., Malmberg, A., & Maskell, P. (2004). "Clusters and Knowledge: Local Buzz, Global Pipelines and the Process of Knowledge Creation". *Progress in human geography*, *28*(1), 31-56.

Blanchet, A., & Gotman, A. (2007). "L'enquête Et Ses Méthodes: L'entretien [the Survey and Its Methods: Interview]". *Sociologie [Sociology]*, 1-133.

Chesbrough, H. W. (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology*: Harvard Business Press.

Chesbrough, H. W., & Bogers, M. (2014). "Explicating Open Innovation: Clarifying an Emerging Paradigm for Understanding Innovation. Ssrn Scholarly Paper Id 2427233". In Chesbrough, H., Vanhaverbeke, W., & West, J. (Eds.), *New Frontiers in Open Innovation* (pp. 3-28). Oxford: Oxford University Press.

Chien, C.-F., & Wang, J.-C. (2010). "Shanzai! Mediatek and The'white Box'handset Market". *Harvard Business School Technology & Operations Mgt. Unit Case No. 610-081*. Retrieved from http://ssrn.com/abstract=2041963

Corrado, C., Haskel, J., Jona-Lasinio, C., & Iommi, M. (2014). "Ict, R&D and Non-R&D Intangible Capital: Complementary Relations and Industry Productivity Growth in European Countries". Paper presented at the 3rd World KLEMS Conference (May 19-20, 2014), Tokyo.

Dale, K., & Burrell, G. (2008). *The Spaces of Organisation and the Organisation of Space: Power, Identity and Materiality at Work*. Basingstoke: Palgrave Macmillan.

Dumay, J., & Cuganesan, S. (2011). "Making Sense of Intellectual Capital Complexity: Measuring through Narrative". *Journal of Human Resource Costing & Accounting*, *15*(1), 24-49.

Dyer, J. H., & Nobeoka, K. (2000). "Creating and Managing a High-Performance Knowledge-Sharing Network: The Toyota Case". *Strategic management journal*, *21*(3), 345-367.

Garnier, C. (2014). "Fablabs: De La Cohabitation À La Coopération, Etude D'artilect, Fablab Toulousain [Fablabs: Coexistence to Cooperation, Survey of Artilect, Toulouse Fablab]". (Master), Université de Toulouse, France.

Gershenfeld, N. (2005). *Fab: The Coming Revolution on Your Desktop - from Personal Computers to Personal Fabrication*. Cambridge: Basic Books.

Keane, M., & Zhao, E. J. (2012). "Renegades on the Frontier of Innovation: The Shanzhai Grassroots Communities of Shenzhen in China's Creative Economy". *Eurasian Geography and Economics*, *53*(2), 216-230.

Kogut, B. (2000). "The Network as Knowledge: Generative Rules and the Emergence of Structure". *Strategic management journal*, *21*(3), 405-425.

Li, D. (2014). "The New Shanzhai: Democratizing Innovation in China". *SJTU ParisTech Review*. Retrieved from http://www.paristechreview.com/2014/12/24/shanzhai-innovation-china/

Liang, S. (2012). "L'analyse Des Telephones Shanzhai [Analysis of Shanzhai Phones]". (Master), University de Toulouse, France.

Lindtner, S. (2014). "Hackerspaces and the Internet of Things in China: How Makers Are Reinventing Industrial Production, Innovation, and the Self". *China Information*, *28*(2), 145-167.

Lindtner, S. (2015). "Hacking with Chinese Characteristics the Promises of the Maker Movement against China's Manufacturing Culture". *Science, Technology & Human Values*, 1-26.

Margretta, J. (1998). "Fast, Global, and Entrepreneurial: Supply Chain Management, Hong Kong Style". *Harvard business review*, *76*(5), 102-114.

Nahapiet, J., & Ghoshal, S. (1998). "Social Capital, Intellectual Capital, and the Organizational Advantage". *Academy of management review*, *23*(2), 242-266.

Oldenburg, R. (1989). *The Great Good Place*. New York: Paragon House.

Renaud, C., Fernandez, V., & Puel, G. (2015). "Changing the Culture of Innovation in Shanghai: Open Innovation Spaces". Paper presented at the Third conference of Geography of innovation.

Richet, X., & Ruffier, J. (2014). "Ci-Gît L'industrialisation Mondiale: Fin Du Rôle Sociétal De La Fabrication Industrielle [Here Lies the Global Industrialization : End of the Societal Role of Industrial Manufacturing]". *Autrepart*, *1*, 3-26.

Simon, L. (2009). "Underground, Upperground Et Middle-Ground: Les Collectifs Créatifs Et La Capacité Créative De La Ville". *Management international/Gestiòn Internacional/International Management*, *13*, 37-51.

Van Marrewijk, A., & Yanow, D. (2010). *Organizational Spaces: Rematerializing the Workaday World*. Cheltenham: Edward Elgar Publishers.

Wang, Q., & Ju, Z.-q. (2010). "The Innovation of Outsourcing Pubilc Services by Governments —— a Case Study of the Sub-District of Xixiang in Shenzhen, Guangdong". *Scientific Decision Making*, *4*, 31-40.

Warf, B., & Arias, S. (2008). *The Spatial Turn: Interdisciplinary Perspectives*. Abingdon: Routledge.

West, J., Salter, A., Vanhaverbeke, W., & Chesbrough, H. (2014). "Open Innovation: The Next Decade". *Research Policy*, *43*(5), 805-811.

---

[i] *Shanzhai*, literally meaning 'mountain village,' refers to counterfeit or coarse imitations of big brand name goods by artisans or small Chinese companies, particularly in electronics.

[ii] Interview with Tomas Diez, FabLab Barcelona's manager, in 2014.

[iii] In the sense of territory, region and geography.

[iv] Three months of fieldwork in the Research Department for Electronics of the China Unicom telephone company, which resulted in a research report (Liang, 2012). All the data in Section 3 can be found in that report.

[v] All of the data is housed on a server of the French National Research Agency (ANR) as open data. As part of the larger research project funded by the French National Research Agency (http://www.agence-nationale-recherche.fr/?Project=ANR-13-SOIN-0006). Other 'third place' models of innovation were examined in other regions of China that corresponded to different socio-economic configurations.

[vi] Excerpt from the interview of the Head of the Electronic Products Research Team at Shenzhen.

[vii] Caijin, http://finance.sina.com.cn/chanjing/sdbd/2015-12-21/doc-ifxmttme6044290.shtml, accessed 2 December 2012.

[viii] http://fab.city/, available 2016/01/22.

APPENDIX

For each space, tasks are:

a. draw a map of the space
b. quick inventory of key machines/objects (with pictures if possible)
c. interview of owner, manager or community manager
d. ask for datasets (previous surveys, mailing lists, social media accounts, etc.)

Table 2. List of interviews

Name	Role	Activity	Time
Momi Han	Manager	Electronics maker	1h30
Eric Dong	Founder	Electronics maker	1h30
Martin Liu	Founder	Electronics maker	2h
Joseph Wang	Founder	Bitcoin	1h
Qu Hang	PR executive	CIC Manager	1h
Huang Xi	Parti leader	CIC HR	1h
C. Eberweiser	Founder	Incubator	1h

Cao Meiying	OpenPlatform	Web business	1h
C. Valenza	Founder	FPGA	1h
Eric Dong	Founder	Electronics	1h30
Fu Na	Urban Planner	Urban Planning	1h30
Tat Lam	Founder	Community	1h30
Nik	Export reseller	Electronics gross sales	2h
Momi Han	Manager	Electronics maker	1h
Mayling C	Sales	LED maker	1h
Jack Lee	Founder	Hardware startup	1h
Lafier Kong	Manager	Fablab	0h45
J. Gadikian	Founder	Hardware startup	1h30
Shu Wen	International lead	Training and education	2h
Si Jinling	Program head	Training and education	1h
Shirley	Founder	Professional designers association	1h
17 people		Users	1h each

Interview questions

1) THE SPACE/ORGANIZATION: the management of their organization (15 min)

a. Quick story of the space
b. What are the key assets that allow your space/organization to be sustainable?
c. What are the most important objects of your space?
d. What is the most important online tool you use? How does it contribute to running the space? Why is it so important?
e. Do you know about open bill, open date, agile management…?

2) THE NETWORKS: The networks of innovation in China

a. What are the networks supporting your activities?
b. Are they more informal or institutional? Governments?
c. What is the scope of those networks? International? Local? National?
d. Which sort of resources do they provide? Visibility? Funding? Structure?
e. How are partnerships with HK? US? EU?
f. TRENDS: Open Innovation in Manufacturing
g. Do you know about “open innovation”/“open source”?
h. How is it perceived in Shenzhen? And in China? Are people aware of it?
i. How does it relate to existing manufacturing/entrepreneurship culture here?
j. What advantages/drawbacks do you identify in “open” models ?
k. What are the management/organizational trends you see emerging in Shenzhen now? Bigger organizations? Smaller/distributed? Local/international?

International review for spatial planning and sustainable development, Vol.4 No.4 (2016), 42-57
ISSN: 2187-3666 (online)
DOI: 4http://dx.doi.org/10.14246/irspsd.4.4_42

Measuring Urban Space of Flows in Information Era: Empirical Evidence from Nanjing, China

Guangliang Xi[1], Feng Zhen[1*] and Enyu Chang[1]
1 School of Architecture and Urban Planning, Nanjing University
** Corresponding Author, Email: zhenfeng@nju.edu.cn*

Received: December 13, 2015; Accepted: April 7, 2016

Key words: ICTs, space of flows, spatial mobility, information era, Nanjing

Abstract: In the information era, the comprehension of space of flows has turned from elemental flows into a combination of technologies, activities and physical spaces with the perspective of a new mobility paradigm. However, how to measure space of flows is still an under-established issue in scholarly discussion. This paper aims to explore the evaluation methods of spatial mobility considering technological accessibility, intensity of activity and spatial activeness. By using residential activity dairies, the present Nanjing traffic system and land use, the spatial mobility of Nanjing was evaluated. The measurement results suggest the extent to which the space of flows affects the space of places, which is critical for understanding urban spatial reconstruction in the information era.

1. INTRODUCTION

Information and communication technologies (ICTs) are becoming more and more important in reshaping urban societies, for example, by changing traditional understandings of space. The wide application of mobile terminal devices not only changes the mode of production, but also impacts consumption activities. The use of ICTs has different effects on residents' activities. Previous studies have identified four relationships between ICTs and residents' activities: substitution, complementarity, modification and neutrality (Mokhtarian, 1990; Salomon, 1986). ICTs alleviate the temporal and spatial constraints of activities, which decompose the traditional activity into several sub-activity fragments, and reallocate them into different times and places (Couclelis, 2000, 2004). ICTs also enhance activity mobility to a large extent. Due to the in-depth development of information technologies accelerating the element flows (e.g., people flow, material flow, information flow, capital flow, etc.) generated by urban activities, the mode, intensity and connection of residents and their activities' mobility leads to all kinds of "flows" being altered fundamentally, thus the spatial mobility is reinforced greatly. Meanwhile, the construction of rapid traffic networks (e.g., high-speed rail, interurban railway, subway, etc.) and smart cities also improves spatial mobility by compressing the interaction distance between different places.

Under the influence of information technologies, fixed locations and space become more mobile than ever. The relationship between cyberspace and physical space also undergoes change, which is crucial to understanding the spatial transformation and the emergence of new spatial form. This transformation could be interpreted from three aspects. Firstly, residents' behavior is no longer constrained by traditional space. For instance, abundant activities (e.g., online shopping, telecommuting, online entertainment, etc.) occur at home and the function of home has been redefined (Hjorthol & Gripsrud, 2009; Ohmori & Harata, 2008; Zhen & Wei, 2008). ICTs improve the tempo-spatial flexibility of residents' activities and lead to changes in the relationship between activities and places. Secondly, the interaction between cyberspace and the physical space changes the meaning of places continually, which makes rigid space turn into flexible space (Kellerman, 2010). Thirdly, production and consumption factors are increasingly exchanged worldwide. The integration of global production flows and localization brings new changes for the organization of urban space as well as spatial mobility (Li, 2011).

Basically, the concept of the space of flows is given on the grounds of the urban informational transformation. Researchers intensively discussed the "death of distance" and the "end of geography" caused by ICTs and virtual flows in the 1990s (Cairncross, 2001; O'Brien, 1992), and most of them agreed that mobility became the new organizational logic of urban space based on the altering of activity time and space by ICTs. From the insights of sociology, Castells (1989) put forward the concept of the "space of flows" and pointed out that the space of flows was the material organization of time-sharing social practices that worked through mobility in an information society. He distinguished the "space of flows" and the "space of places", and then explained that there was an obvious difference between the space connected with the virtual network and the space created by daily life (Castells, 1996). Subsequently, the space of flows was extended to the physical space (the space of places) from pure cyberspace. The space of flows can be treated as the result of a combination of cyberspace and the space of places, which is a distinct approach to understand the mobility and transformation of urban form in the information era.

Measuring the space of flows is a critical approach to understand its influence on the space of places in an information society. The space of flows not only accelerates the interchange of element flows across time and space and amplifies the scope of urban production activity and residents' daily activity, but also reshapes the interactions and relationships between different spaces of places. The time-space compression was considered as the most important means to realize the flexible space accumulation in post-modern society (Harvey, 1989). The measurement of the space of flows could be used to reflect the extent of flexible accumulation. Meanwhile, the space of flows, playing a critical role for revitalizing rigid land use and improving spatial activity, becomes more and more important for urban planning. So measuring the space of flows could help to shed light on the extent to which the physical space is changed under the usage of ICTs. The existing measurement of space of flows mainly focuses on the analysis of relationships of individual flows at global and regional scales (Sassen, 2001; Taylor et al., 2007), but measuring the space of flows at the city scale is insufficient.

The aim of this paper is to propose a new approach to measure urban space of flows from the perspective of coupling cyberspace with the space of places. Three dimensions, accessibility, intensity of residential activity and spatial activeness are used to measure the space of flows in Nanjing. The following section is a literature review. Section 3 proposes a framework of urban space of flows and establishes a methodology to measure it, which will then be empirically examined in Section 4. The final section will be the conclusion and discussion.

2. LITERATURE REVIEW

2.1 The Mobility Turn: from element flows to the space of flows

ICTs have led to a global time-space compression which has made social production modes turn into flexible production and accumulation (Harvey, 1989), so factor flows and mobility have changed greatly. Kitchin (1997) emphasized the changing mobility of economic activities under the impact of ICTs, and the mobility of production and consumption activity nodes changed correspondingly. Virtual information flows could enhance the mobility of substantial elements (Kellerman, 2010). The progress of ICTs not only changes the mobility of material elements, but also has a certain impact on the resident's activity mobility. ICTs alleviate the connection of activities with time and space and decompose the individual activity into several fragments (Alexander et al., 2011; Couclelis, 2004) which changes the tempo-spatial mobility of activities. Based on the changing of activity mobility in the information era, Graham and Marvin (2001) and Urry (2000) put forward the concepts of 'splintering urbanism' and 'instantaneous time', respectively.

In addition, ICTs enhance the interaction between element flows and localization of place. Based on the interaction of element flows and localization of space in the information era, Urry (2008) put forward the idea of "mobility turn" and the new mobility paradigm. The new mobility paradigm stresses the combination of technologies, activities and local place, as well as the integration of cyberspace and physical space. Several concepts have been explored to interpret the result of integration, such as "Geocyberspace" (Bakis & Roche, 1997), "the combination of virtual and physical space" (Graham, 2004) and "Hybrid space" (e Silva, 2006). However, most researchers have agreed upon the concept of the "space of flows" (Bush & Oosterveer, 2007; Castells, 1989; Shen, 2010). The space of flows could be taken as the most appropriate expression of spatial transformation under the new mobility paradigm in the information era. In the beginning, Castells (2000, 2005) distinguished the space of flows and the space of places, then he began to emphasize the combination of the space of flows and the space of places). This combination has obvious effect on urban function, form and the meaning of place, and changes the connotation of the space of flows representing the virtual network space.

2.2 Measurement of the space of flows

Studies on the global space of flows based on connectivity provides a theoretical foundation and empirical method for world city network research. With this argument, the Globalization and World Cities Research Network (GaWK) focused on global city networks. Beaverstock et al. (2000) put forward methodologies to measure the connections between world cities using the data of business news, skilled inter-city migration and the geographical scope of producer services. Based on the division of global production, Alderson and Beckfield (2004) and Taylor (2004a) and Taylor et al. (2007) analysed the network connectivity between world cities through measuring the importance of producer services and NGOs. Using the interlocking network model, global network relationships were built with the technological infrastructure connections of world cities (for example, Telecom network, internet, etc.) to display the system structure of city networks (Derudder & Witlox, 2005; Malecki, 2002; Sassen, 2001; Smith & Timberlake, 1995). The global space of flows raised global production organization and the networking of global cities (Taylor, 2004b), and it results in the agglomeration and diffusion of nodes in global city networks (Leng & Yang, 2012). The measurement of global space of flows aims to reveal the impact of globalization (or informatization) on the local space.

Meanwhile, a lot of researchers have focused on the measurement of the regional space of flows with advanced producer services, people flows and communication and high-speed railway networks to reflect the structure of urban systems in America, Europe and China (Dong, Xiu, & Wei, 2014; Sokol, 2007; Wu, Fang, & Zhao, 2013; Zhen et al., 2013). The mega-city regions of Europe were measured with a spatial interaction analysis of transportation flows, commuting flows and telecom flows to estimate the core-peripheral structure and the polycentric metropolis (Hall & Pain, 2006). In addition, social networks, regression models and the Barabasi-Albert model have been employed to analyse regional space structure (Bailey, Allen, & Bras, 2004). In all, the researchers have tried to reveal the global and regional city networks and structural systems by measuring the connections and interactions of element flows between different cities.

In the information era, residents' mobility reflects much about urban space of flows (Xi et al., 2013) and element flows produced by residents' daily activities play a critical role in shaping urban space. Based on the time geography, researchers have intensively focused on the space-time accessibility and mobility of residents' activities (Kwan, 2013). Hägerstraand (1970) put forward the concept of space-time prisms to analyse individual behaviour and activities. Since then, some new methods, such as using activity diary surveys, GPS, smart phone and others, have been employed to obtain residential behaviour trajectories and analyse individual mobility (Kwan, 2004). The quantitative methods of the structural equation model (SEM) and regression model have been used to analyse the relationship between personal socio-economic attributes, ICT usage, spatial location, the built environment and behaviour (Wang, D. G. & Law, 2007). Meanwhile, several concepts, such as flexibility, multi-tasking and fragmentation, have been used to measure the tempo-spatial distribution and mobility of resident activities (Alexander, Ettema, & Dijst, 2010; Maeng & Nedović-Budić, 2008). Additional analysis on activity space and big data could be used to help to understand urban space of flows from the activity-mobility perspective (Zhao & Chai, 2013; Wilson & Graham, 2013).

In conclusion, the existing measurement of space of flows was mainly conducted through flow analysis and the activity analysis of residents who bear all kinds of flows. Different from the space of flows constituted by the production and management of computer networks (Castells, 1989), the new mobility paradigm emphasizes the system coupling of technologies, activities and physical space. However, understanding the space of flows from the new mobility paradigm, which reflects the interaction of cyberspace and physical space, is crucial for reshaping the space of places in an information society. As Figure 1 shows, technologies, institutions, activities and place are the four critical factors in analysing urban space of flows. Technologies (for example, ICTs, transportation, etc.) bring about space-time compression and change the mobility of activities, which integrates the cyberspace and physical space into the space of flows through the interaction of the virtual activities and physical activities. This is an important approach to understand the space of flows based on the new mobility paradigm in an information society. The current measurements of the space of flows are mainly referring to the connectivity of production elements and the mobility of residents' activities. However, the space of flows according to the new mobility paradigm needs to be reconsidered and a new methodology for measuring it established. This paper represents a modest attempt to fill such a gap. Specifically, examining how to measure urban space of flows by evaluating spatial mobility. This paper tries to shed light on this through an empirical study of Nanjing, China.

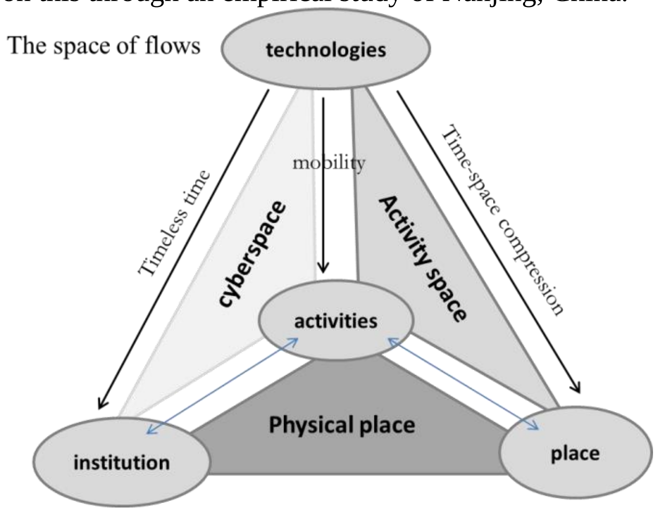

Figure 1. The logical analysis framework of space of flows

3. RESEARCH DESIGN

3.1 The research framework of urban space of flows

With the new mobility paradigm of an information society, the space of flows could be considered as superimposing residential activities, socio-economic interaction and the element flows upon physical space. This paper puts forward a new framework of spatial mobility to measure urban space of flows from three aspects, including technological accessibility, intensity of activity and spatial activeness (see Figure 2). The spatial mobility, which decides the organizational structure of the element flows, network and places within the space of flows, also shapes the boundary and scale of the space of flows through the dynamic changing of technological accessibility, activity intensity and spatial activeness at different times and spaces.

Most studies on spatial form and structure generalize the space as point, line and plane from the perspective of geometry. Shen (2010) adopted geometric features in analysing the structure of regional space of flows and considered that cities were the nodes of space of flows, the linear features were the transportation, information network, energy and other flows, and the plane elements of the space of flows included elite space, new industrial space and new urban space. Considering the three aspects of the spatial mobility and their role in constructing the space of flows, this paper distinguishes urban space of flows as consisting of the nodes of place, the route of flows, the boundary of flows, the network of flows and the functional zones. The nodes of urban space of flows are the different urban activity centres. The routes represent the direction and intensity of flows, and all the routes and nodes form the network of flows. The boundaries reflect the recession threshold of spatial mobility. The functional zones of the urban space of flows include the residential district, innovation space, recreation space production space, and so on.

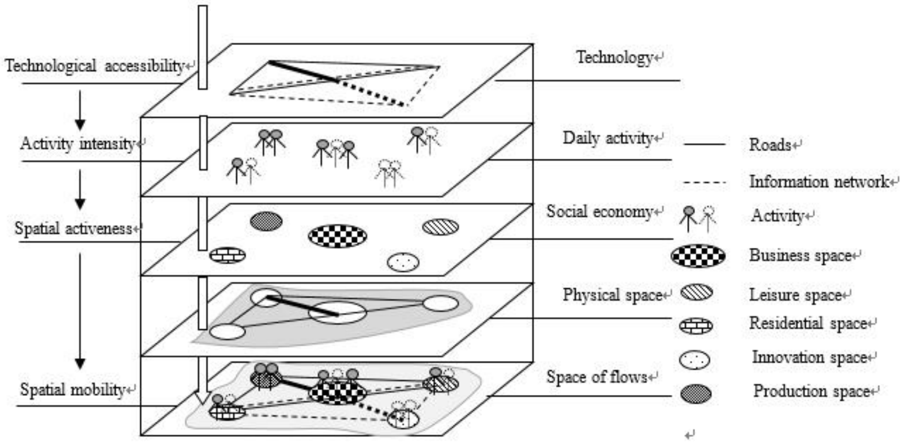

Figure 2. The hierarchy constitution of urban space of flows

3.2 Methodology

3.2.1 Data collection

A 2-day activity diary which was completed by 980 respondents was surveyed from September to October in 2012 in Nanjing, China. The research team selected 20 activity centres and randomly selected 40-60 people to whom they administered the survey at each centre. The activity diary was designed to enable each respondent to record the activities in which they participated during the most recent weekday and most recent weekend, including the types of physical and virtual activities in which they engaged during each period, the precise locations where the activities took place, and the type of activity location. We selected 642 effective samples to analyse the activity intensity. Meanwhile, details of the Nanjing traffic system and land use was obtained from the master plan of Nanjing City (2011-2030)[1].

3.2.2 Index system for evaluating the spatial mobility

This paper establishes an evaluation index system from three aspects, spatial accessibilities, the intensity of activity and spatial activeness.

(1) Spatial accessibility. The space of flows is the result of the interaction between cyberspace and the physical space. Its spatial accessibility includes the information access of cyberspace and the transportation accessibility of the physical space, so these two aspects are used to reflect the spatial accessibility. A measurement method of road importance is adopted to calculate the transportation accessibility. Different grade roads, such as railway stations, metro stations, highway roads, main roads and minor roads, are chosen to conduct a buffer analysis, then the results of transportation accessibility are evaluated through overlaying different buffers. According to the degree of effect of different roads on the activities of the surrounding area,

[1] Source: Nanjing Urban Planning Bureau. The Master Plan of Nanjing City (2011-2030).

the boundaries of the buffer are defined and different values are given. Individual usage of ICTs, which were measured with the usage of information equipment, internet usage and network application, were used to represent the level of informatization. Then, the informatization level of different spatial units (sub-districts) was obtained based on the average value of individual usage of ICTs. The question of whether respondents "*usually use smart phone or not*", "*usually use laptop or not*" and "*usually use Pad or not*" was chosen to reflect the usage of information equipment, then whether respondents "*can get access to internet at home*" and "*use mobile internet*" was chosen to represent the level of internet usage; the answer "*Yes*" is assigned "1" and the answer "*No*" is "0". "*Social network*" and 18 other kinds of network applications were used for evaluating residents' network application level; the answer "*usually use*" is valued "1", "*occasionally use*" is "0.5" and "*no use*" is "0".

(2) The intensity of activity. The intensity of an activity, reflecting the spatial distribution of residents' daily activities, is often closely related with the elemental flows and spatial mobility. The intensity of a physical activity has a close relationship with transportation accessibility, socioeconomic status and land use, and the intensity of a virtual activity reflects the information flows and the complexity of the spatial function. Based on the activity location obtained from the residents' activity diaries, the Kernel density method was adopted to analyse the density of activity on workdays and at the weekend. Thus, five times intensity of an activity on any given weekday, plus twice the intensity of an activity on a weekend makes the total intensity of activity.

(3) Spatial activeness. The spatial activeness, reflecting the condition of urban land use intensity and its dependent activities, can be expressed by analysing the scale of different types of construction land and the land use intensity within a certain spatial scope. Residential land, commercial land and industrial land are the main components of urban land use. The scale and intensity of these three land types represent the spatial activeness to a large extent (Xi et al., 2013). It is difficult to get data of land use intensity, so this study simplified the relative intensity of commercial land, residential land and industrial land to the values "3", "2" and "1", correspondingly. Then, the land use intensity was counted on a GIS platform with the present land use data.

3.2.3 Determining index weights

The Analytic Hierarchy Process (AHP) was adopted to determine the index weights. On the basis of this index system, a fuzzy judgment matrix was constructed to calculate the relative weight of indices, with which the spatial mobility can be weighted. The processes are as follows:

(1) Establishing the hierarchy. According to the index system for evaluating the spatial mobility, the hierarchy was established, which took the intensity of spatial mobility and its degree of effect on the space of flows as the target layer. The spatial accessibility, intensity of activity and spatial activeness were set as the indices of the first level, and its corresponding indices of the second level were the transportation accessibility, informatization level, intensity of activity on workdays and at the weekend, and the intensity of land use.

(2) Constructing fuzzy judgment matrix. A proportional scale from 1 to 9 was used to evaluate the relative importance of the i and j index:

Table 1. The meaning of proportional scale

Relative importance	Equal importance	Moderate importance	Obvious importance	High importance	Vital importance	The middle value of adjacent judgment
Value	1	3	5	7	9	2，4，6，8

The fuzzy judgment matrix is created by comparing one index to another:

$$A = (a_{ij})_{n\times n} \qquad (1)$$

In formula (1), a_{ij} is the relative importance of the comparison of *i* index to *j* index.

Then, a fuzzy judgment matrix was built as follows:

Table 2. The fuzzy judgment matrix

	Spatial accessibility（a1）	Intensity of activity（a2）	Spatial activeness（a3）
Spatial accessibility（a1）	1	1/2	2
Intensity of activity（a2）	2	1	3
Spatial activeness（a3）	1/2	1/3	1

(3) Calculating the index weights. First, measuring the maximum eigenvalue of the judgment matrix, its corresponding characteristic vector *W* was calculated. The component of $W(W_1, W_2,..., W_n)$ is the relative importance of *n* index, namely the coefficients of weight. Asymptotic Normalization Coefficient was used to calculate the weights. First of all, each column of the judgment matrix is normalized, then the judgment matrix is summed by rows, and the result of the summation is normalized for the characteristic vector.

$$W=[W_1,W_2,...,W_n]^T=[0.297, 0.538, 0.164] \qquad (2)$$

According to the single sorting of hierarchy, the judgment matrix meets the consistency check. So the index system and weights of spatial mobility are as follows:

Table 3. The index system and weights of spatial mobility

The first level indices (weights)	The second level indices (weights)	The description of indices		Assignment
Spatial accessibility（0.297）	Transportation accessibility（0.1485）	The buffer of railway (subway) station	First class buffer of railway (subway) station	9
			Second class buffer of railway (subway) station	5
			Third class buffer of railway (subway) station	1
		The buffer of roads	First class buffer of roads	9
			Second class buffer of roads	5
			Third class buffer of roads	1
	Informatization level（0.1485）	The usage of information equipment	Whether usually use smart phone or not	“Yes” is “1”; “No” is “0”
			Whether usually use laptop or not	“Yes” is “1”; “No” is “0”
			Whether usually use Pad or not	“Yes” is “1”; “No” is “0”
			Whether can get access to internet at home	“Yes” is “1”; “No” is “0”

		The level of internet usage	Whether to use mobile internet	"Yes" is "1"; "No" is "0"
		Network application level	Whether usually use the network application of smart phone and computer	"usually use" is "1", "occasionally use" is "0.5" and "no use" is "0"
Intensity of activity (0.538)	Intensity of activity on workday (0.384)	Activities on workday	Physical activities	The intensity of spatial distribution
			Virtual activities	The intensity of spatial distribution
	Intensity of activity at weekend (0.154)	Activities at weekend	Physical activities	The intensity of spatial distribution
			Virtual activities	The intensity of spatial distribution
Spatial activeness (0.164)	intensity of land use (0.164)	The type of land use	Commercial land	3
			Residential land	2
			Industrial land	1

4. RESULTS

4.1 The characteristics of spatial mobility

Based on the three aspects of the spatial mobility evaluation and its weighted results, Figure 3 shows the overall spatial mobility in Nanjing . It can be seen that the highest spatial mobility is concentrated in the old city, especially in Xinjiekou and its surroundings are the maximum mobility areas. The old city is the traditional urban centre of Nanjing with higher construction density, and it also has the most developed transportation system and most agglomerated activities. Therefore, the transportation accessibility and the intensity of activity are quite excellent. All of these conditions bring about the highest spatial mobility for the old city of Nanjing, which means that the old city is still the agglomerated centre of element flows and plays an important role in the whole urban functional organization.

The spatial mobility in the inner cities of Nanjing, such as in Hexi new town, the Nanjing railway station area, Zhonghuamen area, Xiaolingwei area and other areas, is relatively high, and there can be found cluster nodes of mobility in these areas. Hexi is a newly built town, and residents' activity here is less than that in the old city, however, Hexi new town attracts a lot of young people with a higher informatization level. The transportation accessibility remains in a better condition in the Nanjing railway station area, and also in Zhonghuamen and other inner city areas, which supports the residents' activities and efficient element flows. Thus, the spatial mobility in the inner city is relatively high, as are the number of places in the inner city performing as the connectors between the old city, with intensified mobility, and the outer city, with lower mobility.

Meanwhile, the spatial mobility in parts of the outer city is also relatively high, these areas include Nanjing high speed rail station and its surroundings, Jiangning new town, Xianlin centre, Nanjing economic and technological development zone, and so on. With the spatial expansion of the Nanjing metropolitan area, these areas become new urban growth centres and undertake specific urban functions, such as the regional transportation function, urban technology innovation and education function, and so on. The development of these functions brings the aggregation of production and living activities, as well as the aggregation and expansion of element flows in the outer city of Nanjing, so several spatial mobility nodes are gradually forming. However, the rest of built-up areas and suburbs have the lowest mobility.

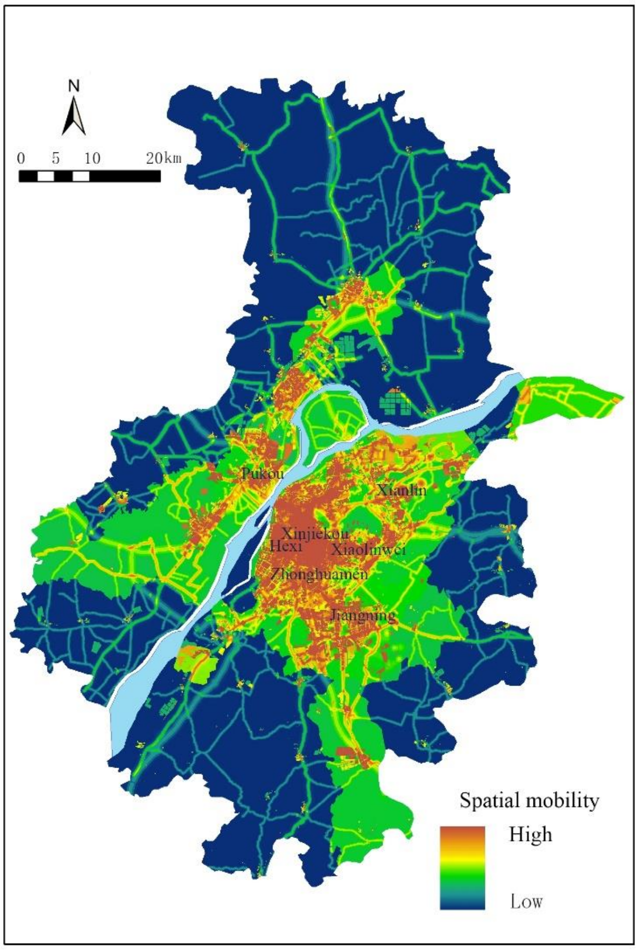

Figure 3. The distribution of spatial mobility in Nanjing

4.2 The topological structure of urban space of flows

The evaluation of the spatial mobility is an important approach to measure urban space of flows, which can be used to analyse the structure of urban space of flows through the intensity of the spatial mobility and connection direction of places. Based on the evaluated results of the spatial mobility, the topological structure of urban space of flows in Nanjing can be interpreted from five components (see Figure 4).

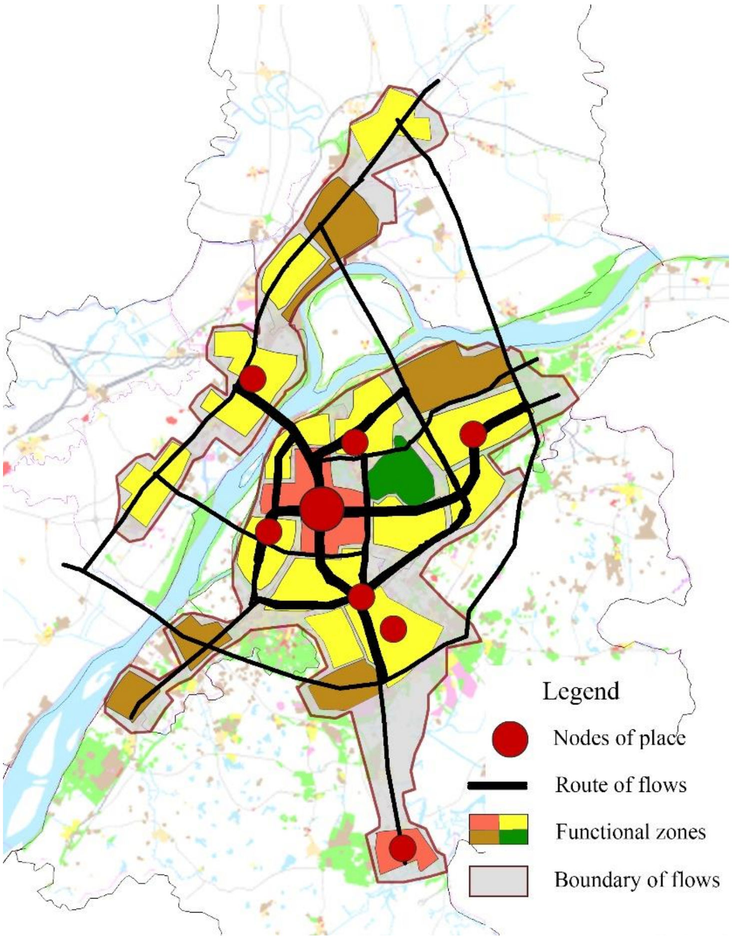

Figure 4. The topological structure of space of flows in Nanjing

4.2.1 The nodes of place

The primary activity centres constitute the nodes of place in the urban space of flows. The nodes of place with different scales, type and function have different effects on the elemental agglomeration and diffusion, which influences the interaction intensity between nodes of place. The old city of Nanjing is the most intensified mobility area with its developed transportation system and places of highly concentrated activity. Xinjiekou area is the core of the old city, which is treated as the Central Activity Zone (CAZ) of Nanjing (Wang, B. et al., 2015). It is also the central node in the Nanjing urban space of flows and plays a crucial role in the agglomeration and diffusion of the element flows generated by the enterprise and resident activity at the regional and metropolitan scales. Meanwhile, the higher mobility areas, such as Nanjing railway station, Nanjing high speed railway station, Xianlin centre, Hexi new town centre, Jiangning new town centre and Nanjing air harbour, are important nodes in the network of urban space of flows, and are also the places with the highest aggregated activity and active spaces.

The railway station and airport are the window nodes for Nanjing to connect to the global and regional space of flows, conversely, the localized accumulation of global and regional element flows enhances the function gathered in these transportation nodes and the appearance of new industrial zones (for example, high-speed rail business district, airport industrial district, and so on). The nodes of new town centres, formed in the process of suburbanization, are comprehensive places with business, catering, leisure, entertainment and other functions, which play a vital role in optimizing the spatial structure of new urban districts.

4.2.2 The route of flows

The direction of routes reflects the interactions between different places and the strength of routes reflects the interaction intensity between places and functional zones. The connection route of nodes and places in Nanjing's space of flows could be treated as a network structure with a 'ring and radial' pattern, which connects different types of functional zones and different scale nodes together.

The ring route of flows connects the functional zone and nodes of space of different urban layers together, and constitutes the channel of element flows for the inner city and the outer city in Nanjing. The inner ring route, supported by the express way around the outside of Nanjing inner city, connects Yuhuatai, Qinhuai, Xuanwu and other districts together, and is also the fast connection channel between the inner city and outer city. The element flows along that channel are intensified. The outer ring route, which is formed by the ring highway across the outer city, connects Xianlin, Jiangning, Pukou, Liuhe and other outer cities. Because the spatial mobility of Nanjing outer city is less intensified than that of the inner city and old city, so are the ring routes.

The radial routes are the important channels between the Xinjiekou CAZ and other urban areas. Several radial routes assemble in the old city to support the functioning agglomeration and diffusion of the CAZ. The radial routes of flows directed from the CAZ to newly built urban districts in the outer city are beneficial for transferring the elements of the old city to the suburbs, playing a positive role in the construction of functions and nodes in the suburban areas.

4.2.3 The boundary of flows

The boundary of flows is the result of the coupling of residents' daily activity, urban infrastructure construction and land use, and is closely related to urban spatial expansion and the urban growth boundary (UGB). The boundary of flows could be characterized by the recession of a region of spatial mobility. The boundary of Nanjing's space of flows is mainly distributed to the south of the Yangtze River, most of that being concentrated within the range inside the ring highway. The boundary range outside the ring highway extends to the southern part of the outer city until it reaches the airport zone. The boundary of flows takes the shape of a belt distribution along the north bank of the Yangtze River and covers Jiangpu Street, Dachang, Liuhe town and other functional zones. The boundary of flows could be considered as a flexible scope for UGB governance.

4.2.4 The functional zones

The functional zones can be divided into a comprehensive business district, residential district, recreation and leisure district, new industrial district, and so on. The old city of Nanjing is the main comprehensive business district and serves the metropolitan and wider regional area. Under the background of transformation development, the land use of the comprehensive business district in the old city has become even more mixed with the application of mobile information technologies and E-commerce, as well as the development of headquarters of economy and technological innovation. Meanwhile, its corresponding places have turned into more complex and flexible areas. The recreation and leisure zones (for example, Xuanwu lake scenic area, Zijin mountain scenic area, and so on) play an important role in improving urban quality. The new industrial districts are mainly distributed in the outer city of Nanjing, such as the economic and technological development area, software industrial park, et cetera. These new industrial districts are important spaces of places for Nanjing to participate in the international division of labour and to engage in element flows of global production. In all, the functional zones are the basic spatial form of the space of flows, and their combinations reflect the spatial relationship and interaction of socioeconomic activities, which also have an effect on the mobility of residential and enterprise activities.

4.2.5 The network of flows

The nodes and routes are the basic components of the network of flows, which can be treated as a combination of the public activity places, mobility support systems (for example, transportation system, information technologies, et cetera) and element flows. The network of flows in the information era is created by the agglomeration and interaction of residents' daily activities. Castells (1996) believed that the network in the space of flows was the spatial organization of the management elite, and the network of the management elite brought the imbalance of social organization. However, with the wide usage of information technologies, this space of flows is no longer a network by the organization of the management elite, but a connection network of urban residents' daily activities. The topological structure of the Nanjing space of flows takes on the characteristics of a flat network. On the one hand, the space of flows shows the scale-free network of cyberspace, on the other hand, it is embedded in the space of places and effected by the hierarchical system of places.

5. CONCLUSION AND DISCUSSION

Based on the new mobility paradigm of the information era, this paper put forward a new methodology to measure urban space of flows through evaluating spatial mobility. Urban space of flows have been considered as the coupling of technologies, activities, socio-economic factors and the physical environment. Following this, spatial mobility was taken as an important measurement for an evaluation of the urban space of flows. The evaluation model was structured from technological accessibilities, the intensity of activity and the spatial activeness. With the data of residential activity dairies and the data of Nanjing's traffic system and land use, a case study of Nanjing was undertaken to understand the topological structure of urban space of flows from the nodes of place, the route of flows, the boundary of flows, the functional zones and the network of flows.

The existing analyses of the space of flows mainly adopted the element flows to describe its structure from the perspective of the nodes and networks. Such research attempted to account for the global city network and regional space structure through analysing the macro-scale element flows (Sassen, 2001; Taylor et al., 2007). Substantially, it focused on the ideas of the production division of labour system and connecting networks in the context of globalization and informatization, and how the geographic embeddedness of mobility elements influenced the development of localization space (Reades &

Smith, 2014). However, the systematic analysis of the coupling of element flows and localization space is insufficient. The residential activity space becomes more and more important in shaping the urban spatial structure in information societies, so this paper evaluated spatial mobility considering the technological support interactions, residential activities and the space of places, and built a new methodology for measuring urban space of flows under the new mobility paradigm.

Based on the evaluation results of spatial mobility, the topological structure of Nanjing's space of flows was identified as the nodes of pubic activity, the routes and network of flows, and the functional zones. In addition, Xinjiekou is treated as the CAZ, and there are some other nodes of transportation and business in the inner and outer city. The boundary of flows is mainly confined to the main urban districts and most of the urban functional zones are distributed in these areas. The routes of the 'ring and radial' pattern connect the nodes of flows and the functional zones to form the network of Nanjing's space of flows. The empirical analysis could help to understand urban spatial structures from the system coupling of technologies, activities and environment in the information era, so as to improve the sustainability and coordination of urban space.

Studies on the spatial mobility and urban space of flows could help to guide the construction of physical space. Aimed at improving the spatial mobility of newly built urban districts, some policies should be implemented to reinforce the agglomeration of different element flows so as to advance the development quality of these zones. The mobility connections between the urban central district and urban fringe areas are through the application of intelligent transportation and other information technologies. On the one hand, in order to alleviate traffic congestion, environmental degradation and other urban diseases in central districts due to the highly concentrated and intensified land use, some element flows in urban central districts should be dispersed to urban fringe areas. On the other hand, the new nodes of a space of flows could be cultivated in the outer city and suburbs to optimize the layout of urban nodes of place and to realize the balanced development of an urban space.

The recording of activity diaries was completed by means of memory recollection, so the data is not as precise as expected. A more accurate data collecting approach (for example, using GPS, smart phone, et cetera) could be used to obtain the trajectory of residential activity (Lee & Kwan, 2011). Although residential daily activities and people mobility have become the most important factors for the reconstruction of urban space, the production element flows still play a critical role in shaping the urban space of flows. It is necessary to explore more complex methods to analyse urban space of flows with the production element flows, residential daily activity and mobility, as well as other factors in future research.

ACKNOWLEDGEMENTS

This work was supported by the National Natural Science Foundation of China under Grant 41571146.

REFERENCES

Alderson, A. S., & Beckfield, J. (2004). "Power and Position in the World City System". *American journal of sociology*, *109*(4), 811-851.

Alexander, B., Ettema, D., & Dijst, M. (2010). "Fragmentation of Work Activity as a Multi-Dimensional Construct and Its Association with Ict, Employment and Sociodemographic Characteristics". *Journal of Transport Geography*, *18*(1), 55-64.

Alexander, B., Hubers, C., Schwanen, T., Dijst, M., & Ettema, D. (2011). "Anything, Anywhere, Anytime? Developing Indicators to Assess the Spatial and Temporal Fragmentation of Activities". *Environment and Planning B: Planning and Design*, *38*(4), 678-705.

Bailey, R., Allen, J. K., & Bras, B. (2004). "Applying Ecological Input-Output Flow Analysis to Material Flows in Industrial Systems: Part I: Tracing Flows". *Journal of Industrial Ecology*, *8*(1-2), 45-68.

Bakis, H., & Roche, E. M. (1997). "Cyberspace-the Emerging Nervous System of Global Society and Its Spatial Functions". In Roche, E. M. & Bakis, H. (Eds.), *Developments in Telecommunications. Between Global and Local*. Brookfield, VT: Ashgate Publishing Company.

Beaverstock, J. V., Smith, R. G., Taylor, P. J., Walker, D., & Lorimer, H. (2000). "Globalization and World Cities: Some Measurement Methodologies". *Applied geography*, *20*(1), 43-63.

Bush, S. R., & Oosterveer, P. (2007). "The Missing Link: Intersecting Governance and Trade in the Space of Place and the Space of Flows". *Sociologia Ruralis*, *47*(4), 384-399.

Cairncross, F. (2001). *The Death of Distance: How the Communications Revolution Is Changing Our Lives*. Boston: Harvard Business Press.

Castells, M. (1989). *The Informational City: Information Technology, Economic Restructuring, and the Urban-Regional Process*. Oxford: Blackwell.

Castells, M. (1996). *The Information Age: Economy, Society, and Culture Vol I - the Rise of the Network Society*. Cambridge: Blackwell.

Castells, M. (2000). "Materials for an Exploratory Theory of the Network Society1". *The British journal of sociology*, *51*(1), 5-24.

Castells, M. (2005). "Space of Flows, Space of Places: Materials for a Theory of Urbanism in the Information Age". In Bishwapriya, S. (Ed.), *Comparative Planning Cultures*. New York: Routledge.

Couclelis, H. (2000). "From Sustainable Transportation to Sustainable Accessibility: Can We Avoid a New Tragedy of the Commons?". In Janelle, D. G. & Hodge, D. C. (Eds.), *Information, Place, and Cyberspace* (pp. 341-356). Berlin: Springer.

Couclelis, H. (2004). "Pizza over the Internet: E-Commerce, the Fragmentation of Activity and the Tyranny of the Region". *Entrepreneurship & Regional Development*, *16*(1), 41-54.

Derudder, B., & Witlox, F. (2005). "An Appraisal of the Use of Airline Data in Assessing the World City Network: A Research Note on Data". *Urban Studies*, *42*(13), 2371-2388.

Dong, C., Xiu, C. L., & Wei, Y. (2014). "Network Structure of 'Space of Flows' in Jilin Province Based on Telecommunication Flows". *Acta Geographica Sinica*, *69*(4), 510-519.

e Silva, A. S. (2006). "From Cyber to Hybrid Mobile Technologies as Interfaces of Hybrid Spaces". *Space and culture*, *9*(3), 261-278.

Graham, S. (2004). *The Cybercities Reader*. London: Routledge.

Graham, S., & Marvin, S. (2001). *Splintering Urbanism: Networked Infrastructures, Technological Mobilities and the Urban Condition*. London: Routledge.

Hägerstraand, T. (1970). "What About People in Regional Science?". *Regional Science*, *24*(1), 7-24.

Hall, P. G., & Pain, K. (2006). *The Polycentric Metropolis: Learning from Mega-City Regions in Europe*. London: Earthscan Publications.

Harvey, D. (1989). *The Condition of Postmodernity: An Enquiry into the Origins of Cultural Change*. Cambridge: Blackwell.

Hjorthol, R., & Gripsrud, M. (2009). "Home as a Communication Hub: The Domestic Use of Ict". *Journal of Transport Geography*, *17*(2), 115-123.

Kellerman, A. (2010). "Mobile Broadband Services and the Availability of Instant Access to Cyberspace". *Environment and planning A*, *42*(12), 2990-3005.

Kitchin, R. (1997). "Social Transformations through Spatial Transformations: From 'Geospaces' to 'Cyberspaces'". In Behar, J. E. (Ed.), *Mapping Cyberspace: Social Research on the Electronic Frontier* (pp. 149-173). New York: Dowling College Press.

Kwan, M. P. (2004). "Gis Methods in Time-Geographic Research: Geocomputation and Geovisualization of Human Activity Patterns". *Geografiska Annaler: Series B, Human Geography*, *86*(4), 267-280.

Kwan, M. P. (2013). "Beyond Space (as We Knew It): Toward Temporally Integrated Geographies of Segregation, Health, and Accessibility: Space–Time Integration in Geography and Giscience". *Annals of the Association of American Geographers*, *103*(5), 1078-1086.

Lee, J. Y., & Kwan, M. P. (2011). "Visualisation of Socio-Spatial Isolation Based on Human Activity Patterns and Social Networks in Space-Time". *Tijdschrift voor economische en sociale geografie, 102*(4), 468-485.

Leng, B. R., & Yang, Y. C. (2012). *Network Growth: From Network Studies to City Network*. Lanzhou: Lanzhou University press.

Li, J. (2011). *Global Production Networks and Spatial Organization of Production in Metropolitan Areas*. Beijing: Science Press.

Maeng, D.-M., & Nedović-Budić, Z. (2008). "Urban Form and Planning in the Information Age: Lessons from Literature". *Spatium*, (17-18), 1-12.

Malecki, E. J. (2002). "The Economic Geography of the Internet's Infrastructure". *Economic Geography*, *78*(4), 399-424.

Mokhtarian, P. L. (1990). "A Typology of Relationships between Telecommunications and Transportation". *Transportation Research Part A: General*, *24*(3), 231-242.

O'Brien, R. (1992). *Global Financial Integration: The End of Geography*. London: Council on Foreign Relations Press.

Ohmori, N., & Harata, N. (2008). "How Different Are Activities While Commuting by Train? A Case in Tokyo". *Tijdschrift voor economische en sociale geografie*, *99*(5), 547-561.

Reades, J., & Smith, D. A. (2014). "Mapping the 'Space of Flows': The Geography of Global Business Telecommunications and Employment Specialization in the London Mega-City-Region". *Regional Studies*, *48*(1), 105-126.

Salomon, I. (1986). "Telecommunications and Travel Relationships: A Review". *Transportation Research Part A: General*, *20*(3), 223-238.

Sassen, S. (2001). *The Global City: New York, London, Tokyo*. Princeton: Princeton University Press.

Shen, L. Z. (2010). *Space of Flow*. Nanjing: Southeast University Press.

Smith, D. A., & Timberlake, M. (1995). "Conceptualising and Mapping the Structure of the World System's City System". *Urban Studies*, *32*(2), 287-302.

Sokol, M. (2007). "Space of Flows, Uneven Regional Development, and the Geography of Financial Services in Ireland". *Growth and Change*, *38*(2), 224-259.

Taylor, P. J. (2004a). "The New Geography of Global Civil Society: Ngos in the World City Network". *Globalizations*, *1*(2), 265-277.

Taylor, P. J. (2004b). *World City Network: A Global Urban Analysis*. London: Routledge.

Taylor, P. J., Derudder, B., Saey, P., & Witlox, F. (2007). *Cities in Globalization: Practices, Policies and Theories*. London: Routledge.

Urry, J. (2000). *Sociology Beyond Societies: Mobilities for the Twenty-First Century*. London: Routledge.

Urry, J. (2008). "Moving on the Mobility Turn". In Canzler, W., Kaufmann, V., & Kesselring, S. (Eds.), *Tracing Mobilities: Towards a Cosmopolitan Perspective*. Aldershot: Ashgate.

Wang, B., Zhen, F., Wei, Z., Guo, S., & Chen, T. (2015). "A Theoretical Framework and Methodology for Urban Activity Spatial Structure in E-Society: Empirical Evidence for Nanjing City, China". *Chinese Geographical Science*, *25*(6), 672-683.

Wang, D. G., & Law, F. Y. T. (2007). "Impacts of Information and Communication Technologies (Ict) on Time Use and Travel Behavior: A Structural Equations Analysis". *Transportation*, *34*(4), 513-527.

Wilson, M. W., & Graham, M. (2013). "Situating Neogeography". *Environment and planning A*, *45*(1), 3-9.

Wu, K., Fang, C. L., & Zhao, M. X. (2013). "The Intercity Space of Flow Influenced by High-Speed Rail: A Case Study for the Rail Transit Passenger Behavior between Beijing and Tianjin". *Acta Geographica Sinica*, *68*(2), 159-174.

Xi, G. L., Zhen, F., Shen, L. Z., & Wang, B. (2013). "The Evaluation of Resident Fluidity and the Spatial Characteristics of Flow in Nanjing". *Scientia Geographica Sinica*, *33*(9), 1051-1057.

Zhao, Y., & Chai, Y. W. (2013). "Residents' Activity-Travel Behavior Variation by Communities in Beijing, China". *Chinese Geographical Science*, *23*(4), 492-505.

Zhen, F., Wang, X., Yin, J., & Zhang, M. (2013). "An Empirical Study on Chinese City Network Pattern Based on Producer Services". *Chinese Geographical Science*, *23*(3), 274-285.

Zhen, F., & Wei, Z. C. (2008). "Influence of Information Technology on Social Spatial Behaviors of Urban Residents—Case of Nanjing City in China". *Chinese Geographical Science*, *18*(4), 316-322.

International review for spatial planning and sustainable development, Vol.4 No.4 (2016), 58-68
ISSN: 2187-3666 (online)
DOI: 4http://dx.doi.org/10.14246/irspsd.4.4_58

Community development in urban Guangzhou since 1980: a social sustainability perspective

Zongcai Wei[1,2], Bo Wang[3], Tingting Chen[4,*], Yunqi Lin[5]
1 School of Architecture, State Key Laboratory of Subtropical Building Science, South China University of Technology
2 Department of Urban Planning and Design, The University of Hong Kong
3 Department of Geography, The University of Hong Kong
4 School of Geography and Planning, Sun Yat-Sen University, Urbanization Institute of Sun Yat-Sen University
5 Department of Urban Planning, Southeast University
** Corresponding Author, Email: cindychenhku@gmail.com*

Received: March 8, 2016; Accepted: June 4, 2016

Key words: Community development, Work-unit compounds, Gated communities, Housing marketization reform, Social sustainability, Guangzhou

Abstract: Following the worldwide trend of housing privatization, housing marketization reform was conducted by the Chinese government to tackle the giant housing shortage. However, since then, community development based on the relatively homogeneous work-unit compound has experienced radical transformations. The residential space in urban China has become more complicated, fragmented and segregated, and gated communities become the dominant component. However, are the new types of housing estates that have emerged after the reform more socially sustainable than the former? What are the typical issues of these housing estates from the perspective of social sustainability? Theoretically, the impact of housing marketization reform in China on the community level has received relatively less attention. Moreover, little research on the social sustainability has been conducted for cities and communities in mainland China. This paper aims to explore evolving housing estates and their social sustainability in China, using a case of Guangzhou, which enriches the international debates on social sustainability at the community level. The paper concludes that it is challenging to identify which types of communities are more socially sustainable, owing to the comprehensive nature of social sustainability. However, one type of community may have advantage over others in some aspects. The living environment of gated communities is indeed better than work-unit neighborhoods, while the social relations within the work-unit compounds are more harmonious.

1. INTRODUCTION

Housing is an important and common issue of peoples' livelihoods in the government agenda globally. Following the worldwide trend of housing privatization, the marketization of public housing has been implemented in China since 1980, which has been considered as some of the most important elements of economic reform (Lee, 2000; Logan, J. R. & Bian, 1993; Wang & Murie, 1996; Wu, 1996; Zhou & Logan, 1996). However, compared with other countries in the world, housing development based on the relatively homogeneous work-unit society in urban China has experienced more radical transformations due to the tremendous transition from the Socialist Planned Economy to the Socialist Market Economy. The residential space has become more complicated, fragmented and segregated, and gated communities become the dominant component.

The housing marketization reform in China has been discussed by many scholars. Gao (1990) compared the different roles of developers and housing consumers in the development process of the Chinese housing market, highlighting the relationships between markets and affordable housing according to the targeted coverage of housing market reforms. Wu (1996) pointed out that the state work-units played a critical role in the changes of public-sector housing in China. Recently, scholars begun to rethink the drawbacks of this housing reform. Wang and Murie (1996) contend that housing reform in Chinese cities has been considered a significant change to the socialist urban system, while the housing market and the socialist status in China still remain in a transitional phase with inequalities. Lee (2000) argues that the reform process has generally neglected its impact on issues such as inequality and distributive justice. (Huang, 2005) holds that a relatively homogeneous society characterized by work-unit compounds in socialist China has been evolving into one with significant stratification and segregation, with the implementation of housing marketization policy. Chen, Chen, and Liu (2008) also point out how housing marketization has aggravated housing and income inequality should be promulgated. Ye, Song, and Tian (2010) consider the effect of social housing policies since the housing marketization, particularly on remedying the emergent weaknesses during this process. The extant literature mainly concentrates the housing marketization process and its effects on the city or country level. Nevertheless, the impact of housing marketization reform on the community level has received less attention.

Sustainable development has aroused extensive attention globally, both academic and political, since the late 1980s, coinciding with the publication of the so-called Brundtland Report 'Our Common Future' in 1987. This notion has become increasingly influential on planning, housing and urban policy worldwide. Although the social dimension of sustainability is widely accepted, there is no consensus on the definition of social sustainability (Bramley & Power, 2009; Colantonio, 2010; Dempsey et al., 2011), since this concept is currently being approached from diverging research perspectives, and another reason is the difficulty of assessing the intangible nature of social aspects of development (Colantonio, 2010). Therefore, there are even less investigations on social sustainability at the community level. However, little research has been conducted for cities and communities in mainland China. There is a high demand to explore whether the current housing estates of the developing countries, especially in transitional urban China, are socially sustainable or not, and to what extent? Moreover, which are more socially sustainable among different types of housing estates?

In the following sections, the definition of social sustainability at the community level is first reviewed to establish an analytical framework for this study. Subsequently, the evolving processes of housing policy in China since 1980 are discussed in section three, with a special focus on Guangzhou. To present a wider picture of the multifunctional socio-spatial connotations of housing estates in urban China, the analytical framework is applied to investigate the typical characteristics and issues of two different types of urban enclaves from the perspective of social sustainability and to unpack their heterogeneities in the following sections. This study would enrich the international debates on social sustainability at the community level and aid in the creation of socially sustainable communities.

2. SOCIAL SUSTAINABILITY: LITERATURE REVIEW

Prior to evaluating the social sustainability of housing estates, it is indispensable to identify the definition of social sustainability at the community level. Social sustainability is an umbrella concept and there is no consensus on this concept. In addition, there is relatively limited literature focusing on social sustainability (Bramley & Power, 2009). Moreover, it is a multi-dimensional concept with the underlying question 'what are the social goals of sustainable development?' (Dempsey et al., 2011).

Communities can be regarded as 'physically delimited spaces within urban settlements, bringing together residents and businesses who live and work in them, and organizations, from within or without, concerned with managing the people and building in the area' (Manzi et al., 2010). Some scholars believe community is a living organism. It grows, improves, deteriorates and changes over time. The elements that influence such change have become more complex as the society emerges (Wiesel, 2012). Community is also considered as one indispensable dimension which should be taken into account to define social sustainability (Pareja-Eastaway, 2012). The neighborhood unit is a physical design tool that provides opportunities for residents to interact with people and to develop sense of place and ownership (Lawhon, 2009).

Compared with the studies on social sustainability at the community level, there are more studies and practices in a broader and more comprehensive field: sustainable community, which mainly focuses on several key themes, including meeting the diverse needs of residents (Office of the Deputy Prime Minister, 2006; City of Vancouver (CoV), 2005; McKenzie, 2004; Raco, 2003), social interaction/social networks (City of Vancouver (CoV), 2005; Dempsey et al., 2011; Manzi et al., 2010), participation (Dempsey et al., 2011; McKenzie, 2004) and safety and security (Office of the Deputy Prime Minister, 2006; Dempsey et al., 2011);. It is clear that these above definitions and principles of sustainable communities are human-orientated, emphasizing more on the social aspects, which mirrors the significant role of social pillars in sustainable development at the community level.

However, successful programs to deliver sustainable communities are delicate and applicable to local circumstances rather than trying to exhibit a 'pattern' that works elsewhere (Congreve, 2012). When we discuss the social sustainability of communities, the main components of social sustainability are basic needs, individual capacity and social capacity. Individual capabilities are linked to education, skills, health, values and leadership, while community capabilities stem from relationships, networks and norms facilitating collective action (Colantonio, 2010). It is obvious that sustainability of community concentrates more on the collective aspects of social life than on the individual ones. However, the basic needs should not be neglected. In addition, Chiu (2004) points out the social sustainability of housing should focus on both the people and the environment.

It can also be found that there is a common ground where the physical context is highlighted in the definition of social sustainability in both the urban context and housing context, indicating that there could be some relationships between the social sustainability and physical/environmental aspects. Therefore, social sustainability at the community level encompasses two dimensions in this study: the living environment for meeting the diverse needs of residents, which contains internal housing conditions, such as the adequacy of dwelling space, degree of self-containment and community facilities and related services; social relations within the community covers the involvement of the public or at least the stakeholders in the community activities, and in the formulation and implementation of housing policies.

3. HOUSING REFORM IN CHINA SINCE 1980

Since 1980, the housing system in China has undergone dramatic transformations from domination by public/collective ownership and administrative allocation to home-ownership and privatization after housing reform. Guangzhou is no exception. The transition from the traditional work-unit system to the gated enclaves in the housing marketization process is achieved. There are three major stages.

3.1 1980 - 1997, housing reform experiments on marketization

During the period from 1949 to the 1980s, the work-units owned by the government played a dominant role in the housing system. These types of housing estates were built and distributed to users by administrative means. However, a critical housing shortage was triggered due to the low efficiency of the social welfare-orientated housing system (Wang & Murie, 1996). To satisfy the increasing demand for housing, China conducted several housing reform experiments following Deng Xiaoping's speeches on the direction for urban housing reform in 1978 and 1980, such as encouragement of the marketization of the housing sector. In 1991, a comprehensive housing reform strategy was issued by the State Council to reinforce the reform, primarily through varying housing prices in accordance with affordability in the mid-1990s. Increasingly, more work-unit compounds were transformed into commodity housing enclaves during this process. Guangzhou was not selected as one of the experimental cities in this reform wave owing to its essential economic role nationwide. Guangzhou initiated its housing reform in 1989 and accomplished this mission around 2000.

3.2 1998 – , deepening of urban housing system reform and the rise of gated communities

In July 1998, to accelerate the pace of housing reform, the Central Government announced further intensified policy on the termination of the administrative distribution of housing and the gradual implementation of housing monetization. However, due to some complex difficulties in the implementation process, especially financial constraints and fragmented organization, this policy could not be set on the ground until January 2000. Even so, the progress of housing commercialization in Chinese cities has sped up and been accomplished.

Since the late 1990s, gated communities have become prevalent in urban China, classifying from luxury housing estates to ordinary commodity housing communities. Actually, the principle of 'gated community' is adopted by almost all the new-built commodity housing estates now (Miao, 2003). The expansion of gated communities developed by real estate developers has become intensive and property management companies have been introduced into community management in the process of market-based property development. The gated communities are constructed extensively in different locations in the cities, while the luxury gated communities are generally clustering into some scarce lots.

As a significant element of rapid urbanization, the construction of gated communities with a large proportion in the suburban areas has been experienced by many Chinese cities, and Guangzhou is a representative case. In Panyu district of southern Guangzhou, several major real estate developers, like Star River, Agile, Country Garden and so on, led an influential new towns' building movement on a super-large scale. All the implemented estates are gated communities, which occupy the cultivated land with a total number of approximately 17 square kilometers and generate massive negative influence on the sustainable development at the city level.

4. SOCIAL SUSTAINABILITY OF WORK-UNIT COMPOUNDS IN GUANGZHOU

Generally, work-unit refers to a special kind of workplace in the context of state socialism where the workplace becomes an extension of the state apparatus and undertakes the function of social organization (Wu, 1996). Although the housing market reform was launched a few decades ago, the work-units are still functioning within the housing system (Huang, 2005). The construction of work-unit urban housing in China was mainly conducted by the government, and its provision, considered as one aspect of socialist welfare, is largely implemented and administrated through work units. Local governments put the achievement of greater, faster, better and more economical outcomes as their top priority, rather than the protection of the natural environment. Thus, there is no difference between the construction of work-unit compounds and the production of industrial products. In addition, all the work-unit compounds seemed quite similar, with a lack of local characteristics and environmentally friendly design. Considering the development intensity, compared with the low-rise dwellings of three or four storeys in the 1950s, the buildings in the 1980s grew higher, with six storeys (Zhang, Chai, & Zhou, 2009), which promoted the rapid increase of building density and of the Plot Ratio of the housing estates. With the scarcity of the land quota for construction in the city proper, increasingly more large-scale work-unit communities were developed in the peri-urban area of the city.

Generally, the self-contained 'corporate-governed' unit is a typical characteristic of the socialist public housing system in China. Although great differences emerged in the scale and layout of the work-unit compounds nationwide, two fundamental function areas, including the working area and the living area, should be covered. The health, education and housing-related services are provided in the living area for the self-sufficiency of the work-unit compounds, which makes residents easily able to access the daily goods and services within the communities.

However, the housing space of the work-unit compound was quite low, due to the scarcity of the housing resources. The per capita living space in the urban area had remained roughly 4 square meters since 1949, and rose to

7.5 square meters in 1993 (Logan, R. et al., 1997). Nevertheless, the living condition of the residents was still very low due to the insufficient investment, and 20 percent of households still had less than six square meters of living space per capita (Logan, R. et al., 1997). Moreover, the building quality of multi-floor walk-ups in the work-unit compounds is relatively low (Wu, 2010).

In Guangzhou, the 'Construction New Village', completed in 1953, was one of the first generation of workers' villages in China, which housed around 4,700 ordinary workers and their households. Similar to other work-unit compounds, there were a health center, child-care center, food market, square and other essential services in this new village. Therefore, residents could easily go to work and get their daily necessities and services in an acceptable walking distance. Generally, the access to these kinds of work-unit compounds is convenient, although several gates may be set up in the entrance.

4.1 Friendly social relations

As the basic social cells of urban China under the Socialist Planned Economic System, work-unit compounds were characterized with a wall or fence with several gates. Every work-unit compound had its own Communist Party branch, which was responsible for the daily operation of the work unit. There was also a set of committees attached to the Communist Party branch to organize the public activities or deal with specific problems (Howenstine, 1986). Taking 'Construction New Village' in Guangzhou as an example, a public security office was set up to maintain the social order and to provide security services against outsiders without reasonable reasons for entry.

Generally, work-unit represented a set of social, economic, political and spatial constrains on the lives of its members. As argued by Howenstine (1986), the social strength of the *danwei* group, or a work-unit, tended to reduce or minimize the number of contacts people had outside it. Thus, the work-unit had an overall repressing effect on the frequent social interaction with an outsider. However, tightening social networks was highly developed within the work-unit compounds and formed an important basis for social stability and social satisfaction. In the pre-reform era, the residents in the same work-unit compounds lived together in the apartments where social interaction was more intense, social cohesiveness more strong, and social inequality less pronounced than in the pre-socialist and post-socialist periods (Ma, 2002). The urban households enjoyed relatively equal income, education, medical treatment, and other social welfares.

The hierarchical structure was adopted by the work-unit system to regulate their members. All the workers and cadres in the work-unit compounds were incorporated into this hierarchical system in the Socialist Planned China. In large work-units, like the Guangzhou Iron & Steel Group, which consisted of several organized sub-work-units, each sub-work-unit was responsible for organizing its workers and their dependents. This greatly promoted the solidarity of members in the same work group, and also made it easier to organize discussions for political study. Moreover, the regulation function of the work units also had other performances on their members. The six-day work cycle also restricted the time that members spent with external contact (Howenstine, 1986). Many measures, such as the weekend films, singing contests and sport contests, held by the work-units enabled their members to concentrate on their internal affairs. Thus, affiliation to the same workplace led to intensive interaction among residents (Wu, 2005).

4.2 Lower quality of the living environment

China confronted a widespread severe housing shortage in the Socialist Planned period. According to the results of the housing census conducted in 1985, the per capita living space in urban areas nationwide was only around 6.4 square meters, a very low living standard. Moreover, families living in self-contained housing only occupied 24 percent. To solve this, some residential blocks were designed for two or more families sharing one kitchen, toilet and bathroom. However, privacy could not be guaranteed. This principle was adopted not only by Guangzhou, but also by all cities in China. Although one or several doors might be installed in the entrance, the security verification was not very stringent, and the unprofessional property management was also a factor. For example, in most communities of Guangzhou, urban dwellers were not stopped because of no significant differences between the residents and outsiders. Thus, theoretically, these communities were gated, but not 'fortified' (Wu, 2005).

In the initial stage, the work-unit compounds operated as full-fledged communities, functioning as a city within a city (Ma & Wu, 2005), which could provide the clinics, childcare, primary education, restaurants, stores, heating services, transportation, and so on. On one hand, this "Chinese Work-unit Society" mode enabled residents easy access to their daily requirements without going outside, which facilitated to strengthen the social cohesion among the work-units. On the other hand, it also generated redundant construction of some housing-related facilities and severe waste of energy and resources. For example, although the work-unit compounds owned by the Guangdong Communist Party School was close to the "Construction New Village" in geographical location, the water infrastructure was constructed in this respective context of "self-sufficiency", other than sharing with its neighbor.

5. SOCIAL SUSTAINABILITY OF GATE COMMUNITIES IN GUANGZHOU

As clarified by (Atkinson & Blandy, 2012), the most salient characteristic of a gated community is 'the presence of physical barriers that prevent non-residents from entering the common areas in an estate or development that would, ordinarily, be accessible by the public'. In urban China, gated communities are characterized as 'spatial enclosures with secured gates, walls and fences, security personnel, and contracts with property management companies' (Wu, 2005).

5.1 Unfriendly social relations

Since the role of local governments in China has experienced a great transition from traditional managerialism to entrepreneurialism, economic development is considered the top priority. The truth is that the capital from land sales for the development of private housing occupies about half of the financial resources of local government, which enables real estate developers to possess more advantage in the real estate game with their respective local governments.

Nowadays, the street office and community residents' committee is of great significance for consolidating to refurbish the functionality of local governments, in response to the downfall of work-units and the decline of the state's 'hierarchical' control (Wu, 2002). Specifically, the street office is the representative agency of district government, rather than a level of government, while the community residents' committee is merely a 'self-organized mass organization'. Nevertheless, the community residents' committee actually addresses the works assigned by the street office, including stabilizing the communities and basic welfare provision. However, the homeowners' association established in the gated community is in charge of all the issues pertinent to its own development, and its members are selected by the homeowners themselves, according to the regulation of property management. Instead of the administrative control adopted by the traditional community residents' committee, the homeowners' association, with a self-governance mode becomes more popular in the gated communities.

In the gated communities, property management companies are responsible for the provision of professional services, such as security guards, greening and the maintenance of facilities, which meets the majority of daily requirements of residents with a relatively lower payment. If residents are not satisfied with the services, the homeowners' association would be required to conduct negotiation with the property management company (Wu, 2005).

The public spaces, such as the square, green space or park, provides a platform for the residents to communicate and share their interest in their spare time. For example, in the *Lijiang* Garden, a gated community in Southern Guangzhou, the male homeowners prefer to discuss their pets, cars and flowers in the open space, while the young female homeowners more like to discuss child-care and household affairs. The popularity of information technology products has generated more channels for residents to communicate with their neighbors more efficiently. A QQ group and WeChat group have been set up for residents to speak their own voices on the common concerns.

However, many residents do not attach great importance to the social interaction within the communities. Unlike the strict regulations on the entry to gated communities in western countries, the only eligibility criterion is affordability. Namely, residents with similar economic status have been filtered into the same gated communities, while the cultural background, occupation, educational status, religious belief and nationality are not taken into consideration. Despite social relations between residents in some gated communities maybe being positive and excellent, the neighbors have weak social cohesion (Atkinson & Blandy, 2012). Moreover, the dwellers treat their residence as a place for living rather than as a place for social interaction (Wu, 2005). Thus, many residents not only have little interest in participating in the activities held within the communities, but also do not attend the election of the homeowners' association to express their opinions.

5.2 Higher quality of living environment

Although there are different types of gated communities for households at different income levels, the housing space is large enough for households to live in, in spite of great disparity in space standards. Each housing unit is well-designed to meet the daily requirement of consumers, which is divided into seven functional areas: entrance, living room, dining room, bedroom, kitchen, bathroom, balcony and storage space. This facilitates residents to achieve a high degree of self-containment and protects the privacy of house owners.

Property developers use ‘packaged’ community services to motivate the marketing of their properties (Wu, 2005), especially for the gated communities in suburban areas where municipal facilities are insufficient. For example, Country Garden of South China (*Huanan Biguiyuan*) labels its community services as resembling a five-star hotel, which not only stresses a high quality of physical environment, but highlights superior community facilities and services. Except for the ordinary services such as cleaning, greening, rubbish collection, security, recreation and amenities, the property developers also provide educational facilities and healthcare facilities which are usually afforded by the local governments. Even shuttle buses for the residents to travel between the communities and their workplaces are provided to solve the shortage of transportation infrastructure. Furthermore, the membership club provided by Country Garden of South China offers a broad range of sports and recreational faculties such as a gym, tennis courts, basketball courts, indoor and outdoor swimming pools, private massage rooms, aerobics studios, audio, visual theatres, and so on. All of the above signifies that many gated communities have produced self-contained habitats for the middle and upper middle income groups to enjoy their exclusive services.

6. CONCLUSIONS

Work-unit compounds and gated communities are the products of particular social and political context. Owing to the comprehensive nature of social sustainability, it is challenging to identify which types of housing estates are more socially sustainable. However, as elaborated above, the quality of living environments of gated communities are better than the work-unit compounds, while the social relations within the work-unit housing system are more harmonious.

Table 1. Comparison of the social sustainability of two types of housing estates

Community type	Work-unit compound	Gated community
Target group	Urban registered residents	Middle income or above
Emergence time	After 1949	After 1998
Provider	Government	Property developer (mainly)
Social relationships	Strong attachment within the communities	Weaker
Quality of living environment	Low standard, self-sustained	High quality, sometimes luxurious

It is revealed that the provision of work-unit housing in China, considered as an important component of socialist welfare, is fully implemented and administrated through work-units. All the work-unit compounds look quite similar, with a lack of local characteristics and environmentally friendly design. Although the concept of sustainable development was not proposed at that time, residents were obliged to live in a sustainable way, such as living in a smaller space of multi-floor walk-ups, self-contained community facilities, and so on. On the contrary, increasingly more gated communities adopted environmentally friendly design principles, with the gradual popularity of the notion of sustainable development increasing. Moreover, some luxury commodity estates even use the environmentally friendly design, building materials and infrastructure systems as their selling points to absorb the high-income consumers.

From the perspective of social relations, the work-unit housing provider, i.e. government, adopted a hierarchical structure to control their residents. A set of social, economic, political and spatial constraints were imposed on the daily lives of residents. In spite of this, the stronger attachment to the social networks was highly developed within the work-unit compounds, while contact with outsiders was minimized.

The rise of commodity housing compounds has changed the way in which urban communities are managed (Wu, 2005). Instead of the community residents' committee and the work-unit, the homeowners' association with a self-governance mode is in charge of all the issues pertinent to the development of the gated communities. Property management companies are responsible for the provision of professional services, while traditional mutual support and assistance has disappeared. Moreover, the social cohesion of gated communities is weak, although residents select their living place intentionally.

The quality of the living environment in the work-unit compounds remained at a low living standard owing to the severe housing shortage in that era. Many households had to share kitchens, toilets and bathrooms. By contrast, there are large disparities among gated communities at different income levels. Each housing estate is well-designed to achieve a high degree of self-containment. Furthermore, the real estate developer not only stresses a high environmental quality but also highlights the provision of high-quality services.

To sum up, the housing reform dramatically changed the housing supply from the government side to the market, which has undoubtedly solved the housing shortage conundrum and given rise to the improvement of living environments, and meanwhile, it also has been considered as contributing to many social problems of contemporary society, especially the weakening of social sustainability issues. Moreover, the social environment of gated communities has not been ameliorated.

ACKNOWLEDGEMENT

This research is supported by Annual Dissertation Fellowship of Peking University - Lincoln Institute (Ref. DS02-20140901-WZC).

REFERENCES

Atkinson, R., & Blandy, S. (2012). "Gated Communities". *International encyclopedia of housing and home*, 232-236.

Bramley, G., & Power, S. (2009). "Urban Form and Social Sustainability: The Role of Density and Housing Type". *Environment and Planning B: Planning and Design*, *36*(1), 30-48.

Chen, Z., Chen, J., & Liu, X. (2008). "The Review and Prospect of the Urban Housing Marketization Reform in China". *World Economic Papers*, *1*, 43-45.

Chiu, R. L. (2004). "Socio-Cultural Sustainability of Housing: A Conceptual Exploration". *Housing, Theory and Society*, *21*(2), 65-76.

City of Vancouver (CoV). (2005). "A Social Development Plan for the City of Vancouver: Moving Towards Social Sustainability, Administrative Report A7". Retrieved from Vancouver.

Colantonio, A. (2010). "Urban Social Sustainability Themes and Assessment Methods". *Proceedings of the Institution of Civil Engineers-Urban Design and Planning*, *163*(2), 79-88.

Congreve, A. (2012). "Sustainable Communities". *International encyclopedia of housing and home*, 97-110.

Dempsey, N., Bramley, G., Power, S., & Brown, C. (2011). "The Social Dimension of Sustainable Development: Defining Urban Social Sustainability". *Sustainable development*, *19*(5), 289-300.

Gao, Y. (1990). "Propeling the Commodity Housing from Consumers". *Economic Studies*, *10*, 64-69.

Howenstine, E. J. (1986). "The Consumer Housing Subsidy Approach Versus Producer Housing Subsidies: International Experience". *Cities*, *3*(1), 24-40.

Huang, Y. (2005). "From Work-Unit Compounds to Gated Communities: Housing Inequality and Residential Segregation in Transitional Beijing". In Ma, L. & Wu, F. (Eds.), *Restructuring the Chinese City: Changing Society, Economy and Space*. London: Routledge.

Lawhon, L. L. (2009). "The Neighborhood Unit: Physical Design or Physical Determinism?". *Journal of Planning History*, *8*(2), 111-132.

Lee, J. (2000). "From Welfare Housing to Home Ownership: The Dilemma of China's Housing Reform". *Housing Studies*, *15*(1), 61-76.

Logan, J. R., & Bian, Y. (1993). "Inequalities in Access to Community Resources in a Chinese City". *Social Forces*, *72*(2), 555-576.

Logan, R., Bian, Y., Guan, Y., Lu, H., & Pan, Y. (1997). "“Work Units” and the Commodification of Housing: Observations on the Transition to a Market Economy with Chinese Characteristics". *Social Sciences in China*, *18*(4), 28-35.

Ma, L. J. (2002). "Urban Transformation in China, 1949–2000: A Review and Research Agenda". *Environment and planning A*, *34*(9), 1545-1569.

Ma, L. J., & Wu, F. (2005). "Restructuring the Chinese City: Diverse Processes and Reconstituted Spaces". In Ma, L. J. & Wu, F. (Eds.), *Restructuring the Chinese City: Changing Society, Economy and Space* (pp. 1-18). Abingdon: Routledge.

Manzi, T., Lucas, K., Jones, T. L., & Allen, J. (2010). *Social Sustainability in Urban Areas: Communities, Connectivity and the Urban Fabric*: Routledge.

McKenzie, S. (2004). "Social Sustainability: Towards Some Definitions". Retrieved from Hawke Research Institute, University of South Australia.

Miao, P. (2003). "Deserted Streets in a Jammed Town: The Gated Community in Chinese Cities and Its Solution". *Journal of Urban Design*, *8*(1), 45-66.

Office of the Deputy Prime Minister. (2006). "Uk Presidency Eu Ministerial Informal on Sustainable Communities". http://www.eukn.org/E_library/Urban_Policy/Bristol_Accord_UK_Presidency_EU_Ministerial_Informal_on_Sustainable_Communities.

Pareja-Eastaway, M. (2012). "Social Sustainability". *International encyclopedia of housing and home*, 502-505.

Raco, M. (2003). "Remaking Place and Securitising Space: Urban Regeneration and the Strategies, Tactics and Practices of Policing in the Uk". *Urban Studies*, *40*(9), 1869-1887.

Wang, Y. P., & Murie, A. (1996). "The Process of Commercialisation of Urban Housing in China". *Urban Studies*, *33*(6), 971-989.

Wiesel, I. (2012). "Can Ageing Improve Neighbourhoods? Revisiting Neighbourhood Life-Cycle Theory". *Housing, Theory and Society*, *29*(2), 145-156.

Wu, F. (1996). "Changes in the Structure of Public Housing Provision in Urban China". *Urban Studies*, *33*(9), 1601-1627.

Wu, F. (2002). "China's Changing Urban Governance in the Transition Towards a More Market-Oriented Economy". *Urban Studies*, *39*(7), 1071-1093.

Wu, F. (2005). "Rediscovering the ‘Gate’under Market Transition: From Work-Unit Compounds to Commodity Housing Enclaves". *Housing Studies*, *20*(2), 235-254.

Wu, F. (2010). "Gated and Packaged Suburbia: Packaging and Branding Chinese Suburban Residential Development". *Cities*, *27*(5), 385-396.

Ye, J.-P., Song, J.-N., & Tian, C.-G. (2010). "An Analysis of Housing Policy During Economic Transition in China". *European Journal of Housing Policy*, *10*(3), 273-300.

Zhang, Y., Chai, Y., & Zhou, Q. (2009). "The Spatiality and Spatial Changes of Danwei Compound in Chinese City: Case Study of Beijing No. 2 Textile Factory". *Urban Planning International*, *24*(5), 20-27.

Zhou, M., & Logan, J. R. (1996). "Market Transition and the Commodification of Housing in Urban China". *International Journal of Urban and Regional Research*, *20*(3), 400-421.

International review for spatial planning and sustainable development, Vol.4 No.4 (2016), 69-87
ISSN: 2187-3666 (online)
DOI: http://dx.doi.org/10.14246/irspsd.4.4_69

Travel Experiences and Aspirations: A Case Study from Chinese Youth

Feifei Xu[1*], Lorraine Brown[2], Philip Long[2]
1 School of Humanities, Southeast University
2 Department of Tourism & Hospitality, Bournemouth University
** Corresponding Author, Email: 101011780@seu.edu.cn*

Received: April 03, 2016; Accepted: June 10, 2016

Key words: Chinese students, Previous travel experience, Holiday aspirations, Cultural values

Abstract: Understanding cultural values is vital in tourism as these influence an individual's travel experiences and expectations. Students represent an important segment of the international tourist population, and Chinese student tourists are an increasingly significant part of that segment. It is therefore important to understand how cultural values influence Chinese students' experiences and aspirations. Will their past travel experiences influence future aspirations? Using data collected from a free-elicitation method, this paper reports on the travel experiences and aspirations of 284 Chinese students. It explores the notional link between past experiences and future aspirations and discusses the impact of Chinese political history and cultural values on tourist experiences and motivations. Implications for marketing are also drawn.

1. INTRODUCTION

1.1 Student tourists

Youth travel accounts for over 20% of international arrivals (UNWTO, 2008). Among them, university students play an important role; 'students are experience-seekers who travel in search of culture, adventure and relaxation' (Richards & Wilson, 2003)(p5), as well as presumably for (higher) education. These experiences serve to give youth tourists 'a thirst for more travel' as they build a 'travel career' (Pearce & Lee, 2005), possibly choosing increasingly novel destinations as they become more experienced. Furthermore, a link can be made between past experiences and future travelling behavior (Jang & Feng, 2007). Therefore, understanding the values and meanings students place on their experiences and aspirations is important in predicting future trends in tourism. It is particularly useful when trying to predict Chinese tourist behavior where there is little past data on which to base predictions. International outbound tourism is relatively new in China (Arlt, 2006), indeed, travelling overseas has only become authorized within the last twenty years (Li et al., 2011).

1.2 Chinese student tourists

China has become an important source market in the world due to its rapid growth in outbound tourism (UNWTO, 2000). China has become the largest tourist-generating country in the world (UNWTO, 2015). Globally, young tourists aged 16-25 account for 21% of overseas travellers (UNWTO, 2013). This suggests that Chinese students represent a source of both present and future income for the tourism industry both within China and abroad.

As well as representing a market for tourism, increasing numbers of young Chinese are choosing to study abroad. Currently there are 440,000 Chinese students studying abroad (BBC, 2011). By 2014, the number is expected to reach 600,000 (China Daily, 2011) and competition between nations as far afield as Europe, North America and Australasia to attract these students is intense (Brown & Aktas, 2012). The image and attractiveness of potential study destination countries will have a major influence on their choice of where to attend university (Llewellyn-Smith & McCabe, 2008). In addition, students may be expected to take the opportunity to travel during their time at the host university (Wang & Davidson, 2008). As Llewellyn-Smith and McCabe (2008) observe, international students travel widely whilst studying abroad, yet their impact on the receiving destination has been under-researched.

1.3 Cultural influences on travel experiences and holiday aspirations

The influences of cultural values on an individual's consumption behavior have been researched widely (Woodside, Hsu, & Marshall, 2011; Soares, Farhangmehr, & Shoham, 2007). Likewise, travel motivation and behavior are influenced by cultural elements (Kim, S. S. & Prideaux, 2005; Reisinger & Turner, 2003; Reisinger, 2009). The experiences of individual tourists are also derived from the values of their own culture (Nicoletta & Servidio, 2012; Tasci & Gartner, 2007). Of interest to the current study is that much of the existing research has been conducted in Australia, Europe or the USA. There is therefore both a lack of empirical findings relating to the Asian region and a dearth of studies on Asian tourists (Kim, S. S. & Prideaux, 2005). Li et al. (2011) state that due to cultural and social-economic differences, Chinese travelers may have particular expectations that are not well understood by western destination marketers. It is therefore of great importance to understand the ways the Chinese student search for holiday experiences and aspirations.

The aim of the study is to identify the holiday experiences and aspirations of Chinese students; will past experience inform long term aspirations, and how does culture influence travel experiences and aspiration among this particular group? Given the magnitude of the Chinese tourist market, it is of great importance to understand the travel aspirations of future Chinese tourists.

2. LITERATURE REVIEW

2.1 Tourist motivation and holiday aspiration

Motivation is regarded as one of the most important variables that explain tourist choice and behavior (Baloglu & Uysal, 1996). A lot of research attention has been devoted to the subject (Hsu, Cai, & Li, 2010), including: Maslow's (1943) hierarchy of needs; Dann's (1977) and Crompton's (1979) push and pull factors; Beard & Ragheb's (1983) leisure motivation scale; Iso-Ahola's (1982) escaping and seeking dimension; and Pearce & Caltabiano's (1983) travel career ladder or travel career pattern (Pearce & Lee, 2005). Researchers tend to agree that motivation is multi-dimensional, and could be influenced by many factors, such as gender, age life stage, previous travel experiences, an individual's cultural background, social roles and social pressure (Jönsson & Devonish, 2008; Lee & Sparks, 2007).

Pearce and Caltabiano (1983) propose a travel 'career ladder', suggesting travel motivation changes as a person acquires more experiences; starting from low level basic physiological needs to relationships and eventually self-fulfillment. Later, a travel career pattern (Pearce & Lee, 2005) was modified to recognize that 'dominant' needs may change in either direction. However, this model did not mention the influence of a memorable experience, whether this might remain or change peoples' motivation is unclear. Jang and Feng (2007) believe that satisfying experiences will lead to repeat visits in the short term, but argue that people are looking for novelty in the longer term, suggesting that people are looking for something new in their travel aspirations. Whether and how a tourist's previous experiences influence their future aspirations is unclear.

Aspiration is defined as a strong desire, longing, or aim (Collins Dictionary, 2013). This may be related to long term motivation. The power of aspiration in influencing consumer behavior cannot be ignored as Cocanougher and Bruce (1971) recognize that there is a strong relationship between the development of an individual's consumption aspirations and his or her perceived behavior in the context of referencing social groups, or in marketing terms an 'aspirational reference group' (Hoyer & Macinnis, 2010)(p393). Aspiration might drive toward future consumption, resources and life-circumstances permitting. However, there is very limited research in the tourism literature concerning aspirational travel. Blichfeldt (2007) suggests that a holiday may fulfill a gap between a person's aspirations and actual lived experience, suggesting the influence of aspiration on holiday choice.

2.2 The meaning of memorable experiences

Like all tourists, students seek experiences (Richards & Wilson, 2003). These are subjective, emotional states full of symbolic significance for the individual (Uriely, 2005). Researchers suggest that leisure experiences are about feeling, fantasy and fun (Holbrook & Hirschman, 1982), escape and relaxation (Beard & Ragheb, 1983), entertainment (Pine & Gilmore, 1999; Farber & Hall, 2007) , and novelty and surprise (Duman & Mattila, 2005). Kim, J.-H., Ritchie, and McCormick (2012) recognize that customers want more than just a satisfactory experience, therein lies the need for research on what constitutes memorable experiences. They develop a 24 item scale to measure memorable experiences. Based on Kapferer's (1998) prism and Echtner and Richie's (2003) work, the extrinsic factors that influence tourist experiences include destination physical attributes and the destination image (brand personality), while the intrinsic factors include personal benefits and meaning (sense of identity) and how the interaction between the tourist and the host community is explained by social and cultural interactions.

The value of the experience depends on the meaning given to it by an individual (Wilson & Harris, 2006). This is derived from their personal life narrative, as a rite of passage or a moment of self-authentication (Abrahams, 1986), from a sense of achievement when mastering a physical challenge or making an intellectual discovery (Beard & Ragheb, 1983) leading to a flow experience of absorption in the activity (Baum, 1997). Travel can also be a journey in search of spiritual goals or self-discovery (Sharpley & Stone, 2010) or transformation (Obenour, 2004). There is also a strong social element to the meaning as shared experiences can bring 'rites of integration' (Arnould & Price, 1993), creating close bonds between people (Obenour, 2004); what Turner (1974) called a sense of 'communitas'. Visiting a particular destination can be a means of establishing identity (Noy, 2004), gaining recognition (Otto & Ritchie, 1996) and status or kudos (Curtin, 2005). Williams (2006) argues that leisure consumers 'create their identities and develop a sense of belonging through consumption'. Recently, Hibbert, Dickinson, and Curtin (2013) argue that it is identity that influences holiday decision making, that identity is pre-existing, and that holidays are a means to demonstrate, confirm, or even avoid one's identity.

2.3 Cultural values and their influences on the meaning of experiences

Research has suggested that culture influences values and that people from different cultures have different preferences and expectations (Adler & Graham, 1989; Hofstede, G, 1980) Pizam, Pine, Mok & Shin, 1997). Researchers agree that cultural values influence an individual's consumption behavior (Woodside, Hsu, & Marshall, 2011) and travel considerations (Reisinger, 2009). The meanings that tourists give to a destination are derived not only from their personal characteristics and experiences, but also from the values of their culture (Nicoletta & Servidio, 2012; Tasci & Gartner, 2007). Tourists visit a destination with a set of assumptions created by the interaction of the visitor's own cultural background and their understanding of the historical and cultural significance of the location (Nicoletta & Servidio, 2012; Obenour, 2004; Seddighi, Nuttall, & Theocharous, 2001; Snepenger et al., 2007). Mok and DeFranco (2000) believe that an understanding of cultural values is vital in tourism marketing as customer satisfaction is largely based on meeting (and ideally exceeding) expectations.

Cultural values shape people's beliefs, attitudes and behavior (Fan, 2000). They serve to give a sense of shared identity distinguishing one cultural group from another (Leavitt & Bahrami, 1988). Hofstede, G (1980) describes this as the collective programming of the mind.

Hofstede's (1980) study on cultural values has been widely cited. Hofstede, Geert (2001) suggests that China has a masculine orientation towards assertiveness, achievement and success, which suggests the dominant values in society are success, money and material. China has the lowest individuality score in Asia; as a collectivist society, it stresses relationships with family or other groups. China scores highly on power distance, indicating respect for authority and acceptance of inequalities. China also tends to be uncertainty-avoiding rather than adventure-seeking. Table 1 illustrates China's score on Hofstede's cultural dimensions.

Table 1. China's Score on Hofstede's Cultural Values

	Power distance	Individualism	Masculinity	Uncertainty avoidance
China	80	20	66	30

Source: Hofstede, Geert (2001)

'Traditional' Chinese cultural values are formed from interpersonal relationships and social orientation (Mok & DeFranco, 2000). Confucianism and Taoism are the key philosophies influencing Chinese society (Kwek & Lee, 2010), they encourage a respect of nature, a notion of harmony, and regard one's task in life as trying to acquire skills and education (Mok & DeFranco, 2000). The Chinese harmonious relationship with the natural world is viewed as one of the major differences between Eastern and Western societies (Reisinger & Turner, 2003). Yau's (1988) value orientation model classifies Chinese culture into five orientations: man-nature orientation, man-himself orientation, relational orientation, time orientation and personal activity orientation, of which the most influential factor on marketing to Chinese consumers is relational orientation, which includes the respect for authority, interdependence, group orientation and face(ego). However, the open door policy since 1978 has had a great influence on the values of Chinese people in understanding capitalism and materialism (Sofield & Li, 2011). Young generations, particularly those born after the 1980s, are greatly influenced by modern western culture and media (Xu, Morgan, & Moital, 2011). This combination and evolution of 'modern' and 'traditional' values may influence individual travelling behavior in complex and subtle ways (Kwek & Lee, 2010). Ryan and Huang (2013) (p7) state that 'for many Chinese, to be able to afford to be a tourist, to travel and to see the sights of their country while enjoying comfortable serviced accommodation, is a symbol of being part of the modern world, or of being a global citizen'. Therefore, due to cultural and social-economic differences, Chinese tourists may have particular expectations that are not well understood by western destination marketers (Li et al., 2011). However, careful consideration is needed in using cultural dimensions to explain travel behavior (Xu, Morgan, & Song, 2009), as within each culture, there is a wide spectrum of different attitudes and behaviors, which are unlikely to be fully explained by cultural factors.

Nevertheless, researchers broadly agree that cultural values influence consumer behavior (Woodside, Hsu, & Marshall, 2011; Soares, Farhangmehr, & Shoham, 2007). However, there is still limited research on the implications of cultural values in destination marketing (Mok & DeFranco, 2000). There is also very limited research into holiday aspirations among Chinese youth.

3. METHODOLOGY

3.1 Free-elicitation method

This paper reports findings from four open questions on a survey of Chinese students studying tourism management, using a free-elicitation technique. Often used in the psychological literature, Reilly (1990) was the first to use free-elicitation in tourism research. Echtner and Ritchie (1993) used the same method to measure destination images. They claimed free elicitation to be useful in allowing unique images of each country to emerge. Indeed, the advantages of such a method are that 'it allows for spontaneous responses' (Parfitt, 2005)(p91), and it avoids imposing the researcher's biases on the respondents (Berg, 2007; Reilly, 1990). Recently, Ballantyne, Packer, and Sutherland (2011) used this method in their study of visitors' memories of wildlife tourism, using four open questions on a survey. The results of open questions are 'more likely to reflect the full richness and complexity of the views held by the respondents' (Denscombe, 2007) (p166).

3.2 Question design

The free-elicitation questions discussed in this paper formed part of a comparative study of UK and Chinese student travel behavior. The questionnaire contained two pages of conventional closed questions about students' travel behavior. At the end of the second page there were two open questions designed to elicit the value and meaning that students give to their travel experiences. The first question (What is the most memorable or enjoyable place you have visited?) was asked in acknowledgement of the notion that 'lived experience can never be fully grasped in its immediate form, but only reflectively as past presence' (Van Manen, 1990) (p37), and 'lived experiences gather significance as we reflect on and give memory to them' (Curtin, 2005) (p3). It is claimed that remembered experiences have a great influence on future holiday decisions. However, this is an under-researched area (Braun-LaTour, Grinley, & Loftus, 2006; Kim, J.-H., Ritchie, & McCormick, 2012). The second question (What is your dream country for a holiday?) was asked because the researchers sought an understanding of how previous experiences (Pearce & Lee, 2005) related to 'ideal' destinations. Therefore, an investigation of future aspirations might be useful to understand motivations, in particular, to explore whether a positive experience will lead tourists to go back to the same place.

In both cases, respondents were asked to answer freely and produced a rich variety of unprompted responses (Morgan & Xu, 2009). Discourse theory sees all leisure pleasure-seeking activities as expressions of a dominant cultural discourse(Urry, 2002; Quan & Wang, 2004). This discourse, that is the way a particular social group talks about a subject, and in this case travel, provides the language in which people discuss their holiday experiences. Indeed, some argue that the language creates the experience (Jørgensen & Phillips, 2002). A close study of the words used to describe holiday experiences, and the meanings given to particular destinations, can therefore give an insight into how individuals in specific cultures construct meaning and attach value to different types of tourism experiences.

3.3 Data collection & analysis

Questions were devised in English and translated into Chinese using back translation to check for errors. The Chinese replies were translated into English for analysis, and any nuances of meaning were discussed among the authors to ensure that the right interpretation was made. A convenience sample was identified in the Nanjing University of Finance and Economics, Nanjing, China. Questionnaires were distributed and collected in a class, when verbal informed consent was obtained and guarantees of confidentiality and anonymity were made (Creswell, 2008). 300 questionnaires were distributed, and 284 responses were collected. Although it is a self-selected small sample, it represents students who study tourism management. As Jiang and Tribe (2009) stated, there are 252 higher education institutions and 943 vocational schools which provide tourism education programs in China. Students on these courses might be future decision makers in tourism. They may also be expected to have a 'world-view' in contrast to other Chinese people of their generation. The majority of respondents were female (79.2%) and ranged in age from 18 to 25, including undergraduate, year one to four students. The 3706 words generated by respondents in response to the open questions were analyzed through thematic analysis. Responses were first organized and then read repeatedly in order to gain familiarity with the data. Subsequently, coding was used to identify discrete concepts through labeling and categorizing, from which themes were formulated (Clarke & Braun, 2008).

4. FINDINGS

4.1 What is the most memorable place you have visited?

The destinations identified by students were plotted on a map (see Figure 1) and reasons for their choice were coded.

Figure 1. Memorable places mentioned, by province

Source of map: http://www.muztagh.com/map-of-china/ accessed 23-10-2011
Note: the numbers show the number of answers naming places in the particular province. The survey place, Nanjing is the capital of Jiangsu Province. There are 7 replies mentioning places outside China, which are not shown in this map.

4.1.1 Destinations within China

There are 23 provinces, four municipalities, five autonomous regions and two special regions in China. Except eight, all were mentioned by students. The greatest concentration of places named was in Jiangsu (40%), the province in which the respondents' university is situated. It is a well-developed tourist destination with many World Heritage sites. In 2011, Jiangsu attracted 7.37 million international tourists (Chinese National Tourism Administration (CNTA), 2012) and an estimated 323 million domestic tourists (People, 2012). The next most popular places mentioned are major cities, such as Beijing (10%) and Shanghai (5%), followed by nearby provinces, such as Shangdong (9%) and Zhejiang (7%), eastern coastal provinces of China, and relatively close to the respondents' university. The rest of the destinations mentioned are scattered in other provinces and areas within China, but each place was mentioned by only a few respondents.

The above results show that respondents had travelled to destinations close to their university, indicating the importance of student travel in the study destination, a topic that has been long overlooked by both academics and destination marketers (Llewellyn-Smith & McCabe, 2008).

4.1.2 Destinations outside China (3%)

Revealing the relative inexperience of Chinese students as tourists, only seven of the 214 places chosen by respondents were foreign. Indeed, this was commented on by four students who noted that their most memorable place could only be in China. This reflects the fact that outbound travel is relatively new in China (Li et al., 2011), being formerly a restricted market, which was only open to politicians, government officials and organized business delegations (Arlt, 2006). Official permission for outbound travel for the general public was given after 1997 (Arlt, 2006). Since 2005, it has shown huge growth (Li et al., 2011).

4.2 Why was it memorable?

Table 2 shows the reasons respondents gave for their memorable places.

Table 2. Reasons for Memorable Places and Dreams

	Memories No.	Memories %	Dreams No.	Dreams %
Social: family and friends	11	6.0	1	0.5
Discovering culture	40	21.9	57	26.8
History	22	12	27	12.7
Nature and scenery	59	32.2	52	24.4
Adventure and achievement	14	7.7	12	5.6
Hedonic: Sun, sea and relaxation	19	10.4	10	4.7
General atmosphere	8	4.4	46	21.6
Place attachment/patriotism	10	5.5	8	3.8
Total	183	100	213	100

4.2.1 Nature and scenery, linking to the spiritual function of nature (32.2%)

Physical attributes were deemed to be important pull factors for respondents at 32.2%, with this usually linked to nature and scenery. Respondents remembered lakes, gardens, forests, hills and snow-covered peaks. These were associated with cleanness, fresh air, a fresher climate away from the heat of the summer in the city. These places were described as beautiful, picturesque, peaceful and close to nature. This is reflected in the following responses:

'Wuyi Mountain: a combination of mountain and water, a beautiful natural environment. You can feel nature, and relax'.

'Xishuangbanna: it's natural, beautiful, and makes me feel close to nature'.

These destinations were linked to traditional folk customs and a quieter, simpler way of life. Some responses had a quasi-spiritual property:

'…it is like being in heaven, I feel out of this world. Unforgettable moment'.

'Lin'an Mountain, Suzhou: …the temple helps your thinking, it is so quiet'.

These findings point to the spiritual function of nature, and its influence on emotional, cognitive, aesthetic and even spiritual development (Kellert, 1993). A few went further in their criticism of the natural environment, stating that there were no memorable places:

'too many tourists (in China), the environment is not good. It is too crowded ',

Policies for economic development in China since 1978 have given priority to modernization over environmental considerations. However, in the past decade, under pressure from climate change lobbyists, the government has tried to keep a balance between its modernization agenda and environmental concerns (Sofield & Li, 2011). Respondent comments clearly reflect a popular concern for environmental issues in contemporary China and the extension of such thinking to 'ideal' tourist destinations.

4.2.2 A holistic image of the destination (4.4%)

A small group of students remembered places because of the holistic impression of the destination:

'Shishuangbanna: It was so different, so amazing. I liked everything there, the warm hearted minority people, hot and spicy local snacks, big rainforest jungles, just so amazing!'

'Wuzhen: I liked the small village of South Yangtze River, the atmosphere, everyone in the village was relaxed, enjoying the sunshine, and it was very quiet as well.'

These comments show the respondents' total impressions, a holistic conceptualization of the destination image (Echtner & Ritchie, 2003).

4.2.3 Personal benefits and self-achievements of travel (7.7%)

The personal benefits of travel and feelings of self-achievement cited by 7.7% of respondents can be described as push factors, referring to an individual's needs and desires (Crompton, 1979; Dann, 1977). Places were memorable because they represented the first time respondents had travelled alone, been abroad or seen the sea:

'Baidaihe, the place where I first saw the sea, a fresh, exciting moment for me'.

'Suzhou, it was the first time that I travelled alone as a tourist'.

Respondents had limited travel experience, yet they valued the trips they had made; they saw the importance of tourism. Hedonic factors were also important to respondents (10.4%), and included relaxing on the beach, entertainment and shopping:

'Beautiful beach, I felt very relaxed, just what I needed after a long day'.

4.2.4 Social interaction with family, friends and local people (6%)

Social interaction refers to relationships between the tourist and the host community and within the tourist's own social group (Kapferer, 1998). In this study, places were linked with the person respondents travelled with, and memories were of social occasions with a best friend, a companion, and/or their first family holiday:

'(I) met a travel partner, and he was quite humorous and made the trip so full of laughing and fun. We have now become good friends.'

'Guilin, the only place I have ever been with my family. It was nice to have some time together with Mum and Dad as they were so busy with work. That was the only time they did not talk about work, but listened to me talking'

Social interaction has been reported as an important factor in the study of tourist experience. As Tung and Ritchie (2011) observe it is the outcome of the interaction which is important to a memorable experience, such as the development of a new friendship and improved family relationships as reflected in the above statements.

4.2.5 Learning culture and history (21.9%)

Intellectual development represents the acquisition of new knowledge of the destination (Tung & Ritchie, 2011), and was usually linked with history, tradition and modern local cultures in the data generated in this study. Although the traditional cultural objects to be found in places like Beijing or Tibet were important to respondents, also attractive was the prospect of experiencing the modern, busy and clean urban settings of Shanghai, Hong Kong and Shenzhen:

'It is a modern, busy city (Shenzhen), clean. People are busy, walking quickly on the street, past tall buildings. The modern, busy mega city culture is different from my city. It surprised me'.

'(Shanghai): ...Prosperous and modern city flavor, an atmosphere of an international mega city. Very fresh'.

These comments probably reflect the Chinese value attached to modernization. In the past 30 years, the Chinese government has put great emphasis on modernization as their national policy (Sofield & Li, 2011). It is likely that this has influenced respondents' attraction to urban tourism. Ryan and Huang's (2013) statement about the Chinese view of tourists as a symbol of the modern world is also reflected here by respondents' admiration of busy, vibrant cities.

Heritage and history were also important, linked by respondents with historical cities and towns such as Beijing, Suzhou, Tongli, Shaoxing, Yangzhou and the heritage tourist attractions of the Forbidden City, Grand Canal, ruins and temples:

'(Grand Canal): ...You can feel and imagine its history, such as the Emperor Qian Long's journey to South Yantze'.

'Fenghuang ancient town, a good combination of history, culture, nature and custom'

'Nanjing: Historical city, cultural remains, cultural background, the atmosphere of culture, I like it.'

Such comments reflect the inextricable link for the Chinese between history, culture and tourism.

4.2.6 Local place attachment (5.5%)

Ten respondents cited their hometown as their most memorable place: of these, two admitted that their hometown was the only place they had ever been. Another one commented:

'Nanjing: it's the place where I studied for four years. I travelled a lot in this area. I feel at home; I like it a lot.'

Responses could be seen to be driven by a sense of place attachment. As one student said, *'it is my hometown, I remember every flower and every blade of grass, and I feel really attached to it'.*

Jorgensen and Stedman (2006) recognize sense of place is a multidimensional construct representing beliefs, emotions and behavioral commitments concerning a particular geographic setting. In this case, respondents clearly showed their attachment to their home town or the place where they studied.

A summary of the above themes has been included in a diagram based on Kapferer's (1998) experience prism (See Figure 2). Morgan and Xu (2009) suggest 'the meaningful experiences' should be placed at the center of the diagram, as they are co-created together with the individual and the destination. The Chinese student emphasis on the physical attributes of the destination, the nature and landscape of the destination, are often linked to the emotional feeling of nature, showing a contrast to their living environment. The cultural and historical interactions are often linked with a learning motive showing a desire for intellectual development, confirming other research on memorable tourist experiences (Tung & Ritchie, 2011; Kim, J.-H., Ritchie, & McCormick, 2012).

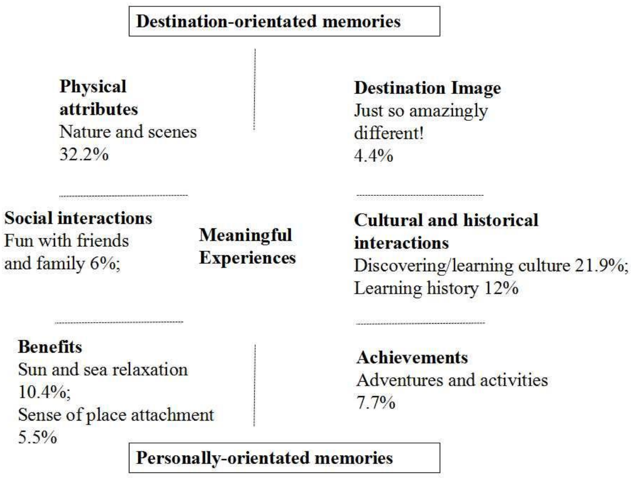

Figure 2. Students' memorable experiences

Note: % of total respondents n=183 who explained the reason; There are 101 students unable/unwilling to give a reason. Total survey n=284

4.3 What is your dream country for a holiday?

Respondents were asked their dream destination to explore a possible link between past experiences and future aspirations.

Table 3. Places mentioned as a dream country for a holiday

	Countries mentioned (number of times)
Europe in total: (N=166)	France (64); UK(17); Italy(14); Switzerland(13);Netherlands(9); Greece(6); Spain(5); Norway(19);Sweden(4); Iceland(3); Finland(2); Denmark(1); other European countries(9)
Asia in total: (N=51)	China(17); Singapore(11); Japan(9); Korea(5); Indonesia(3);India(2); other Asian countries (4)
Others in total: (N=54)	Egypt(5);Australia(13);USA(11); Maldives(9); Hawaii(8);New Zealand(5); Canada(3)

4.3.1 Europe

Europe was mentioned by 161 students (59.8%, N=269), accounting for the largest group (See Table 3). France, and in particular Paris, was the most popular choice, with 64 respondents naming it as their dream country. This reflects the popularity of France as the top tourist destination in the world (UNWTO, 2000). The result is also consistent with France being China's top outbound tourism destination in Europe (Mintel, 2007). The word used to explain the choice was usually 'romantic', though other comments included; culture, arts, food and hospitality. Other destinations named included Italy for its history and architecture, Greece, for its mystery; Spain because of its Olympic culture, and the UK, for its traditional culture and beautiful landscape. Other European countries were chosen for their scenery, notably Switzerland, Norway, Sweden, Finland and Iceland. This result is consistent with the Mintel report (2007) that among Chinese outbound tourists, Paris attracts most interest and carries the most prestige among Chinese travelers, followed by Rome, Venice and Vienna. UNWTO (2013) also confirmed that Europe is the most desired destination for Chinese overseas travelers.

4.3.2 Asia and the rest of the world

Outside Europe, Asia was the next most popular choice (51 respondents), with China the most popular country (17 out of 51). Others included Singapore for its clean, beautiful environment, Korea, which respondents had seen on TV, and Japan for its 'similar' and 'interesting' culture. Answers reflected the general trend for outbound travel in China, as 70% of Chinese outbound tourists take holidays in nearby Asian countries (European Travel Commission (ETC), 2011). Australia and New Zealand were named for their vast open spaces and beautiful environment, and their welcoming atmosphere to Chinese students. This reflects Australia and New Zealand as popular outbound destinations for the Chinese (Fountain, Espiner, & Xie, 2011). The US was chosen for a variety of reasons including sports, the environment and its modernity – 'It is 100 years ahead of China,' said one respondent. Hawaii (eight respondents) and the Maldives (nine respondents) were mentioned for their beaches and beautiful scenery. Egypt, the only African country named, was mentioned for its cultural significance.

4.4 Why do you dream of visiting?

4.4.1 Discovering and learning about culture: a holiday becomes a learning opportunity

As Table 1 shows, similar themes run through respondents' dreams as through their memories. The most significant theme is learning about a different culture, most commonly linked with history. This was the most important attraction for respondents (27.4%) as the comments below reflect:

'Greece: (I) would like to know the culture and history…the land of legends, I want to experience (it) myself'

'France: want to know about French culture, its elegance, romance…so different, very attractive'

Egypt: 'want to see the pyramids, to experience the old civilization'

Chinese students appear to be culture-seekers. This has been interpreted by Xu, Morgan, and Song (2009) as a desire to please their parents who fund their travel. It is possible that the desire to consume cultural tourist attractions is also a reflection of the Confucian tradition of scholarly travel (Mok & DeFranco, 2000). To the young Chinese, learning about other cultures is an important motivation: a holiday becomes a learning opportunity (Wang & Davidson, 2008).

4.4.2 Exploring the natural environment: a Chinese cultural view of nature

Also of high importance to respondents (at 24.9%) was the beauty of the natural environment, often interlinked with way of life:

'Switzerland: the mountains are covered in snow; (it is) so beautiful. Life is simple and quiet there. This is where we can achieve nature and human beings in harmony'

'New Zealand; very natural, you can be totally relaxed and think about life quietly'.

'Sweden: beautiful environment, simple customs, social harmony, an ideal democratic country for holiday and living'.

As noted earlier, responses point to a marked desire to escape the crowded cities in which respondents live. A deeper influence revealed by the replies is the Chinese cultural view of nature, which is probably the most significant difference between Eastern and Western people. Whereas the British see the natural world as a setting for activities and adventures (Morgan & Xu, 2009), the Chinese see it as a place to escape to, to find harmony and peace. This reflects the cultural values of Confucianism and Taoism, which cast man and nature in a relationship of harmony. Sofield and Li (2011) and Han (2006) agree that both traditional and contemporary values have influenced the Chinese view of nature, reflecting the cultural value that people and nature are in harmony.

4.4.3 A holistic and emotional feeling of the destination, vague, stereotyped and media formed

Another theme of importance to respondents (at 22%) related to the holistic atmosphere associated with the destination, such as the romance of Paris, and the mystery of Greece and Egypt.

'(Paris) you can feel the atmosphere of freedom and romance. I remembered seeing it somewhere on TV, that Paris is the capital of Romance. I can imagine myself getting immersed in a romantic place.'

Such comments showed a desire for emotional experiences, 'the feeling of old Rome'; 'the true Italy', 'the ancient civilization of Egypt', ‘the gentlemanly atmosphere' of the UK, etc. When discussing experiences, this theme occupied a low rate of mention (4.4%), while when discussing aspirations, it was often mentioned (22%). This suggests that memories are specific, while aspirations are vaguer, based on general impressions, and respondents’ own interpretation of a destination and linked to their ‘ideal world’. Tung and Ritchie (2011) suggest that the vagueness of expectations is because tourists want to preserve the spontaneity or uniqueness of experiences and may be motivated to imagine what their trip will be like in a general sense. Those aspirations were often influenced by information from a third party such as friends and family, tour operators and media, as expressed by one respondent ‘…Friends showed me pictures of there, it was a lovely Christmas atmosphere’.

4.4.4 Patriotism—identity drives holiday consumption

Patriotism (3.8%) was an interesting and unexpected theme. Out of 209 students who reasoned their dream destination, 17 respondents (8.1%) chose China as their dream destination. Among those 17, nine respondents indicated that China is a big country, and there is a lot to see; while eight others cited ‘Patriotism’.

‘It is my motherland; I am proud of China’;

‘Because I am patriotic’.

Patriotism here is associated with respondents’ identity. As Ward, Bochner, and Furnham (2005) state, patriotism involves people’s recognition, categorization and self-identification as members of a national group, which induces a sense of affirmation and pride. Orwell (1945) defined it as “devotion to a particular place and a particular way of life, which one believes to be the best in the world” (p361). Indeed, Goulbourne (1991) argues that belonging to a national group is intrinsic to an individual’s self-definition and self-evaluation, performing powerful psychological functions at both a personal and a group level (Hinshelwood, 2005). Patriotism could also be interpreted as a product of a patriotic education (Beech & Jiang, 2011). Furthermore, Barmé (2009) identifies evidence of nationalist policy that aims to construct and consolidate China’s national identity. A patriotic attitude is reflected in the so called ‘red tourism’ product, officially sponsored tours to sites connected to the history of the Communist Party (Arlt, 2006). Williams (2006) argues that consumers develop a sense of belonging through consumption, but in this case belonging can be said to drive consumption, supporting Hibbert et al.’s finding that pre-existing identity will drive holiday choice (Hibbert, Dickinson, & Curtin, 2013). Bauman (2000) suggests that group identity offers confirmation of the self, with Branscombe and Wann (1994) arguing that the desire to see the self favorably is powerful.

5. CONCLUSIONS

5.1 Conclusions

This paper discussed socio-cultural and indirect political influences on the tourist experiences and aspirations of Chinese students of tourism. It thus sheds light on an important and yet under-researched area, student tourists, an emerging Chinese tourist market. Chinese students are potential tourists over the next decade, whether they travel as postgraduate students or on holiday (Wang & Davidson, 2008). The findings from this study show that Chinese students offer a big potential market for Europe, accounting for 59.8 % of their 'dream destinations'. Australia and New Zealand also seem to be popular choices, and although the USA is a recently opened potential destination, it is attractive to the Chinese.

5.2 Implications

In this study, students showed a consistent motivation across their past experiences and future aspirations, with an emphasis on nature and learning about culture. Although the word 'nature' is usually conceived as a physical attribute of a destination, it is always linked with an emotional and cognitive attitude in this study, reflecting the 'traditional' Eastern cultural view that people and nature are in harmony, although this view is compromised by policies favoring rapid economic development, regardless of environmental consequences (Reisinger & Turner, 2003). Destination managers targeting young Chinese should emphasize harmonious relationships between people and nature, and combine these to construct an attractive destination image. Marketing messages should also emphasize educational value in response to the Chinese Confucian emphasis on education, a holiday is therefore also a learning opportunity (Mok & DeFranco, 2000). This study shows that for Chinese youth, past travel experiences (which are limited in extent) do not seem to be linked with a tendency to revisit the same place, but rather encourage interest in wider exploration. The results are consistent with Jang & Fang's (2007) statement that people are looking for novelty in the long term and that previous memorable experiences do not take them to the same place, but lead to new places in their long term motivation. However, this is related to the specific socio-political Chinese context which limited the ability to participate in foreign travel in the past. Indeed, possibly related to limited overseas travel opportunities, there is the 'patriotic' choice of China as a 'dream destination'. Self-identity, localism and national identity might therefore influence the choice of holiday consumption in the Chinese context (Hibbert, Dickinson, & Curtin, 2013).

5.3 Future research

This research investigated tourism students at one particular university in China. Future research could target young Chinese people of different social groups to identify the notion of class and its influence on travel behavior. Further exploration is needed on attitudes towards 'home' and 'nature' as well as the influence of media and social reference groups on the perceptions of other countries and potential destinations. Although, this research explores students' holiday aspirations, it is of course impossible to know whether young people will retain their dreams through adulthood. Life circumstances will of necessity intervene and as consumers, people change their values, lifestyles and consumption patterns as they move through their life cycle (Mowen & Minor, 1998). Thus it would be worthwhile to target a variety of age groups in future research.

ACKNOWLEDGEMENT

This research is funded by the Chinese National Science Foundation (41571133).

REFERENCES

Abrahams, R. D. (1986). "Ordinary and Extraordinary Experience". In Turner, V. & Burner, E. (Eds.), *The Anthropology of Experience* (pp. 45-72). Chicago: University of Illinois Press.

Adler, N. J., & Graham, J. L. (1989). "Cross-Cultural Interaction: The International Comparison Fallacy?". *Journal of International Business Studies*, *20*(3), 515-537.

Arlt, W. G. (2006). *China's Outbound Tourism*. Abingdon, New York: Routledge.

Arnould, E. J., & Price, L. L. (1993). "River Magic: Extraordinary Experience and the Extended Service Encounter". *Journal of consumer research*, *20*(1), 24-45.

Ballantyne, R., Packer, J., & Sutherland, L. A. (2011). "Visitors' Memories of Wildlife Tourism: Implications for the Design of Powerful Interpretive Experiences". *Tourism Management*, *32*(4), 770-779.

Baloglu, S., & Uysal, M. (1996). "Market Segments of Push and Pull Motivations: A Canonical Correlation Approach". *International Journal of Contemporary Hospitality Management*, *8*(3), 32-38.

Barmé, G. R. (2009). "China's Flat Earth: History and 8 August 2008". *The China Quarterly*, *197*, 64-86.

Baum, T. (1997). "Making or Breaking the Tourist Experience: The Role of Human Resource Management". In Ryan, C. (Ed.), *The Tourist Experience: A New Introduction* (pp. 92-111). London: Cassell.

Bauman, Z. (2000). "Modernity, Racism, Extermination". In Back, L. & Solomos, J. (Eds.), *Theories of Race and Racism: A Reader* (pp. 93-116). London: Routledge.

BBC. (2011). "Chinese Overseas Students Hit Record High". Retrieved from http://www.bbc.co.uk/news/world-asia-pacific-13114577 on May 08, 2012.

Beard, J. G., & Ragheb, M. G. (1983). "Measuring Leisure Motivation". *Journal of Leisure Research*, *15*(3), 219-228.

Beech, H., & Jiang, C. (2011). "Red State". *Time International (Atlantic Edition)*, *178*(4), 24-29.

Berg, B. L. (2007). *Qualitative Research Methods for Social Sciences*. New York: Pearson Education Inc.

Blichfeldt, B. S. (2007). "A Nice Vacation: Variations in Experience Aspirations and Travel Careers". *Journal of Vacation Marketing*, *13*(2), 149-164.

Branscombe, N. R., & Wann, D. L. (1994). "Collective Self-Esteem Consequences of Outgroup Derogation When a Valued Social Identity Is on Trial". *European Journal of Social Psychology*, *24*(6), 641-657.

Braun-LaTour, K. A., Grinley, M. J., & Loftus, E. F. (2006). "Tourist Memory Distortion". *Journal of travel research*, *44*(4), 360-367.

Brown, L., & Aktas, G. (2012). "The Cultural and Tourism Benefits of Student Exchange". Retrieved from http://www.universityworldnews.com/article.php?story=20120502134619905 on July 20, 2012.

China Daily. (2011). "More Students Choose to Study Abroad". Retrieved from http://www.chinadaily.com.cn/cndy/2011-04/25/content_12383944.htm on July 18, 2012

Chinese National Tourism Administration (CNTA). (2012). "Tourism Receives by Provinces". Retrieved from http://www.cnta.gov.cn/html/2012-2/2012-2-28-15-48-19152.html on May 08, 2012.

Clarke, V., & Braun, V. (2008). "Gender". In Fox, D., Prilleltensky, I., & Austin, S. (Eds.), *Critical Psychology: An Introduction* (2nd ed., pp. 232-249). London: Sage.

Cocanougher, A. B., & Bruce, G. D. (1971). "Socially Distant Reference Groups and Consumer Aspirations". *Journal of Marketing Research*, *8*(3), 379-381.

Collins Dictionary. (2013). Retrieved from http://www.collinsdictionary.com on June 03, 2013.

Creswell, J. W. (2008). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. London: Sage.

Crompton, J. L. (1979). "Motivations for Pleasure Vacation". *Annals of Tourism research*, *6*(4), 408-424.

Curtin, S. (2005). "Nature, Wild Animals and Tourism: An Experiential View". *Journal of Ecotourism*, *4*(1), 1-15.

Dann, G. M. (1977). "Anomie, Ego-Enhancement and Tourism". *Annals of Tourism research*, *4*(4), 184-194.

Denscombe, M. (2007). *The Good Research Guide: For Small-Scale Social Research Projects* (3rd ed.). Buckingham: Open University Press.

Duman, T., & Mattila, A. S. (2005). "The Role of Affective Factors on Perceived Cruise Vacation Value". *Tourism Management*, *26*(3), 311-323.

Echtner, C. M., & Ritchie, J. (2003). "The Meaning and Measurement of Destination Image". *Journal of tourism studies*, *14*(1), 37-48.

Echtner, C. M., & Ritchie, J. B. (1993). "The Measurement of Destination Image: An Empirical Assessment". *Journal of travel research*, *31*(4), 3-13.

European Travel Commission (ETC). (2011). "Market Insights China". Retrieved from http://www.etc-corporate.org/resources/uploads/ETCProfile_China-1-2011.pdf on July 30, 2012.

Fan, Y. (2000). "A Classification of Chinese Culture". *Cross Cultural Management: An International Journal*, *7*(2), 3-10.

Farber, M. E., & Hall, T. E. (2007). "Emotion and Environment: Visitors' Extraordinary Experiences Along the Dalton Highway in Alaska". *Journal of Leisure Research*, *39*(2), 248-270.

Fountain, J., Espiner, S., & Xie, X. (2011). "A Cultural Framing of Nature: Chinese Tourists' Motivations for, Expectations of, and Satisfaction with, Their New Zealand Tourist Experience". *Tourism Review International*, *14*(2-3), 71-83.

Goulbourne, H. (1991). *Ethnicity and Nationalism in Post-Imperial Britain*. New York: Cambridge University Press.

Han, F. (2006). "The Chinese View of Nature: Tourism in China's Scenic and Historic Interest Areas". (PhD), Queensland University of Technology. Retrieved from http://eprints.qut.edu.au/16480/

Hibbert, J. F., Dickinson, J. E., & Curtin, S. (2013). "Understanding the Influence of Interpersonal Relationships on Identity and Tourism Travel". *Anatolia: An International Journal of Tourism and Hospitality Research*, *24*(1), 30-39.

Hinshelwood, R., D. (2005). "The Individual and the Influence of Socia Settings: A Psychoanalytic Perspective on the Interaction of the Individual and Society". *British Journal of Psychotherapy*, *22*(2), 155-166.

Hofstede, G. (1980). *Culture's Consequences: International Differences in Work-Related Values*. London: Sage.

Hofstede, G. (2001). *Culture's Consequences: Comparing Values, Behaviors, Institutions and Organizations across Nations*. London: Sage.

Holbrook, M. B., & Hirschman, E. C. (1982). "The Experiential Aspects of Consumption: Consumer Fantasies, Feelings, and Fun". *Journal of consumer research*, *9*(2), 132-140.

Hoyer, W. D., & Macinnis, D. J. (2010). *Consumer Behavior* (5th ed.): South-Western Mason.

Hsu, C. H., Cai, L. A., & Li, M. (2010). "Expectation, Motivation, and Attitude: A Tourist Behavioral Model". *Journal of travel research*, *49*(3), 282-296.

Iso-Ahola, S. E. (1982). "Toward a Social Psychological Theory of Tourism Motivation: A Rejoinder". *Annals of Tourism research*, *9*(2), 256-262.

Jang, S. S., & Feng, R. (2007). "Temporal Destination Revisit Intention: The Effects of Novelty Seeking and Satisfaction". *Tourism Management*, *28*(2), 580-590.

Jiang, B., & Tribe, J. (2009). "'Tourism Jobs-Short Lived Professions': Student Attitudes Towards Tourism Careers in China". *Journal of Hospitality, Leisure, Sports and Tourism Education*, *8*(1), 4-19.

Jönsson, C., & Devonish, D. (2008). "Does Nationality, Gender, and Age Affect Travel Motivation? A Case of Visitors to the Caribbean Island of Barbados". *Journal of Travel & Tourism Marketing*, *25*(3-4), 398-408.

Jorgensen, B. S., & Stedman, R. C. (2006). "A Comparative Analysis of Predictors of Sense of Place Dimensions: Attachment to, Dependence on, and Identification with Lakeshore Properties". *Journal of environmental management*, *79*(3), 316-327.

Jørgensen, M. W., & Phillips, L. (2002). *Discourse Analysis as Theory and Method*. London: Sage.

Kapferer, J. N. (1998). *Strategic Brand Management* (2nd ed.). New York: Kogan Page.

Kellert, S. R. (1993). "Attitudes, Knowledge, and Behavior toward Wildlife among the Industrial Superpowers: United States, Japan, and Germany". *Journal of Social Issues*, *49*(1), 53-69.

Kim, J.-H., Ritchie, J. R. B., & McCormick, B. (2012). "Development of a Scale to Measure Memorable Tourism Experiences". *Journal of travel research*, *51*(1), 12-25.

Kim, S. S., & Prideaux, B. (2005). "Marketing Implications Arising from a Comparative Study of International Pleasure Tourist Motivations and Other Travel-Related Characteristics of Visitors to Korea". *Tourism Management*, *26*(3), 347-357.

Kwek, A., & Lee, Y.-S. (2010). "Chinese Tourists and Confucianism". *Asia Pacific Journal of Tourism Research*, *15*(2), 129-141.

Leavitt, H. J., & Bahrami, H. (1988). *Managerial Psychology: Managing Behavior in Organizations* (5th ed.). Chicago, IL: University of Chicago Press.

Lee, S.-H., & Sparks, B. (2007). "Cultural Influences on Travel Lifestyle: A Comparison of Korean Australians and Koreans in Korea". *Tourism Management*, *28*(2), 505-518.

Li, X. R., Lai, C., Harrill, R., Kline, S., & Wang, L. (2011). "When East Meets West: An Exploratory Study on Chinese Outbound Tourists' Travel Expectations". *Tourism Management*, *32*(4), 741-749.

Llewellyn-Smith, C., & McCabe, V. S. (2008). "What Is the Attraction for Exchange Students: The Host Destination or Host University? Empirical Evidence from a Study of an Australian University". *International Journal of Tourism Research*, *10*(6), 593-607.

Maslow, A. H. (1943). "A Theory of Human Motivation". *Psychological review*, *50*(4), 370-396.

Mintel. (2007). *China Outbound Travel International Tourism Reports*. London: Mintel Intelligence.

Mok, C., & DeFranco, A. L. (2000). "Chinese Cultural Values: Their Implications for Travel and Tourism Marketing". *Journal of Travel & Tourism Marketing*, *8*(2), 99-114.

Morgan, M., & Xu, F. (2009). "Student Travel Experiences: Memories and Dreams". *Journal of Hospitality Marketing & Management*, *18*(2-3), 216-236.

Mowen, J. C., & Minor, M. (1998). *Consumer Behavior* (5th ed.). Upper Saddle River, NJ: Prentice-Hall.

Nicoletta, R., & Servidio, R. (2012). "Tourists' Opinions and Their Selection of Tourism Destination Images: An Affective and Motivational Evaluation". *Tourism Management Perspectives*, *4*, 19-27.

Noy, C. (2004). "Performing Identity: Touristic Narratives of Self-Change". *Text and Performance Quarterly*, *24*(2), 115-138.

Obenour, W. L. (2004). "Understanding the Meaning of the 'Journey'to Budget Travellers". *International Journal of Tourism Research*, *6*(1), 1-15.

Orwell, G. (1945). "Notes on Nationalism". In Orwell, S. & Angus, I. (Eds.), *The Collected Essays, Journalism, and Letters of George Orwell: As I Please, 1943-1945*. Michigan: Harcourt, Brace & World.

Otto, J. E., & Ritchie, J. B. (1996). "The Service Experience in Tourism". *Tourism Management*, *17*(3), 165-174.

Parfitt, J. (2005). "Questionnaire Design and Sampling". In Flowerdew, R. & Martin, D. (Eds.), *Methods in Human Geography: A Guide for Students Doing a Research Project* (2nd ed., pp. 78-109). Harlow: Prentice Hall.

Pearce, P. L., & Caltabiano, M. L. (1983). "Inferring Travel Motivation from Travelers' Experiences". *Journal of travel research*, *22*(2), 16-20.

Pearce, P. L., & Lee, U.-I. (2005). "Developing the Travel Career Approach to Tourist Motivation". *Journal of travel research*, *43*(3), 226-237.

People. (2012). "Jiangsu Tourist Arrivals Go Beyond 400 Million". Retrieved from http://js.people.com.cn/html/2012/01/18/70506.html on May 22, 2012.

Pine, B. J., & Gilmore, J. H. (1999). *The Experience Economy: Work Is Theatre & Every Business a Stage*. Boston: Harvard Business Press.

Quan, S., & Wang, N. (2004). "Towards a Structural Model of the Tourist Experience: An Illustration from Food Experiences in Tourism". *Tourism Management*, *25*(3), 297-305.

Reilly, M. D. (1990). "Free Elicitation of Descriptive Adjectives for Tourism Image Assessment". *Journal of travel research*, *28*(4), 21-26.

Reisinger, Y. (2009). *International Tourism: Cultures and Behavior*. Oxford: Elsevier.

Reisinger, Y., & Turner, L. W. (2003). *Cross-Cultural Behaviour in Tourism: Concepts and Analysis*. Oxford: Elsevier.

Richards, G., & Wilson, J. (2003). "New Horizons in Independent Youth and Student Travel. A Report to the International Student Travel Confederation (Istc) and the Association of Tourism and Leisure Education (Atlas). Amsterdam: International Student Travel Confederation".

Ryan, C., & Huang, S. (2013). "The Role of Tourism in China's Transition: An Introduction". In Ryan, C. & Huang, S. (Eds.), *Tourism in China, Destinations, Planning and Experiences* (pp. 1-8). Bristol: Channel View Publications.

Seddighi, H., Nuttall, M., & Theocharous, A. (2001). "Does Cultural Background of Tourists Influence the Destination Choice? An Empirical Study with Special Reference to Political Instability". *Tourism Management*, *22*(2), 181-191.

Sharpley, R., & Stone, P. R. (2010). *Tourist Experience: Contemporary Perspectives* (2nd ed.). London: Routledge.

Snepenger, D., Snepenger, M., Dalbey, M., & Wessol, A. (2007). "Meanings and Consumption Characteristics of Places at a Tourism Destination". *Journal of Travel Research*, *45*(3), 310-321.

Soares, A. M., Farhangmehr, M., & Shoham, A. (2007). "Hofstede's Dimensions of Culture in International Marketing Studies". *Journal of Business Research*, *60*(3), 277-284.

Sofield, T., & Li, S. (2011). "Tourism Governance and Sustainable National Development in China: A Macro-Level Synthesis". *Journal of Sustainable Tourism*, *19*(4-5), 501-534.

Tasci, A. D., & Gartner, W. C. (2007). "Destination Image and Its Functional Relationships". *Journal of travel research*, *45*(4), 413-425.

Tung, V. W. S., & Ritchie, J. B. (2011). "Exploring the Essence of Memorable Tourism Experiences". *Annals of Tourism research*, *38*(4), 1367-1386.

Turner, V. W. (1974). "Social Dramas and Ritual Metaphors". In Turner, V. W. (Ed.), *Dramas, Fields and Metaphors: Symbolic Action in Human Society* (pp. 23-59). New York, NY: Cornell University Press.

UNWTO. (2000). *Tourism 2020 Version: East Asia and Pacific*. Madrid: WTO.

UNWTO. (2008). "Youth Travel Matters". Retrieved from http://pub.unwto.org/WebRoot/Store/Shops/Infoshop/482C/09E7/89D4/2506/AA82/C0A8/0164/F5B4/080514_youth_travel_matters_excerpt.pdf on July 25, 2012

UNWTO. (2013). "The Chinese Outbound Travel Market 2012 Update". Retrieved from https://pub.unwto.org/WebRoot/Store/Shops/Infoshop/5152/D8CD/E446/2367/56E9/C0A8/0164/C390/130327_chinese_outbound_2012_update_excerpt.pdf on June 03, 2013.

UNWTO. (2015). "Unwto World Tourism Barometer Oct 8(3)". Retrieved from http://mkt.unwto.org/en/barometer/october-2010-volume-8-issue-3 2010 on May 13, 2016

Uriely, N. (2005). "The Tourist Experience: Conceptual Developments". *Annals of Tourism research*, *32*(1), 199-216.

Urry, J. (2002). *The Tourist Gaze: Leisure and Travel in Contemporary Societies* (2nd ed.). London: Sage.

Van Manen, M. (1990). *Researching Lived Experiences*. Albany, NY: State University of New York Press.

Wang, Y., & Davidson, M. C. G. (2008). "Chinese Student Travel Market to Australia: An Exploratory Assessment of Destination Perceptions". *International Journal of Hospitality & Tourism Administration*, *9*(4), 405-426.

Ward, C., Bochner, S., & Furnham, A. (2005). *The Psychology of Culture Shock* (2nd ed.). Taylor& Francis e-Library: Routledge.

Williams, A. (2006). "Tourism and Hospitality Marketing: Fantasy, Feeling and Fun". *International Journal of Contemporary Hospitality Management*, *18*(6), 482-495.

Wilson, E., & Harris, C. (2006). "Meaningful Travel: Women, Independent Travel and the Search for Self and Meaning". *Tourism*, *54*(2), 161-172.

Woodside, A. G., Hsu, S.-Y., & Marshall, R. (2011). "General Theory of Cultures' Consequences on International Tourism Behavior". *Journal of Business Research*, *64*(8), 785-799.

Xu, F., Morgan, M., & Moital, M. (2011). "Cross-Cultural Segments in International Student Travel: An Analysis of British and Chinese Market". *Tourism Analysis*, *16*(6), 663-675.

Xu, F., Morgan, M., & Song, P. (2009). "Students' Travel Behaviour: A Cross-Cultural Comparison of Uk and China". *International Journal of Tourism Research*, *11*(3), 255-268.

Yau, O. H. M. (1988). "Chinese Cultural Values: Their Dimensions and Marketing Implications". *European Journal of marketing*, *22*(5), 44-57.

International review for spatial planning and sustainable development, Vol.4 No.4 (2016), 88-104
ISSN: 2187-3666 (online)
DOI: http://dx.doi.org/10.14246/irspsd.4.4_88

Greenhouse Gas Inventory Accounting for Chinese Cities: A Preliminary Study

Ruixi Zhao[1] and Yan Li[1]*
1 Graduate School of Asia Pacific Studies, Ritsumeikan Asia Pacific University
**Corresponding Author: yanli@apu.ac.jp*

Received: August 04, 2015; Accepted: Dec 15, 2015

Key words: GHG inventory, Chinese cities, Beijing, GHG emission

Abstract: City Greenhouse Gas (GHG) inventory, a framework for measuring a city's detailed emissions from all activities, provides scientific evidence for the purpose of policy-making. As one of the largest GHG emitters in the world, China aims to reduce CO2 emissions per unit of GDP to 60 to 65 percent below 2005 levels by 2030. However, city GHG inventories in China have not yet been published by the city governments. Furthermore, previous studies on city inventory accounting are neither complete nor globally comparable. Hence, a case study of Beijing was conducted for the purpose of reporting the city inventory completely and enabling data to be comparable internationally. This research quantifies Beijing's latest emissions based on available data through multiple methods, including Community-Scale Greenhouse Gas emissions inventories (GPC), a method devised by the Japanese Ministry of Environment (Japanese Ministry of Environment, 2010) and a method from recent academic research on CO2 emissions in the Chinese iron and steel industry (Zhao, Y. Q., Li, & Li, 2012). According to these methods, Beijing's GHG emissions were 373,558,617 t CO2 in 2012. Additionally, comparisons between Beijing and six other mega-cities of Shanghai, Tokyo, New York, Washington D.C., London and Paris show that Beijing's 2012 GHG emission per capita and per 10,000 CNY GDP ranked the highest. This study creates a timely and relatively complete GHG emission inventory that can be widely applied for comparisons and presents recommendations for city inventory building.

1. INTRODUCTION

A city's greenhouse gas (GHG) emission inventory, a framework for city governments to account for and report on urban GHG emissions data, estimates the quantity of GHG emissions associated with city sources and activities taking place during a chosen year (International Council for Local Environmental Initiatives (ICLEI), 2013). The GHG inventory is playing an essential role in mitigation, especially for assisting urban policy making, indicating the reduction outcomes and motivating urban actions. Currently, city inventories have been studied by a number of entities, including international organizations, governments and researchers worldwide. According to the UN Intergovernmental Panel on Climate Change (IPCC) (2006), GHG inventories shall calculate emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Hydro Fluoro Carbons (HFCs), Per

Fluoro Carbons (PFCs) and Sulphur Hexafluoride (SF_6) with the following equation: *GHG emissions= Activity data× Emission factor*.

As one of the largest GHG emitters, China's mitigation efforts attract global attention. As the capital, Beijing is the centre of this urgent concern. However, a city inventory and CO_2 emissions are not publicized by the Beijing government and research on Beijing is facing the following series of issues: 1) most of the data are outdated because the latest emissions reporting calculated for Beijing, by Yuan and Gu (2011), took place in 2009; 2) accounting of gases was incomplete since only CO_2 emissions were calculated and neither forestry carbon sinks nor indirect emissions were covered; 3) studies were not globally comparable because most internationally recognized city inventories cannot be adopted. For instance, the study of Yuan and Gu (2011) shows that the International local government GHG emissions analysis protocol (IEAP) method is inapplicable for accounting Beijing's emissions.

Initially, this research follows the Global Protocol for Community Scale Greenhouse Gas Emissions (GPC) framework, as it is the latest globally recognized city inventory method established by reputable inventory authorities including the United Nations Environmental Programme (UNEP), World Bank, World Resource Institute and ICLEI. Furthermore, the GPC's framework has been adopted by 100 cities worldwide and even has a special version for Chinese cities (GPC, 2014). However, this study reveals that the GPC method can only cover 77% of Beijing's 2012 GHG emissions. In order to compensate, this study refers to two additional methods – one from Japan, called the Manual of Planning against Global Warming for Local Governments (Japanese Ministry of Environment, 2010), and one academic paper from China used specifically for iron and steel production (Zhao, Y. Q., Li, & Li, 2012).

This research aims to answer the following questions: What volume of GHG emissions did Beijing discharge in 2012, what issues have been found, and what relative improvements can be made? The calculation process follows four steps: 1) setting the geographical boundary and scope; 2) collecting activity data; 3) selecting factors; and 4) calculating emissions. For the activity data, it will mainly be collected from the Beijing City Statistical Yearbook and Beijing City Environmental Protection Bureau's reference documents.

2. GHG CITY INVENTORY

The GHG City inventory is playing an increasingly essential role for the following reasons. First, the city inventory provides technological support and references for setting mitigation goals and scenarios for both government and individuals. Second, it assists cities in reporting GHG emissions data and assessing emission reduction outcomes. Third, it is a cornerstone for low-carbon city planning and helps to improve the quality of low-carbon development. Moreover, development of an urban level inventory also promotes the establishment and perfection of national level inventory schemes. Finally, accounting processes and consequences of emission inventories contribute to city comparisons and enhance improvements for both domestic cities and international ones.

2.1 GHG Composition and Inventory Contents

According to the UN Intergovernmental Panel on Climate Change (IPCC) (2006), cities shall account for Greenhouse Gas emissions of six gases including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Hydro Fluoro Carbons (HFCs), Per Fluoro Carbons (PFCs) and Sulphur Hexafluoride (SF_6). In detail, HFC includes HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-227ea, HFC-236fa and HFC-245fa, while CH_4 and C_2F_6 are calculated in terms of PFCs. In 2012, Nitrogen Tri Flouride (NF_3) was added to the second compliance period of the Kyoto Protocol, yet it has not been widely quantified since most of the well-used inventory protocols were released before 2012.

In general, GHG emissions are collected from different sectors and usually cover a 12 month period. A Japanese case is shown in the table below, wherein emissions are accounted from various sectors, and some sectors cover more than one type of gas. For instance, the transportation sector covers emissions of CO_2, CH_4 and N_2O. Table 1 provides a case of Oita Prefecture, which has similar calculation fields to those of Tokyo and is a prefecture in which the authors have performed emissions calculations in previous studies.

Table 1. Accounting Contents of GHG Inventory (a case of Oita Prefecture, Japan)

Sectors	**Calculated GHG**	**Fields**
Energy Industry	CO_2	Manufacturing Industry Agriculture, Forestry and Fisheries Construction and Mining
Residential	CO_2	Residential energy consumption
Commercial	CO_2	Commercial Sewage Waste Finance and Real Estate Public Service Specified Business Operators Services Individual Services
Industrial Process:	CO_2	Cement
Transportation	CO_2, CH_4 and N_2O	Automobiles (CO_2, CH_4 andN_2O) Railway(CO_2); Shipping(CO_2); Aviation(CO_2)
Waste	CO_2, CH_4 and N_2O	Municipal Solid Waste Industrial Waste; Organic Waste Solid Waste Disposal on Land Water Treatment
Agriculture	CH_4 and N_2O	Livestock breeding process Livestock waste Emission from paddy field Burning of crop residue Cultivation of organic soils
HFC, PFC,SF6	HFC, PFC, and SF6	Household refrigerator Air conditioners (automobile use) Specified business operators
Forestry	CO_2	Private Forests National Forests

Source: Environmental Affairs Office of Oita Prefecture (2015)

2.2 City Inventory Methodology

Currently, there are a number of GHG inventory accounting methods that can be divided into two categories. The first category covers both direct and indirect emissions. Direct emissions are caused by citizens' activities and are discharged within city geographical boundaries, while indirect emissions are also caused by citizens' activities, but occur outside the city boundaries. Carbon Flows (Zhao, R. et al., 2014), Carbon Footprint (Sovacool & Brown, 2010), DPSC (Greater London Authority (GLA), 2014) and GPC are included this category. Detailed descriptions are shown in Table 2. In the second category, only direct emissions are calculated. For instance, the UN Intergovernmental Panel on Climate Change (IPCC)'s framework, which is the first international standard for GHG inventory accounting, is included in this second category.

Table 2. Existing GHG accounting methodology

Approach	Accounting Method (Indicators)	Scope Concept	Application (city)	Functions
Carbon Flow	1. Flow between Urban and External System 2. Flow between different inner sub-system of urban system 3. Flow between Urban and Rural system	Yes	Nanjing (Zhao, R. et al., 2014)	1. Reflect urban efficiency and sustainable development 2. Formulate low-carbon and sustainable energy polices for cities
Carbon Footprint	1. Local production for local consumption 2. Remote production for local consumption (emissions occur outside)	Yes	Delhi, Manila, Seoul (Sovacool & Brown, 2010)	1. Figure out consumption users and assign responsibility 2. Enable the evaluation of individual emissions
DPSC	1. Direct emissions within the city 2. Indirect emissions consumption of grid-supplied electricity, heating and/or cooling, transboundary travel 3. Supply chains from consumption of key goods and services produced outside the city boundary**	Yes	London (Greater London Authority (GLA), 2014)	Indirect inclusions can assist in the analysis of regional cross-scale and cross-sector infrastructure efficiencies.
GPC	1. Local production for local consumption 2. Local production for remote consumption (emission occurs locally) 3. Out boundary production for local consumption (emissions occur outside the	Yes	New York, Washington D.C. (GPC, 2014)	Fully reflect GHG drivers and easy for individuals to analyze their carbon activities; provide reference to government on setting mitigation goals

	city's geographical boundaries) 4. Transportation emissions occurring when production occurs outside the boundary and is carried out of the boundary for consumption

Note: All goods consumed by households, government and business capital (goods and services). For example: water supply, food, building materials

2.3 Chinese City Inventory

As one of the highest carbon dioxide emitters in the world (International Energy Agency (IEA), 2009), China is suffering from ecological fragility due to climate change. The country is therefore determined to make efforts towards mitigation. For example, President Xi Jinping (CNN Beijing, 2014) has declared a goal of 26%-28% emissions reductions by 2030.

Although reports of city GHG emissions have not been published by city governments in China, there are a number of academic studies on the subject. There is also a trend of attempting to apply international inventories and making city emissions comparable at the global level. For example, the IPCC methodology is being applied to estimate emissions from Nantong City (Wang, 2013), and the IEAP is being used for accounting Tianjin City's emissions (Deng et al., 2013). Some authors have also combined the above two methods to calculate the emission totals for Shanghai (Zhao, Q., 2011).

However, there are a number of issues and the Chinese city inventory is expected to be improved into a more scientific, formal and operable one. For instance, there is no unified city inventory system and some current methodologies are incomplete (Cai, 2012). Measures such as improvements on the allocation of GHG emissions, inventory frameworks, inventory borders and inventory scopes have been suggested (Bai et al., 2013).

2.4 Beijing City Inventory

The accounting work on Beijing's GHG emissions began in 1994, when China and Canada cooperated on a GHG inventory and released the Beijing emissions for the year 1991 (Beijing Municipal Environmental Monitoring Center, 1994). Though it began early, the development speed was slow (Cai, 2012). Over the years, analysis on Beijing's emission trends and comparisons with the emission trends of other metropolises have increased (Zhu, 2009), yet there is a limited number of studies on Beijing's GHG inventory.

Research on Beijing City's GHG emissions can be divided into three categories. The first is accounting city emissions by applying a global methodology. For example, the Beijing Environmental Protection Bureau has adopted the IPCC instructions. Meanwhile, some scholars apply the ICLEI method. For instance, Yuan and Gu (2011) examined the statistical data and concluded that it is not possible to report emissions in three scopes following the ICLEI method, due to the differences in statistics between the Beijing and ICLEI inventories. Additionally, Dhakal (2004) also followed the ICLEI in estimating Beijing's emissions and pointed out that the per capita emissions for Beijing were apparently higher than those of Tokyo and Seoul (1990-1998).

The second category calculates city emissions by applying scholars' self-developed city inventories. For example, Zhang, M. et al. (2012) established a method that focuses on the biochemical processes of CO_2 by gathering emissions from energy consumption like coal, oil, gas, physiological processes of the human population and soil respiration.

The third category accounts specific sectors of the city and offers its relative analysis. For example, Zhang, L., Hu, and Zhang (2014) provided outcomes of Beijing's energy consumption through Input-Output modelling. Furthermore, fossil fuel consumption in Beijing was evaluated through the same method by Guo et al. (2012). Additionally, Sovacool and Brown (2010) found that the city has a carbon footprint of 1.18 metric tons per person by applying the carbon footprint method.

3. BEIJING INVENTORY ACCOUNTING

3.1 Background

Based on analyses of current international city inventories, GPC Version 1.0 was selected to calculate a Beijing GHG inventory for the following reasons.

First, the GPC protocol offers an integral and robust inventory framework for Chinese city inventories by providing spreadsheet tools and instructions in Chinese. Moreover, it proposes instruction of activity data collecting and relative factors, which improves research efficiency and accuracy. Second, the GPC Version 1.0 has a high consistency in approach and methodology and its scope boundary concept enables comparisons between international cities. Third, it has a high update speed that provides timely inventory formulation and feedback through reliable testing for international metropolises. For example, Version 1.0 was released just three months after the publication of Version 0.9.

By following the GPC's calculation standard and its assessment boundary arrangements (GPC, 2014), the research aims to propose a more systematic calculation of Beijing's emissions from the following three scopes. Scope 1 covers all GHG emissions from sources located within the boundary of Beijing; Scope 2 contains all GHG emissions occurring as a consequence of the use of grid-supplied electricity, heating and/or cooling within Beijing's boundary; Scope 3 includes all other GHG emissions that occur outside the city boundary as a result of activities within the city boundary.

This paper calculates six sectors, which are Stationary Energy, Transportation, Waste, Industrial Processes and Product Use (IPPU), Agriculture Forestry and other Land Use (AFOLU), and other indirect emissions. Scope 3 was calculated in the Stationary Energy sector. The following table shows calculation contents based on the GPC framework.

Table 3. Beijing-Inventory Contents Overview

Required Reporting Content	Activity Data				Method	Counted Content			
	CO_2	CH_4	N_2O	HFC		CO_2	CH_4	N_2O	HFC
1. Stationary Energy									
1) Energy Balance Sheet									
Scope 1 (CO_2,CH_4,N_2O)	○	×	○		GM	CC	NC	CC	

Scope 2 (CO_2,CH_4,N_2O）	○	○	○		GM	CC	CC	CC	
Scope 3 (CO_2,CH_4,N_2O) :									
Airplanes from Beijing that refuel overseas	○	×	○		GM	INR	NC	INR	
Overseas Airplanes that refuel in Beijing	○	×	○		GM	CC	NC	CC	
2) Biomass Fuel Combustion									
Straw Combustion (CH_4, N_2O)		○	○		GM		CC	CC	
Fuel wood (CH_4, N_2O)		○	○		GM		CC	CC	
Wood Charcoal (CH_4, N_2O)		×	×				NC	NC	
Livestock Manure (CH_4, N_2O)		×	×				NC	NC	
2. Industry Processes and Production Use（12 productions tCO_2）									
1) Cement Production	○				GM	CC			
2) Steel Production	○				RAM	CC			
3) Aluminium Production	0.0	0.0	0.0	0.0	GM	NP	NP	NP	NP
4) Magnesium Production	0.0	0.0	0.0	0.0	GM	NP	NP	NP	NP
3. Agriculture Activity									
1) Rice Field（CH_4）	0.0	0.0	0.0	0.0	GM	NP	NP	NP	NP
2) Fertilization of Crops（N_2O）:									
Vegetables, Tubers, Soybeans, Tobacco Leaves, Peanuts			○		JM			CC	
Others			○					NC	
3) Livestock Fermentation（CH_4）		○			GM		CC	--	
4) Livestock Manure Management（CH_4,N_2O）		○	○		GM		CC	CC	
4. Waste Management									
1) Waste Landfill (CH_4)		×					NC		
2) Waste Incineration and Open Burning CO_2									
Domestic Waste	○				GM	CC			
Hazardous Waste	○				GM	CC			
Sludge Treatment in Wastewater	×					NC			
3) Waste Water Domestic and Industry (CH_4)		○			GM		CC		
4) Waste Water Domestic and Industry (N_2O)			○		GM			CC	
5. Forestry Activity and Other Land Use（Carbon Sink and Carbon Emissions）									
1) Forestry Activity：									
Stumpage Carbon Sinks and Carbon Emissions	○				GM	CC			
Bamboo Forest, Cash Crop Tree and Shrubbery Carbon Sink	○				GM	IC			
2) Land Use									
Bamboo Forest, Cash Crop Tree, Shrubbery's Combustion and Decomposition	×	×	×			NC	NC	NC	
6．HFC									
Household Refrigerators and Cars				○	JM				IC

Note: Grey Blank Not Required by GPC
○ Activity data available
×: 0.0 Activity data unavailable (cannot be found); Not produced in Beijing
GM GPC's Method

RAM Research Article's Method
JM Japan's Method
CC Complete Calculated
IC Incomplete Calculated
NC Not Calculated due to data limitation
NP Not calculated due to no production in Beijing

3.2 Beijing GHG Inventory Accounting

3.2.1 Beijing City Emission 2012 Overview

Table 4 summarizes the accounting results. In 2012, Beijing's GHG emissions were 373,558,617 tCO_2e. Among calculated gases, CO_2 emissions ranked at the top with 64.16%, followed by emissions of N_2O with 32.99%, CH_4 with 2.8% and HFC with 0.05%. Furthermore, among the accounted six sectors, the Stationary Energy sector emitted the most at 61.11% followed by the Agricultural Activity sector with 35.61%. Next were the Industrial Processes and Production Use sector with 2.52%, the Waste Management sector with 0.75%, and the Substitutes for Ozone Depleting Substances sector with 0.05%. Meanwhile, the carbon sinks of the Forestry Activity sector were 138,093 tCO_2 emissions, which contributed to this city's mitigation.

Table 4. Beijing City Emission 2012 Overview

Sectors	tCO_2	tCH_4	tN_2O	t HFC	Total Emissions
1.Stationary Energy	226,285,374.0	35,560.0	3,693.5		228,275,037.0
2.IPPU (Industrial Process and Production Use)	9,396,930.0			135.7	9,590,981.0
3.Agricultural Activity		380,914.8	414,494.4		133,042,201.2
4.Forestry Activity	-138,092.5				-138,092.5
5. Waste Management	1,766,878.7	8,598.2	2,706.8		2,788,460.1
Subtotal	237,311,090.1	425,072.9	420,894.8	135.7	
Emission Converted into tCO_2	237,311,090.1	10,626,822.9	125,426,639.0	194,065.0	
Total tCO_2 e				373,558,617.0	
GHG (tCO_2 e) per capita	18.5				
GHG(tCO2 e) /10^4 RMB GDP	2.3				
Carbon (tCO_2 e) per capita	11.8				
Carbon (tCO_2 e) /10^4 RMB GDP	1.5				

Note: Grey Blank: Not Required by GPC

3.2.2 Stationary Energy

According to GPC's instruction for Chinese cities, the stationary energy sector contains three categories that include fossil fuel combustion, biomass fuel combustion and fugitive emissions due to combustion. However, the fugitive emission calculation is not accessible due to lack of data.

The fossil fuel combustion and biomass fuel combustion are shown in Table 5 and Table 6 in detail. The method for calculating emissions is the activity data multiplying factor, among which activity data are mainly collected from the Energy Balance Sheet and the Beijing Statistical Yearbook (China Statistics Press, 2012). Factors are provided by GPC guidelines.

Table 5. Beijing 2012 Stationary Energy Sector GHG Emission

Gases	tCO_2	tCH_4	tN_2O	Transforming to tCO_2	% of the Sector
1.Stationary Energy					
1.1 Fossil Fuel Combustion (from Energy Balance Sheet)					
Scope 1	120,158,299.0	NC	1,269.4		
Scope 2	102,881,765.0	1,065.8	1,543.2		99.5%
Scope 3	3,245,310.0	NC	27.7		
Subtotal	226,285,374.0	1,065.8	2,840.3	227,158,428.4	
1.2 Biomass Fuel Combustion					
Straw Combustion		33,048.7	826.2		
Fuel wood		1,445.4	27.0		0.5%
Subtotal		34,494.1	853.2	1,116,606.1	
Total	226,285,374.0	35,560.0	3693.5	228,275,034.5	

Table 6. Beijing 2012 GHG emission of Biomass Fuel Combustion

Category	Total Yield (ton)	Crop Straw Combustion Amount (t)
1.Grain		
1.1 Grouped by Season		
Summer Grain	274,507.4	274,507.4
Autumn Grain	863,226.2	863,226.2
1.2 Grouped by Variety		
Rice	1,302.1	1,302.1
Winter Wheat	274,383.4	375,905.3
Corn	835,814.3	1,671,628.6
Tubers	12,242.6	
Soybean	8,870.5	
2. Cotton	271.7	815.1
3. Oil-bearing Crops	13,404.6	26,809.2
4. Medicinal plants	2,102.7	2,102.7
5.Vegetables and Edible Mushrooms	2,799,019.5	2,799,019.5
6. Melon and Strawberry	340,210.7	340,210.7
Crop Straw Combustion Total		6,355,526.8
CH_4 Factor (g/kg combustion)		5.2

N_2O Factor (g/kg combustion)	0.1
Emission tCH_4	33,048.7
Emission tN_2O	826.2

Note: Grey Blank: Not Required by GPC

3.2.3 Industrial Processes and Product Use

According to GPC framework, data of Industrial Processes and Product Use (IPPU) is applied for the calculation. In the case of Beijing (<Beijing Statistical Yearbook> 11-4), steel, cement, dolomite, iron and steel are to be reported by multiplying the activity data by the emission factor.

However, only the input data for cement is available, which matches the factor provided by the GPC. Details are shown in Table 7-1.

As a supplement, Iron and Steel emissions were able to be calculated by applying previous research on CO_2 emissions and point source distributions in the Chinese iron and steel industries (Zhao, Y. Q., Li, & Li, 2012). This method has a different factor from that of the GPC because it adopts the clinker data instead of input data of Iron and Steel. A detailed explanation is shown in Table 7-2.

Table 7-1. Beijing 2012 GHG emission of IPPU's cement

Item	Cement Production (t)	Factor (tCO_2/t production)	Emission (tCO_2)
Cement	568.4	0.54	3,058,127.0

Table 7-2. Beijing 2012 GHG emission of IPPU's Iron and Steel

Item	Weight of Clinker	Factor (tCO_2/t clinker）	Emission (tCO_2)
Iron and Steel	256.4	1.8	4,692,120.0

3.2.4 Waste Management

According to the GPC framework, the Waste Management sector contains four categories: Waste Landfill, Waste Combustion, Domestic Water Treatment and Industrial Water Treatment. However, due to the insufficient Solid Waste landfill data of Food Landfill, Clothing Landfill and Paper Landfill, only Waste Incineration and Open Burning and Wastewater Treatment are able to be accounted for, as shown in Table 8.

Table 8. Overview of GPC requested contents

Waste Management	tCO_2	tCH_4	tN_2O	% of total
Waste Incineration and Open Burning	1,766,878.7			63.4%
Wastewater Treatment		8,598.2	2,706.8	36.6%
Total (tCO_2)	2,788,460.1			

Note: Grey Blank: Not Required by GPC

The first item is Waste Incineration and Open Burning, accounting for both Domestic Waste and Hazardous Waste. Data are collected from the <City Sanitation Statistics> and the Beijing Municipal Environmental Bureau Official Website. It follows the equation below and outcomes are shown in Table 9.

CO_2 Emissions＝ΣAmount of Waste Combustion i× Rate of Carbon Content in Waste× i Rate of Mineral Carbon Content in Carbon Content i× Oxidation of Coal during combusting i×CO_2- C Rate（44/12）

i Stands for different waste category from Domestic Waste or Hazardous Waste

Table 9. Beijing 2012 *GHG* emission of Waste Incineration and Open Burning

Category	Amount of combustion (t)	Factor (tCO_2/t)	Carbon Content in Waste	Mineral Carbon Content	Oxidation of Coal	CO_2-C	Emission (tCO_2)
Domestic Waste	6,483,100.0	0.3	0.2	0.4	95%	3.7	475,594.0
Hazardous Waste	122,000.0	0.0	0.0	0.9	97%	3.7	117.0
Total (tCO_2)	75,711.0						

Note: 2011 data was applied for combustion of Hazardous Waste as it was the most recently available data.

Second, CH_4 emissions of Domestic Water and Industrial Waste Water are shown in Table 10 and Table 11 respectively. Meanwhile, NO_2 emissions of Domestic Wastewater and Industrial Wastewater Treatment are shown in Table 12. In this part, the 2011 emissions were accounted for since the latest data available were from the 2011 edition of the China Statistical Yearbook.

Table 10. Beijing 2011 GHG emission of Domestic Water Treatment

COD (t)	Transition BOD/COD	$kgCH_4$/kg BOD	tCO_2
87,100.0	0.5	0.1	3,880.0

Table 11. Beijing 2011 GHG emission of Industrial Waste Water Treatment (CH4 Emissions)

COD amount of Degradable Organic Matter in Industrial Waste Water (t)	BOD/COD Transition	$kgCH_4$/kg BOD	tCH_4
37,491,000.0	0.5	0.04	696.0

Table 12. Beijing 2011 GHG emission of Domestic Wastewater and Industrial Waste Water Treatment (N_2O)

Nitrogen Content (N kg)	Factor（kgN_2O/kgN）	N_2O-N（44/28）	Transition	tN_2O
167,506,092	0.005	1.6		1,315

3.2.5 Agricultural Activity

Beijing's Agricultural Activity Emissions incurs CH_4 and N_2O emissions from three sectors, which are fertilization of crops, enteric fermentation from livestock and livestock manure management. The overview is shown in Table 13. Detailed outcomes of each sector's discharge amounts are provided in Table 14, Table 15 and Table 16. Regarding emissions from livestock, there is a slight difference between enteric fermentation and manure management. This is due to the fact that hens are not ruminant livestock and therefore chicken manure is accounted for in the manure management factor, but not the enteric fermentation factor as per the requirements of the GPC (2014).

Table 13. Overview of Beijing 2012 Emissions of AFOLU

Category	tCO_2	tCH_4	tN_2O	tCO_2	% of Total
Fertilization of Crops			195.6	58,288.8	0.04%
Enteric Fermentation from Livestock		365,349.2	409,130.5	131,054,619.0	98.5%
Livestock Manure Management		15,565.5	5,168.4	1,929,320.7	1.5%
Total tCO2		133,042,228.5			

Note: Grey Blank: Not Required by GPC

Table 14. Beijing 2012 Fertilization Emissions

Category	Sown Areas(ha)	Total Yield (t)	Emission Factor ($t\ N_2O$/ha)	Emission Factor (t N/t)	Emission ($t\ N_2O$)	% of total
Vegetables	64,090.4		0.002		134.6	68.8%
Tubers	2,132.6		0.001		2.6	1.3%
Wheat	52,183.0		0.001		52.2	26.7%
Soybeans	4,716.3		0.0003		1.4	0.7%
Tobacco Leaves	3.7		0.002		0.0	0.0%
Peanuts		12,400.4		0.0004	4.8	2.5%
Total (tCO_2)			58,287.6			

Note: Grey Blank: Not Required by GPC

Table 15. Overview of Beijing 2012 Emissions of Livestock Enteric Fermentation

Category	Kg CH_4/number/year	Number	Emission($t\ CH_4$)	kg/number/year	Emissions ($t\ N_2O$)	% of total
Cattle and Buffalo	80.1	1,873,900.0	150,146.2	46.7	87,448.7	22.7%
Sheep	8.1	25,963,500.0	211,169.8	12.0	311,562.0	74.9%
Goat	8.3	414,300.0	3,452.5	2.0	828.6	0.3%
Pig	1.0	580,700.0	580.7	16.0	9,291.2	2.1%
Subtotal	365,349.2			409,130.5		
Total ($t\ CO_2$)	131,054,610.0					

Table 16. Overview of Beijing *2012* Emissions of Livestock Manure Management

Category	Number	Factor: KgCH_4/Number/Year	Emission (tCH_4)	Factor: Kg N_2O/Number/Year	Emission tN_2O)	% of total
Cattle and Buffalo	1,873,900	5.1	9,631.8	1.3	2,473.5	50.7
Sheep	25,963,500.0	0.2	3,894.5	0.1	2,414.6	42.3
Goat	414,300.0	0.2	70.4	0.1	38.5	0.7
Pig	580,700.0	3.1	1,811.8	0.2	131.8	4.4
Hens	15,696,000.0	0.0	157.0	0.0	109.9	1.9
Total (t CO2)			1,929,314.2			

3.2.6 Forestry Activity and Other Land Use Change

Regarding Forestry and other Land Use Change sectors, emissions from forestry emissions, carbon sinks, combustion caused by land use and decomposition are requested. However, due to data limitations, only forestry emissions are calculable.

The final outcome of this forestry activity is a combination of emissions and carbon sinks. Among them, carbon sinks are negative numbers since they contribute to the absorption of emissions. Thus the total amount was -0.01362tCO_2. The method is divided into two, as shown in the following calculation:

Carbon Sink (tCO_2) =living wood growing stock × Growing rate of living wood × Average Density of wood × Biomass Conversion × Carbon Content × CO_2- C Conversion (44/12)

Carbon Emission (tCO_2) = living wood growing stock × Consumption Rate of

living wood × Average Density of wood × Biomass Conversion × Carbon Content × CO_2- C Conversation (44/12)

Table 17. Overview of Beijing 2012 Forestry Activity Algorithm

Stock M3	Growth Rate	Consumption Rate	Average Density t/m3	Biomass Conversion (All)	Biomass Conversion (Above Land)	Carbon Content	CO_2-C Rate	Carbon Sink tCO_2	Carbon Emission tCO_2
29.2	6.4%	4.3%	0.5	1.8	1.4	0.5	44/12	-0.04	0.03

4. DISCUSSION AND CONCLUSIONS

4.1 Data Availability Analysis

Table 18. Data availability and Method application Analysis

Categories	Items	Portion of Total
1:Data Collection Analysis		
○: Data Available	27	52%
×: Data Unavailable (occurred but cannot be found)	12	24%
0.0: Not produced in Beijing	12	24%
Total required contents (○+×+0.0)	51	
Data Availability (= "○" + "0.0")	39	77% (39/51)
Data Unavailability	12	23% (12/51)
2. Applied Method Analysis (the same with Factor)		
GPC Method	18	86%
Japan Method	2	10%
Research Article Method	1	4%
Total	21	100%

This study shows that data availability of the Beijing GHG emissions inventory is 77%. Details are shown in Table 18. Regarding the method, the usage rate of the GPC method is 86%. Meanwhile, other methods that include those from Japan and China account for 10% and 4% respectively.

4.2 Data Unavailability Analysis

In this paper, based on the GPC framework, 23% of the required items cannot be calculated due to data unavailability. However, these items account for a small portion. As shown in Table 3, those contents denoted with a "×"are not calculated items. However, most of them are not calculated by others, as in the case of Oita Prefecture. Based on the authors' previous study, it can be found that the only item which was calculated by Oita, but not by this study, was Waste Landfill, which was 47,166 tCO_2e and accounted for 0.11% of Oita's total emissions (42,445,556 tCO_2e).

4.3 Comparison Study between Beijing 2012 Emissions and Other Metropolitan Areas

This study compares Beijing's 2012 emissions with six mega cities that include Shanghai (China), Tokyo (Japan), London (United Kingdom), Washington D.C. (United States), New York (United States) and Paris (France) with conclusions shown in Table 19.

Table 19. GHG *Emission* per capita and per GDP Comparison at a Global Level

Category	Beijing (This study)	Shanghai (Zhao, Q., 2011)	Tokyo (Tokyo Metropolitan Government, 2014)	London (Greater London Authority (GLA), 2014)	Washington, D.C. (District of Columbia, 2012)	New York (City of New York, 2012)	Paris (COP Cities 2012 Global Report, 2012)
GHG (tCO2) per Capita	18.5	13.2	4.9	14.2	14.3	6.5	10.9
Gap: (Beijing 2012 vs. other cities)	--	5.3	13.6	4.4	4.2	12.0	7.6
GHG(tCO_2)/104 RMB GDP	2.4	1.3	0.1	0.5	0.4	0.1	0.1
Gap:(Beijing 2012 vs. others)	--	1.0	2.2	1.9	1.9	2.3	2.3
GDP (10^4 RMB)	160,004,000	136,981,500	481,340,440	243,882,013	220,717,280	829,174,580	382,050,240
Latest Data	2012	2008	2011	2010	2010	2010	2010
Primary Data	Research	Research	Government	PAS 2009	State Government	Government	COP cities 2012 Report

First, from the GHG (tCO_2) per capita perspective, Beijing's 2012 emissions were the highest with 18.5 tCO^2e. Specifically, it had a relatively large GHG emission gap between New York (6.5 tCO_2) and Tokyo (4.91 tCO_2). On the contrary, it was close to that of Shanghai, London and Washington D.C., with differences of 5.3 tCO_2, 4.35 tCO_2, and 4.21 tCO_2 respectively. Second, from the GHG emissions (tCO_2) per GDP (104 RMB) perspective, Beijing's emissions were the highest in 2012 as well. Third, regarding the reporting year, Table 19 presents that this study was the most up to date one in terms of disclosing city emissions. Fourth, regarding availability of GHG emission reports, emissions from Japan, UK, the US and France were disclosed, while those from China were kept private. Information on Tokyo, London, Washington D.C, New York and Paris were published through governments, international organizations' reports and academic studies, while those of Beijing were not. GHG emissions from Chinese cities like Beijing can only be accessed through academic research.

4.4 Issues and Recommendations

In this study, four issues have been found and relative recommendations are provided and aggregated in Table 20. The first issue regards the consistency between the GPC's activity data collection method and the Beijing Bureau of Statistics (BSY)'s activity data reporting method. Because the statistical methods are inconsistent, some emissions are not able to be accounted for. Hence, this study recommends that the GPC and BSY unify the data category.

The second issue is a boundary issue because boundary principles are ambiguous and boundary data is insufficient. Therefore, this study recommends that inventory authorities set and clarify boundary principles. Furthermore, enriching boundary activity data is suggested to BSY.

The third issue is insufficient activity data. The evidence for this is shown in Table 20 and the main reason is that data provided by the Beijing Bureau of Statistics is insufficient. Therefore, this study recommends that the Beijing Bureau of Statistics enrich its data category.

The fourth issue is that there is no publicised emissions report from private enterprises, which makes accounting difficult. Hence, this study suggests that governments establish a private enterprise reporting scheme and make companies set mitigation goals.

Table 20. General Issues of Beijing's 2012 Inventory and Recommendations

Issues	Examples	Recommendations	Targets
Inconsistent inventory method and statistical category of activity data	1)Stationary Energy-Fossil Fuel CH_4 2) IPPU Sector	Unify the data category	GPC; BSY
Boundary issue on boundary at national level and domestic level	1)Stationary Energy- Scope 3 in balance sheet 2)Waste Management Sector	1) Clarifying boundary principles 2)Enrich boundary activity data published by the urban Bureau of Statistics	International and Domestic inventory setting authorities 2) BSY
Lacking activity data	1)Stationary: Energy-Fugitive Emission and Biomass Fuel Combustion 2)Waste Management Sector: Landfill and combustion	Enrich categories of data (e.g., Biomass Fuel Combustion, Waste Combustion, Forest Combustion)	Beijing Bureau of Statistics
No public report from enterprises	Substitutes for Ozone Depleting Substances Sector	Establishing enterprise GHG emission reporting scheme	For government and enterprises

In conclusion, this study makes a preliminary Chinese city inventory by accounting Beijing city's GHG emissions. Through combining the GPC method, the Japanese method and the method reached in a previous research article, it creates a timely and relatively complete GHG emission inventory. Furthermore, this study enables global comparisons between Beijing and other mega-cities. Additionally, this research also identifies issues and provides four recommendations to improve GHG inventory accounting in Beijing.

ACKNOWLEDGEMENTS

This work was supported by grants from the Japan Society for the Promotion of Science (KAKENHI No. 26420634).

REFERENCES

Bai, W., Zhuang, G., Zhu, S., & Liu, D. (2013). "Discussion of Four Issues About Inventorying Urban Greenhouse Gas Emissions in China". *Progressus Inquisitiones DE Mutatione Climatis*, *9*(5), 335-340.

Beijing Municipal Environmental Monitoring Center. (1994). "Beijing Greenhouse Gases Emission and Abatement Research".

Cai, B. (2012). "Research on Greenhouse Gas Emissions Inventory in the Cities of China". *China Population,Resources and Environment*, *22*(1), 21-27.

China Statistics Press. (2012). *Beijing Statistical Yearbook 2012*. Beijing: China Statistics Press.

City of New York. (2012). "Inventory of New York City Greenhouse Gas Emissions, December 2012". Retrieved from http://s-media.nyc.gov/agencies/planyc2030/pdf/greenhousegas_2012.pdf on Nov, 2015.

CNN Beijing. (2014). "U.S. And China Reach Historic Climate Change Deal, Vow to Cut Emissions". Retrieved from http://edition.cnn.com/2014/11/12/world/us-china-climate-change-agreement/ on May, 2015.

COP Cities 2012 Global Report. (2012). "Per Capita Ghg Emissions for C40 Cities". Retrieved from http://smedia.nyc.gov/agencies/planyc2030/pdf/greenhousegas_2012.pdf on Nov, 2015.

Deng, N., Chen, G., Cui, W., Zhang, Y., & Ma, H. (2013). "Municipal Greenhouse Gases Inventory and Analysis: A Case of Tianjin". *Journal of Tianjin University Science and Technology*, *46*(7), 635-640.

Dhakal, S. (2004). "Urban Energy Use and Greenhouse Gas Emissions in Asian Mega-Cities". *Institute for Global Environmental Strategies, Kitakyushu, Japan*.

District of Columbia. (2012). "Reducing Greenhouse Gas Emissions While Growing the City". Retrieved from http://doee.dc.gov/sites/default/files/dc/sites/ddoe/publication/attachments/GHGinventory-1205-.pdf on Nov, 2015.

Environmental Affairs Office of Oita Prefecture. (2015). "Ghg Inventory for Oita Prefecture". Retrieved from http://www.pref.oita.jp/10400/advice/bosyu/h17/ondanka/data/shiryou.pdf on May, 2015.

GPC. (2014). "Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (Gpc): An Accounting and Reporting Standard for Cities". Retrieved from http://ghgprotocol.org/files/ghgp/GHGP_GPC.pdf

Greater London Authority (GLA). (2014). "Application of Pas 2070 - London, United Kingdom, an Assessment of Greenhouse Gas Emissions of a City". Retrieved from http://shop.bsigroup.com/upload/PAS2070_case_study_bookmarked.pdf on Nov, 2015.

Guo, S., Shao, L., Chen, H., Li, Z., Liu, J. B., Xu, F. X., . . . Chen, Z. M. (2012). "Inventory and Input–Output Analysis of Co^2 Emissions by Fossil Fuel Consumption in Beijing 2007". *Ecological Informatics*, *12*, 93-100.

Intergovernmental Panel on Climate Change (IPCC). (2006). "2006 Ipcc Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas

Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. And Tanabe K. (Eds). ". Retrieved from www.ipcc-nggip.iges.or.jp/public/2006gl

International Council for Local Environmental Initiatives (ICLEI). (2013). "U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions". Retrieved from http://icleiusa.org/publications/us-community-protocol/ on July, 2015.

International Energy Agency (IEA). (2009). "Co^2 Emissions from Fuel Combustion 2009-Highlights". Retrieved from http://www.iea.org/co2highlights/co2highlights.pdf on May, 2015.

Japanese Ministry of Environment. (2010). "Manual of Planning against Global Warming for Local Governments". Retrieved from http://www.env.go.jp/earth/ondanka/sakutei_manual/manual_kani1008/full.pdf on July, 2015.

Sovacool, B. K., & Brown, M. A. (2010). "Twelve Metropolitan Carbon Footprints: A Preliminary Comparative Global Assessment". *Energy Policy*, *38*(9), 4856-4869.

Tokyo Metropolitan Government. (2014). "Tokyo 2011 Emissions". Retrieved from http://www.kankyo.metro.tokyo.jp/climate/other/emissions_tokyo.html on Nov, 2015.

Wang, P. (2013). "Estimation of Greenhouse Gas Emissions for Nantong". *Environmental Monitoring in China*, *29*(4), 147-151.

Yuan, X. H., & Gu, C. L. (2011). "Urban Greenhouse Gas Inventory and Methods in Beijing". *Urban Environment & Urban Ecology*, *24*(1), 5-8.

Zhang, L., Hu, Q., & Zhang, F. (2014). "Input-Output Modeling for Urban Energy Consumption in Beijing: Dynamics and Comparison". *PLoS ONE*, *9*(3), e89850.

Zhang, M., Suo, A., Wang, T., & Ge, J. (2012). "Estimation on Beijing Co^2 Emissions". Paper presented at the 8th Biennial Conference of Chinese Ecological Economics Society, Urumchi, Xinjiang.

Zhao, Q. (2011). "Shanghai Ghg Inventory Study". (Master), Fudan University.

Zhao, R., Huang, X., Zhong, T., Liu, Y., & Chuai, X. (2014). "Carbon Flow of Urban System and Its Policy Implications: The Case of Nanjing". *Renewable and Sustainable Energy Reviews*, *33*(2), 589-601.

Zhao, Y. Q., Li, X. C., & Li, G. J. (2012). "Current Situation of Co^2 Emission and Point Sources Distribution in China's Iron and Steel Industry". *Journal of Iron and Steel Research*, *24*(5), 1-4.

Zhu, S. (2009). "Present Situation of Greenhouse Gas Emission in Beijing and the Approach to Its Reduction". *China Soft Science*, *9*, 93-106.

IRSPSD International

ISSN 2187-3666 (Online)

For investigation regarding the impact of planning policy on spatial planning implementation, International Community of Spatial Planning and Sustainable Development (SPSD) seeks to learn from researchers in an integrated multidisciplinary platform that reflects a variety of perspectives—such as economic development, social equality, and ecological protection—with a view to achieving a sustainable urban form.

This international journal attempts to provide insights into the achievement of a sustainable urban form, through spatial planning and implementation; here, we focus on planning experiences at the levels of local cities and some metropolitan areas in the wolrd, particularly in Asian countries. Submission are expected from multidisciplinary viewpoints encompassing land-use patterns, housing development, transportation, green design, and agricultural and ecological systems.

Kanazawa office
Director: Prof. Zhenjiang SHEN
Prof. Mitsuhiko KAWAKAMI
Editorial secretary: Yuanyi ZHANG

2B519, Natural science and technogly hall 2, Kanazawa Univeristy, Kanazawa
Tel&Fax: 0081-76-234-4650
Email: spsdpress@gmail.com

Beijing office
Director: Prof. Qizhi MAO
Prof. Anrong DANG
Dr. Ying LONG
Editorial secretary: Li LI

School of Architecture, Tsinghua University, Beijing
Email: lilicareer@hotmail.com

International Review for Spatial Planning and Sustainable Development
https://www.jstage.jst.go.jp/browse/irspsd
http://spsdpress.jimdo.com/volumes
http://dspace.lib.kanazaa-u.ac.jp/dspace/bulletin/irspsd