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The Role of “Big Data” in Regional Low-Carbon Management: A Case in China

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Abstract—Low-carbon management is an important area of urban study and city management, and it is a critical element of the modern city system. Even though the importance of low-carbon management has been recognized, low-carbon problems are still salient and even worse than ever before in some developing countries, like China. Nowadays, "big data" techniques may change this dilemma in the regulatory process and innovation of social governance. However, few studies have been conducted to examine the role of big data in regional low-carbon management, especially in developing countries. In this study, by drawing on the experience of other countries and using “big data” methods, we have developed an approach of using a big data model to improve low-carbon management in Beijing (the capital of P.R. China), and we have proposed some policy suggestions.

Keywords—Low-carbon management; Big data; GIS; Regulatory regime

1. Introduction

Stable climate conditions are necessary for human activities. However, since the industrial revolution, human activities, especially economic activities associated with a large amount of fossil fuel burning, industrial chemicals, deforestation, and land-use change have led to a significant change in the global climate system. Climate change mainly includes three things: global warming, acid deposition and ozone depletion. In 2007, the fourth assessment report by the Intergovernmental Panel on Climate Change (IPCC) indicated that above 90% global climate anomalies are possibly due to Greenhouse Gas (GHG) emissions. Thus, reducing greenhouse gas emissions is one of the most important concerns for regional government.

Among several ways to deal with the GHG problem, air quality control is considered as a major achievement of human social development, and the regulatory regime is the important content of the regional air quality and safety system. However, even though the monitoring systems of most countries have attracted great recognition, air quality and safety incidents are still salient. In this situation, people have tried to find some potential solutions from “big data”, which is semi-structured and unstructured data associated with the environment. Then, many questions arise, such as: what kinds of change of regulatory processes have the internet and big data created? And how can social governance and stringent regulatory systems be changed to cover the entire process? According to the lessons learned from various countries’ experiences, it is necessary and urgent to sort and summarize the established thinking and build more accurate inference and description of regulatory systems.

As we know, the concepts of Geographic Information System (GIS) and Big Data have been widely integrated in many fields. GIS is a computer system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data (Burrough and McDonnell, 2005). Many pioneers use them to solve environmental problems. GIS has the advantage for researchers of being a visual system. For instance, a systematical management model for low-carbon related information about urban facilities can be provided by using GIS, a methodology which can be used to support local decision-making especially for daily services and transport infrastructure based on GIS (Salonen et al. 2014).

In the field of big data, several scholars have conducted deep investigations on how to apply big data techniques into environmental areas. In general, the role of big data can be concluded as having two aspects. The first aspect is the analysis, where a mass of data is used to explore the characteristics in a particular environment. Some scholars have proposed that data science can accurately assess how energy is consumed in buildings and what can be done to save energy (Lee et al. 2013). Furthermore, researchers used regional air quality and weather records of 77 of China's cities along with some big data sets of climate, geographical location and urbanization to create a big spatial-temporal data framework for the analysis of severe smog in China to find the possible short-term and long-term factors to PM2.5 (Chen et al. 2013). Due to the features of 4V (i.e., volume, velocity, variety and veracity) of big data, the results are generally accurate. For example, a study about the effect of vehicle electrification on greenhouse gas emission reduction demonstrated the benefit and accuracy of using big data to better understand environmental implications of fleet electrification and inform better decision-making (Cai et al. 2013). The second stream is the forecasts and significant suggestions based on the first one. After analysis of data produced in an environment, some scholars give policy suggestions with the forecast which comes from the data analysis (Shahrokni et al.,2014). Especially with the development of information technologies, big data is usually generated from the internet such as mobile network, where mobile tools are usually used to collect data and environment problems are mentioned. In the era of mobile internet, environmental data can be collected by smartphone users and calculated with the help of GIS platforms (Das,2014). Then, we can propose that big data has the potential to make contributions to low-carbon management. However, even though most researchers and practitioners have recognized the important relationships among big data, GIS and low-carbon management, few studies have been conducted to examine the role of big data in regional low-carbon management. In this paper, from the perspective of GIS, we have conducted a case study on regional low-carbon management in Beijing, P.R. China.

2. Literature Review

2.1 Big data in low-carbon management

In the process of industrialization and urbanization, human activities have brought great changes to the global climate system, including global warming, acid deposition and ozone depletion. Scientific studies on climate change not only include observation, simulation and prediction, but also include requirements of mass scientific data storage, information analysis and decision service, and this increasing requirement for scientific detail has triggered a new trend of big data. At the same time, a large amount of accurate and high-quality scientific data is playing a vital role in global climate change research (Wu et al. 2014). Thus, numerous scholars have tried to apply big data techniques to environmental issues such as air quality monitoring and greenhouse gas emissions. Especially in China at present, air pollution has attracted people's attention, and scholars have conducted several studies about it. Among these studies, some used air quality and weather records along with some big data sets of climate, geographical location and urbanization to create a big spatial-temporal data framework for the analysis of severe smog in China to find the possible short-term and long term factors to PM2.5 (Chen et al. 2013); while some other scholars have tried to build a system that can infer real-time and fine-grained air quality information throughout a city, with the help of big data and cloud-platform, and have developed it into smart-phone applications (e.g., Apps in Apple and Android stores) (Zheng et al. 2014; Zheng et al. 2013).

Big data has also been widely used in research into greenhouse gas emissions. For example, one study about the effect of vehicle electrification on greenhouse gas emission reduction demonstrated the benefit and accuracy of using big data to better understand environmental implications of fleet electrification and inform better decision-making (Cai et al. 2013). Some researchers developed an application to estimate greenhouse gas reduction for individual waste cooking oil recycling practices by collecting users' daily cooking practices as big data, and this application might contribute to drive people's behavior towards a low-carbon society (Fujita et al.). Furthermore, big data can play an essential role in forecasting; for example, based on a large set of panel data, researchers identified the effect of weather on household electricity consumption, and provided estimates of electricity consumption under climate change forecasts (Aroonruengsawat et al. 2011). With the help of big data, there are many studies dedicated to the study of air quality (PM2.5) forecasting (McKendry 2002).

2.2 Low-carbon management in China

Throughout the history of civilization of human societies, there is a supervision of product quality because of the community's need for quality and safety. Every serious quality problem and impact on quality control has made each country's regulatory system encounter serious challenges, giving rise to the adjustment of the quality management system. National laws have developed various nuanced tools. For example, in 1890 the Federal Food and Drugs Act marked the beginning of United States food safety legislation, which was adopted in 1938. The Federal Food, Drug, and Cosmetic Act was established in 1993, and the Food and Drug Administration (FDA), the FDR era "times of severe law" of agricultural products quality safety supervision system was in rough shape (Bedell and Jeffrey 1998). Under the responsibility of regulatory agencies, the quality and safety of agricultural products generally has the following three patterns: Mode I, patterns in the agricultural sector; Mode II, independent safety overseeing bodies; and Mode III, multiple departments (Dimitrios, Evangelos, and Panagiotis 2013). In the late 90s, after the raging global BSE and foot-and-mouth outbreaks, systems and quality standards were hard hit by "Bud" strategic thinking, the "hazard analysis and critical control points" system (HACCP), the pharmaceutical production enterprises standard (GMP) and the drug-handling enterprise specification (GSP) application and extension (Johnson 2011). As early as 1980, the EU promulgated and implemented the system of EU food safety and health through legislation, "from farm to fork" respectively, and access to markets and a series of safety management mechanisms. In 1947, Japan enacted a law on food hygiene. Each agricultural product that is distributed has an "identity card"; for example, cow wears a personal identification number which provides the basis for enquiring from consumers and retrospection (Sarah and Geoffrey 2010). Developed countries have to establish a warning system for imported products, their own products, refuse, waste product recalls, warnings and notification (Cheng, Fan and Luo 2012).

Product quality and safety in China has a wide range of features, but the basic message specification has not become an obstacle to the effective implementation of the system (Cui 2013). Since reforming and opening up, China's quality supervision has made rapid development. The 18 third plenary session for the near future direction of work has paid attention to scientifically dealing with steady decentralization of government functions and strengthening of market supervision, in order to develop "four modes of thinking": market thinking, modern thinking, control thinking, and law thinking in governance and the rule of law. In 2014, it is necessary to strengthen agricultural product quality and food safety supervision. The local progressive implementations of "three-strict" are "the most stringent standard, the most stringent regulation and the most severe punishment". Moves have been put forward by means of technical standards and risk prevention barriers, highhanded forms of punishment; canonical reputation platforms, complete delisting measures of companies, and a public "blacklist" as well as full coverage of samples, the progressive implementation of GMP, GSP, and HACCP regulations, an additional "12331" food and drug complaint hotline, and product identification that is "unique, accurate, authoritative" (Yu Yang Yao. 2012).

Compared to the traditional product quality supervision system, current research methods face challenges. On the one hand, comparative methods previously used a single indicator, countries, institutions, regulations, systems, and quality evaluation criteria such as a comparison have not met the requirements of system analysis (Liu 2006). The multidimensional analysis proposed by Codd (On-Line Analysis Processing, OLAP) and the structured data have formed a complete set of effective analysis systems (Meng and Ci 2013). One can drill down or roll up multiple dimensions, and produce deeper knowledge. At the same time, it has been used in many areas of application, such as rent, insurance, oil drilling, quality control of traditional Chinese medicine, the integrated health care system, and the administrative punishment of traffic. The dimension analysis of the regulatory system is very helpful. On the other hand, it is true that some researchers put effort into exploring the strategy of low-carbon management by using GIS, yet they are not inclusive and mainly resolve urban individual problems (Gil et al. 2014; Salonen et al. 2014). So, research on low-carbon management in a national scope with GIS is essential. Based on this, this paper will explore regional low-carbon management in the perspective of Big Data and GIS.

3. The Development Approach of Big Data Models

3.1 Big data structure and index related to low-carbon management

As the above section has shown, there are many semi-structured and unstructured data related to low-carbon management, which can be captured, calculated, or visualized by different techniques like GIS.

These data are very important for improving the efficiency of cities' low-carbon management. In this study, we have summarized relevant data or index in Table 1 and 2.

Table 1. Examples about low-carbon emissions index

Human development coefficient \ State \ carbon emission index	Low-carbon emission index（0~0.1）	Medium carbon emission index（0.1~0.3）	High carbon emission index（0.3~0.5）	Very high carbon emission index（0.5~0.7）
Very high human development coefficient（1.0~0.9）	Iceland	Norway, Sweden, France, Switzerland, Japan, Finland, Austria, Spain, Belgium, Italy, New Zealand, the United Kingdom, Singapore, Slovenia, Portugal	Australia, Canada, Ireland, the Netherlands, Luxembourg, the United States, Denmark, Germany, China, Hong Kong, Greece, South Korea, Israel, Brunei, Kuwait, Cyprus, Czech Republic, Malta	United Arab Emirates, Qatar
High human development coefficient（0.8~0.9）		Slovakia, Hungary, Chile, Croatia, Lithuania, Latvia, Argentina, Uruguay, Cuba, Mexico, Costa Rica, Venezuela, Panama, Albania, Dominica, Brazil, Colombia, Peru, Ecuador	Poland, Libya, Oman, Saudi Arabia, Bulgaria, Saint Kitts and Nevis, Romania, Malaysia, Belarus, Macedonia, Bosnia and Herzegovina, Turkey, Lebanon	Bahrain, Estonia, Trinidad and Tobago, Serbia, Russia, Kazakhstan
Medium human development coefficient（0.5~0.8）	Paraguay, Myanmar, Nepal, Kenya, Haiti, Sudan, Tanzania, Cameroon, Nigeria	Armenia, Thailand, Georgia, Dominica, Tunisia, Sri Lanka, Gabon, Algeria, the Philippines, El Salvador, Indonesia, Honduras, South Africa, Bolivia, Vietnam, Guatemala, Botswana, Tajikistan, Namibia, Congo (Brazzaville), Cambodia, Yemen, Pakistan, Angola, Bangladesh, Ghana, Benin, Sale Gal	Azerbaijan, Iran, China, Jamaica, Syria, Kyrgyzstan, Morocco, India	Ukraine, Uzbekistan, Turkmenistan
Low human development coefficient（0.3~0.5）	Eritrea, Ethiopia, Mozambique, Congo (DRC)	Benin, Sale Gal		

Table 1. Examples of low-carbon emissions indices

Table 2. The main calculation methods of carbon clearance

Classification of 《The United Nations Framework Convention on Climate Change》		Formula	Annotation
Energy	Stationary emission sources	The CO_2 emission factor = Average net calorific * potential carbon emission factor * oxidation rate	The average low calorific value of energy varieties and average carbon content, as default values in previous, and with reference to the IPCC potential emission factors, the oxidation rate default values of different equipment, get the CO_2 emission factor of energy finally.
		The CO_2 emissions = fuel consumption * emission factor	The CO_2 emissions (ten thousand tons) is calculated by fuel type; Amount of fuel consumption: fuel combustion (ten thousand tons); Emission factor is given according to the IPCC reference data for sure.
	Mobile emission sources		The fuel estimates is based on the total estimate fuel use according to the driving distance data. I for vehicle type, j as fuel types.
	Fugitive emissions	The CH_4 Emissions = CH_4 emission factor * Underground Coal Production * Conversion Factor	CH_4 emission factor: according to the coal mining depth selection of the low CH_4 emission factor in IPCC; Conversion factor: the density of CH_4, at 20 ℃, under the condition of 1 atmospheric pressure, density value is 0.67 * 10-3 t/m3.
Industrial production process	Extractive industrial emissions	The CO_2 emissions =Mcl*EFcl*CFckd	Mcl: the clinker weight of production (mass t); The emission factor of EFcl clinker, according to the recommended values of IPCC for 0.52t CO_2/t clinker; CFckd: The correction factor of CKD emissions .
	Chemical industrial emissions	ECO2=AD*EF	ECO2: CO_2 emissions (t); AD: activity data related to calcium carbide production, the unit is produce tonnages of calcium carbide; EF: CO_2 emission factor, on the advice of the IPCC, the values are 2.62 tCO_2/t calcium carbide and 11.6 kg of CH_4 / t calcium carbide.
	Metal industrial emissions	ECO2=AD*EF	ECO2: CO_2 emissions (t); AD: activity data related to metal production, unit for produced metal tonnage; EF: CO_2 emission factors. According to the IPCC recommendations, the value of produced pig iron emission factor is 1.35t CO_2 / t pig iron, the value of produced steel emission factor is 1.06t CO_2 / t steel, the value of produced aluminum emission factor is 1.7t CO_2 / t aluminum, the value of produced lead emission factor is 0.52t CO_2 / t lead.
	Planting	Rice paddies carbon emissions = Rice growing period * Annual harvested area * Day emission factor	Planting carbon emissions come mainly from CH_4 produced by paddy field, there are different emission factors of paddy field under different water conditions in the different regions , it is need to classify paddy field and dry farmland for arable land, and determine the rice growing days, according to the default value of day emission factors of 1.30kgCH_4/ (hm2*d)to account.
	Animal husbandry		Enteric fermentation emissions from a livestock category. EF (T): emission factors of the livestock populations in

Agriculture			captivity, kg CH4/ (head *a); N (T): the number of heads of domestic livestock types or categories of T; T: Livestock types or categories.
			The total emissions from livestock enteric fermentation. Ei: Livestock i categories and subcategories emissions.
			Enteric fermentation emissions from a livestock category. EF (T): emission factors from some limited livestock populations, kg CH4/ (head *a); N (T): the number of heads of domestic livestock types or categories of T; T: Livestock types or categories.
Land use changes and forestry		Forestry carbon sequestration amount = Forest land patch areas* The quality of dry matter * Carbon content of dry matter	The quality of dry matter is 4.0 t/(hm2 * a), carbon emissions of dry matter in the IPCC's recommended value of 0.47.
Waste		Solid waste methane emissions coefficient = Emission factor * (1 - moisture content) * (1 - methane capture rate)	Solid waste emission factor uses the default value of 0.167 in the IPCC energy listing guidelines.
		Industrial wastewater methane emissions coefficient = Emission factor * Methane correction factor * (1 - methane capture rate)	Industrial wastewater emission factor uses the default value of 0.2 in the IPCC energy listing guidelines, the modifying factor value of CH4 is 0.1.
The carbon emissions of population		The carbon dioxide emissions of population = Population * exhaled carbon content per day	About the multiple data of carbon dioxide through breathing releasing per person per day, such as 0.9 kg, 1.14 kg, 1 kg, in general, the amount of carbon dioxide daily discharged by adults is about 1 kg.

Table 2. The main calculation methods of carbon clearance

3.2 Development approach of information systems

In this study, we have proposed that information flow is critical for regional low-carbon management. Thus, from the perspective of information flow, we have defined the flow diagram and logical model, and then developed different information systems as:

(1) Case repository: In this part, we establish the case repository on low-carbon management in China. According to the law, system, market and social aspects of the case, we collected the cases which report the actual situation in China. Within the repository, typical cases are classified, analyzed and compared with others, as per the selected standards (e.g., HACCP, and GAM, and GSP). We also developed the case retrieval engine for facilitating knowledge sharing and reuse.

(2) Regulatory system on air quality control: Regulatory system is closely related to information management. Data storage has gone through three phases: the operational phase (characteristic: the data record), the original phase (characteristics: micro-blogs, blogs, the smartphone), and the perception data phase (characteristics: sensors in every corner of society, as well as automatically generated data). With the development of data storage, business process reengineering comes to be necessary for the supervision. The study cannot get away from "big data" and contemporary trends.

(3) Greenhouse gas accounting system (GGAS): Greenhouse gas accounting system provides a series of free standards and tools to the enterprise, in order to assist the enterprise to calculate the volume of greenhouse gas emissions. For example, the greenhouse gas accounting system includes the enterprise accounting and report standard, namely "enterprise standard", the products accounting and report standard, namely "products standard", and the enterprise value chain (range three) accounting standard, namely "value chain standard".

4. Case Study: The Role of Big Data in Beijing's Low-carbon Management

4.1 Low-carbon city plan of Beijing

In 2011, Beijing started the low-carbon city plan. Low-carbon cities are proposed due to the increasingly serious subject of climate change, which threatens the resource, environment and a low-carbon economy in human society. Since 2003, after the low-carbon economy concept came out, the study of the connotation and development mode of a low-carbon economy and the practice have rapidly increased; at the same time, the concept of a low-carbon city has been proposed under the construction of a low-carbon economy in cities. The low-carbon city is relative to the low-carbon economy which has merged into the new city development mode of urban development. Generally, the low-carbon city plan covers all aspects of urban development and construction, but in our study we have mainly focused on the city's industrial development being guided in the direction of low-carbon, for example, the concept of consumption and lifestyle existing with low-carbon use, and the city planning and management based on the idea of a low-carbon city. The goal of a low-carbon city is to develop a low-carbon economy, increase energy efficiency and establish a more livable urban environment.

One of the major objectives of the low-carbon city plan is to reduce the city's carbon footprint, which is also known as the carbon fingerprints and carbon emissions. For imaging and accurately measuring the impact of greenhouse gases on the climate and human life, environmental groups and academics carrying out relevant research have proposed the metaphorical new phrase, "carbon footprint". It refers to individuals, families, groups (company) or products (devices) throughout their life cycle in the total amount of greenhouse gases released by that "consumption of carbon", which is used to measure the energy consumption. It is often expressed in number of tons produced for the purpose of the calculating standard. The "Footprints" metaphor indicates that every step and process of everyone's life has its own carbon footprint (greenhouse gas emission), which will be left in the environment increasing greenhouse gases in the atmosphere or traces of light or heavy pollution, or "people have left marks". "The "carbon footprint" includes a person's energy awareness and impacts on the natural environment, namely the personal energy consumption and pollution emission. The "carbon" refers to the carbon element contained in natural resources such as wood, oil, coal and natural gas. It is clear that the consumption of carbon is huge as well as the carbon footprint, leading to global warming and more greenhouse effects.

Carbon footprint marks a person or a group's "carbon consumption". "Carbon" is contained in oil, coal, timber and other natural resources. If the carbon consumption is large, which increases global warming and the manufacture of "carbon dioxide", the "carbon footprint" will be large, whereas the "carbon footprint" will be small. However, we are aware that there are many other greenhouse gases as well as CO_2. Greenhouse gases (GHG) include carbon dioxide (CO_2), methane (CH_4), Nitrous Oxide (N_2O), hydrogen fluoride carbide (HFCs), full fluoride carbide (PFCs), six fluoride of sulfur (SF_6), chlorine fluoride hydrocarbon class compounds (CFCs), hydrogen generation chlorine fluoride hydrocarbon class compounds (HCFCs), ozone (O_3), vapor (H_2O), etc., and re-launching radiation of some gases provided by the Kyoto Protocol. Numerous studies show that emissions from greenhouse gases such as CH_4 and NO_X are relatively small, which would have a negligible impact on climate change. Therefore, a more perfect definition should contain the total quantity of CO_2 extended for the total quantity of greenhouse gases. The carbon footprint is a product or a service system in its full life cycle within the total quantity of carbon emissions, or activity of subjects (including the personal and the organization) during a certain activity process in the total quantity of carbon emissions. The carbon dioxide equivalent is used as the representation.

Under normal circumstances, carbon emissions calculations are as follows:

The quantity of greenhouse gas emission = activity level data x emission factor

4.2 Relevant data about Beijing's energy production

On April 16 in 2014, Beijing Municipal Bureau (BMB) officially published the latest research results of the source analysis of PM2.5 in Beijing. It proposed countermeasures and suggestions including the determination of the direction of the haze-control, making the haze prevention and control of regulatory gravity moving forward, and containing the carbon emission in the product quality supervision system according to the annual PM2.5 sources of status in Beijing, the characteristics of modern networks and the "big data" era in order to achieve the prevention and control of Beijing-Tianjin-Hebei haze-tracking, and the integration of tracing and monitoring. In this study, we recognized some relevant activity data about energy production in the energy sector, from 2007-2012 (see Table 3).

Activity level data refers to the energy consumption of production or consumption activities, such as the number of tons of coal consumption of boiler combustion and the consumption of enterprises. Greenhouse gas emission factor indicates per unit of activity level (such as per ton of coal or per kilowatt-hour) corresponding to emissions of greenhouse gases, such as "tons of CO_2 emissions per ton of coal". The results may be biased compared to the actual situation. To avoid this bias, enterprises should set the emission factor according to the actual situation. In 2011, the book, "Greenhouse gas accounting system and the guidance on greenhouse gas emissions using energy consumption calculation tools" written by Song Ranping and Yang Shu published by the World Resources Institute, analyzed the concept of greenhouse gas accounting, emission factors, and tools in detail. In particular, the emission factors are given, which are based on the Intergovernmental Panel on Climate Change (the IPCC), or the default value of Europe and the United States, factors of the international standards and China's specific situation.

Table 3. Beijing relevant data about energy production in energy sector (2007-2012)

Item		2007	2008	2009	2010	2011	2012
Primary energy	(ten thousand tons of standard coal)	466.1	414.2	475.7	481.1	482.0	501.8
Raw coal	(ten thousand tons)	648.8	578.5	641.3	500.1	500.1	493.1
Secondary energy	(ten thousand tons of standard coal)	2895.2	3213.3	3346.7	3457.3	3209.1	3267.2
Gasoline	(ten thousand tons)	176.5	215.5	272.6	257.1	251.2	261.9
Kerosene	(ten thousand tons)	36.4	85.2	111.6	116.1	126.4	132.9
Diesel	(ten thousand tons)	268.2	373.3	364.2	350.4	355.7	319.1
Fuel oil	(ten thousand tons)	41.9	42.1	29.6	34.9	21.4	24.0
Liquefied petroleum gas	(ten thousand tons)	66.2	50.0	40.3	32.9	30.2	35.0
Heat	(10 billion coke)	12951.1	13846.2	14476.1	15710.9	15127.7	15632.4
Electricity	(million kilowatt hour)	224.4	244.9	242.0	263.3	257.3	284.7

Table 3: Beijing relevant data about energy production in the energy sector (2007-2012)

4.3 Applying big data and GIS in Beijing low-carbon management

By using the above data to improve the regional efficiency of low-carbon management, some colleagues had great achievements. Professor Jiao Zhiyong from the Law School of Capital University of Economics and Business conducted the research project on "Building effective haze-prevention and control system", and his report was adopted by the National Planning Office of Philosophy and Social Science in Beijing in September, 2014. The achievement indicates that, with the deepening control of air pollution, Beijing has made some progress in combating haze. For example, "the law needs to be obeyed, and lawbreakers need to be punished", which indicates that, although the legal atmosphere has formed, an effective haze-control system has not been established yet. Therefore, he proposed some countermeasures and suggestions from seven aspects: the coordinated treatment of haze, the legal treatment of haze, the science and technology treatment of haze, the group controlling haze, the kind treatment of haze, the regional treatment of haze and the exemplary treatment of haze. His result has also been included in the "Achievement Report", which is an internal briefing serving Beijing. Looking at the major problems in the construction of different areas in Beijing, it reflects on philosophy and social science research results, which has benefits for the decisions of the party and government, and has the outstanding, significant guidance for the economy and society.

Following Prof. Jiao's research project, we conducted several research projects on tracing regional carbon footprints by using big data techniques and GIS tools. For example, regional energy consumption was calculated and analyzed, as illustrated in Table 4. Figure 1 indicates the total energy consumption by region in China in 2012 using GIS tools. From this figure, we can learn about different areas of energy consumption in order to take more targeted measures for different areas. In addition, it also shows the trends of energy consumption in China.

Table4. Total energy consumption by region in China 2012

Unit：Ten thousand tons of standard coal (10 000 tce)

Region	
Beijing	7177.68194187688
Tianjin	8208.00831295803
Hebei	30250.2136775676
Shanxi	19335.5883666474
Inner Mongolia	19785.7078528035
Liaoning	23526.4047564996
Jilin	9443.03838707599
Heilongjiang	12757.800062191
Shanghai	11362.152392259
Jiangsu	28849.8414454837
Zhejiang	18076.1830989559
Anhui	11357.9480890531
Fujian	11185.4410552141
Jiangxi	7232.91990889604
Shandong	38899.2491220609
Henan	23647.1136977334
Hubei	17674.6591170068
Hunan	16744.082202927
Guangdong	29144.0130078866

Guangxi	9154.50464928442
Hainan	1687.98106837805
Chongqing	9278.40601049728
Sichuan	20574.9973686791
Guizhou	9878.37888294382
Yunnan	10433.6831950802
Shaanxi	10625.7099115429
Gansu	7007.04113252406
Qinghai	3524.06000467675
Ningxia	4562.38945718815
Xinjiang	11831.3864131409

Table 4. Total energy consumption by region in China in 2012

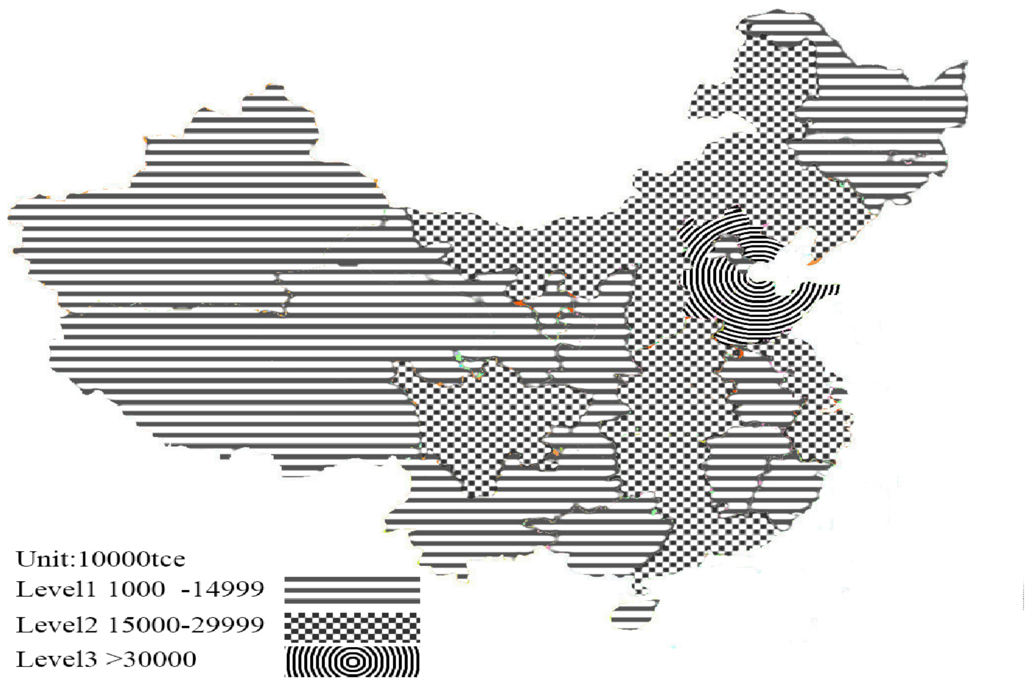

Figure 1. Total energy consumption by region in China 2012

Figure 1. Total energy consumption by region in China in 2012

5. Discussion and Implications

5.1 The role of GIS on Beijing's low-carbon management

From Figure 1, we can find that most high energy consumption is located in the eastern part of China. Hence, we recommend the government to consider moving some plants or factories which consume a lot of energy to western or northeast areas. Then the energy consumption of districts in level 3 would decrease.

We can also read from the figure that air pollution in China is severe, especially in the prosperous cities. So the primary missions for us now are regulation and control, instead of merely governance. The major regions which are badly in need of governance should be the ones in level 3, such as Beijing, Tianjin, Hebei and so on. The other heavily polluted regions generally surround the cities in level 3, which suggests that the policy should be regional. For instance, the map helps to choose the locations where afforested areas should be and it can also help to divide areas which leads to energy economy. Figure 1 also displays that the developed districts such as Beijing are the districts that consume more energy as well. From this perspective, the government can make a comprehensive analysis of the causes of more energy consumption. Based on this, developing provinces in China such as Anhui Province can try to set up some new strategy to consume less energy while ensuring the speed of development is maintained.

5.2 Implications for Policy

In recent years, the municipal government has achieved initial results in the fight against haze, but the problems of the existence of "heavy haze control, light carbon emission prevention and control in advance" also need to be solved. According to PM2.5 source apportionment results of Beijing, and the problems of how to build an effective haze-control system, how to implement the "The Beijing Air Pollution Control Ordinance" and how to effectively control the haze of Beijing, Tianjin and Hebei "regional transport contribution" in the age of "big data", we propose the following countermeasures and suggestions:

1. Reducing the resource consumption – main direction of controlling haze pollution

PM2.5 source apportionment in Beijing shows that motor vehicle emissions (31.1%), coal (22.4%), and industrial production (18.1%) occupy the top three places. IPCC provides the quantitative information on energy carbon emission. Therefore, based on the IPCC and international research results, there are some suggestions: 1) list of resources are formed from high to low; 2) studying and training international carbon footprint standards; 3) mining in numerous standard investigations of carbon and carbon footprint of typical cases and increasing awareness.

2. Carbon emissions leave a trace: Creating a transparent carbon management traceability and overseeing environment

We know that information is the foundation of quality monitoring, tracing and implementation. Information plays a vital role, embodying two aspects: firstly, along with the other stream, there is the information flow; secondly, the flow of information reflects the status of other stream and the other flow controls and regulates it. For this reason, the "regulatory information" is essential. It is suggested that the haze needs to be controlled before the focus is moved to "advance" to overcome the work of haze prevention and control in the "heavy haze control, mist and haze prevention and control" problems, making the carbon footprint labeling and product "peers" to form a carbon record trace of carbon management and supervision of the chain in order to create a transparent environment providing a basis for the carbon trade.

3. Perfecting the climate quality supervision system: including carbon management in the quality supervision system

The 18 of the decision of the third plenary session proposed "establishing a sound social credit system, praising integrity, disciplinary breach". The credit system for air quality is an important reference. Setting the concept as the starting point and using the international capability maturity model, carbon management can be divided into different levels: chaotic grade, standard grade, share grade, cooperation grade, measurement grade, prevention grade and so on. It is suggested that carbon emissions standards, as well as the product are also included in the law system of product quality by applying the "low-carbon certification management business cards" in order to raise the capacity of carbon management.

4. A cloud platform: contributing to the "emissions reduction" of the allocation of information resource

Using hardware resources such as computers, the network and communication equipment consumes a lot of electricity, producing a large amount of indirect emissions. It is suggested that using computer technologies such as resource-sharing and the cloud platform will enhance computer resource allocation efficiently. In particular, strengthening the research into cloud storage and cloud platform in the age of "big data" is an important path to target Beijing's information resource for carbon emission.

5. "Big data" carriers: achieving the integration of prevention and control of Beijing-Tianjin-Hebei haze

With the development of the data storage and the need of monitoring business process reengineering, the emission reduction cannot be considered away from "big data" and contemporary trends. It is suggested that, based on "big data" as an important carrier, the internet in Beijing, Tianjin and Hebei province and "big data" construction should be coordinated, building integrated regulatory processes, haze cover prevention and the whole process of regulatory systems in order to optimize the allocation of resources.

6. An important basis and reference for carbon emissions and combating the haze

The carbon emissions management, the management capability of carbon emissions and the management certification of carbon emissions are included in the low-carbon research. At the same time, these aspects could become an important support for low-carbon research: the basic data and process management, the integration of information and industry support, the "big data" and international quality certification standards support.

5.2 Implications for Theory

This research has some implications for theory and methodology. First, analysis of countries' experiences and lessons can help refine the analysis of patterns and trends of our regulatory regime. Second, big data is a new stage of information development, and detailed big data could influence and guide the design and implementation of the regulatory system. Third, the research has important theoretical research value for the multidimensional comparing approach and the quality management system, such as building system databases, case comparison database, query and develop software systems and filing software copyrights. Fourth, this research will help us to establish the co-governance mechanism of the main responsibility in the enterprise, the awareness of the public, and the lead formed by the government, as well as enabling the government to play an institutional role.

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