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Big/open data in Chinese urban studies and planning: A brief review

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Abstract: In line with the human-oriented focus and the need for new urbanization, big data has become a new paradigm in the field of urban planning and computer science. It brings great opportunities for research, planning practice, and business consulting. This article aims to provide an overview of urban big data studies from the institutional, academic, and practical perspectives, respectively. Particularly, it elaborates a number of research projects carried out by Beijing City Lab, a virtual research community dedicated to urban dynamics studies. Four major transformations of BCL urban studies have been highlighted in the paper.

Key words: big data, quantitative urban studies; Beijing City Lab; city planning

1 Background

As the place of the most rapid urbanization in the world, Chinese cities have accommodated more than 700 million people and are attracting another 30 million annually. Consequently, China's urbanization has attracted extensive attention from the academia, the government, the industry and the general public. In order to achieve a solid and unbiased understanding of China's urbanization, an accurate and comprehensive measurement is needed in the current situation. Meanwhile, urban big/open data has become a hotspot of Chinese urban research, which is thought to correspond well to the human-oriented "New Type Urbanization" in China. In the past, urban data were mainly produced and maintained by government departments, and were usually nonaccessible to the public as well as the academia, which presented huge obstacles for quantitative urban research. Now things have changed a lot due to both the government's awareness of the importance of open data, and the emergence of new data sources related the development of ICT. Big/open urban data have been identified as an important complement to conventional survey data and data collected by various administrative departments in understanding urban form and functions (Jia and Jiang, 2010; Goetz and Zipf, 2012; Crooks et al., 2014). Furthermore, the data infrastructure in developing countries is quite insufficient comparing with developed countries, in which situation big/open urban data are even more important as a viable and cost-efficient option for collecting urban data. Therefore, the application of big/open data is opening up important development opportunities for urban studies, planning practice and commercial consultancy in China.

Before further discussion, we would like to provide a definition of big/open urban data to be used this report. The types of data that could be categorized under this term should meet two criteria. First, they would characterize certain aspects of urban form

and functions (Crooks et al., 2014). Second, they are openly accessible to the public. In terms of data sources, there are generally three overlapping though different sources of such data. The first are official data portals, enabled by the recent open government initiatives that grant public access to previously non-accessible data sources. The second are big data initiatives, generating data from mobile phone activities, vehicle trajectories, public transit smart card data, business catalogues, as well as other smart city programs (Batty, 2012). Such data enables researchers to capture urban dynamics at very fine spatiotemporal scales and therefore gauge urban dynamics at finer spatial and temporal scales (Kitchin, 2014; Yue et al., 2014). The third source is Volunteer Geographic Information (VGI) and Crowdsourcing (Goodchild 2007; Crooks et al., 2014), which allows the general public to contribute to the urban data pool in a 'bottom-up' approach. Examples of such data type include collaborative VGI mapping platforms (e.g., OpenStreetMap) and geo-tagged social media applications (e.g., Foursquare, Twitter, and Flickr) (Liu et al., 2015).

However, despite of these positive changes, there are also several challenges of big/open data applications in urban studies and planning in China. First, most of existing urban studies are for one single city, which makes them not applicable to gain knowledge on the universal law of Chinese cities. Second, visualization has been highlighted for research using instant or short-term big/open data, and very few studies are for understanding cities using big/open data accumulated for a long time like two years. Third, some studies aggregate spatial units into grids and individuals into grids, thus leading loss of the essence of big/open data. Last, most of studies have not enjoyed the favor of crowd sourcing in designing and conducting academic studies as well as validating the results.

In response to the challenges mentioned earlier, we set up the Beijing City Lab (BCL; http://www.beijingcitylab.org), an online research network to produce and store data about Chinese cities. The Beijing City Lab (BCL) is a virtual research community, dedicated to studying, but not limited to, China's capital Beijing. The Lab focuses on employing interdisciplinary methods to quantify urban dynamics, generating new insights for urban planning and governance, and ultimately producing the science of cities required for sustainable urban development. The lab's current mix of planners, architects, geographers, economists, and policy analysts lends unique research strength. Through the endeavor of the core research team led by Dr. Ying Long, BCL has been developing fast and steadily and drawing vast attention from the urban planning community both in China and overseas. It has now become one of the major gateway for foreign colleagues to learn about the latest progress in urban research in China.

BCL lays much emphasis on urban modeling and quantitative urban research in multi-scales, for instance the mega-model paradigm. Moreover, the research conducted by BCL centers on the living quality of human settlement in the country's "New Type Urbanization", which aims to provide comprehensive measurement and monitor of China's urban development. Our research is expected to support related policy decision making. Furthermore, BCL also works on spreading messages on China's quantitative urban research in the international research community. Besides publishing Chinese scholars' works and data on international journals and platforms,

BCL also brings in the words of foreign scholars. For instance, an interview to Prof. Michael Batty, the director of Centre of Advanced Spatial Analysis (University College London), was conducted in the name of BCL in 2013 on the past and prospect of urban modelling, as well as another interview to Sir Peter Hall on China's New Type Urbanization.

Through the works of BCL we have identified four major transformations of urban studies in China under the above mentioned technological and institutional background, which are transformation in spatial scale, in temporal scale, in granularity, and in methodology. The transformations are further illustrated below.

2 Major transformations of urban studies in China

2.1 Transformation in spatial scale – The Mega-model

Existing Chinese urban and regional research can be generally categorized by the scale of study. The first type is in-depth research on a single city, for instance, the study on the poverty issue of Guangzhou City (Yuan et al., 2008) or the study of the distribution of public facilities in Beijing. The second type is analysis on the regional scale, which covers several provinces or the entire country and uses province or county as the basic unit of analysis. An example of this type of research is national macroeconomic study. Most existing research is not able to achieve both wide coverage and high spatial resolution. In other words, the wide coverage of the study area is usually achieved by sacrificing details, while in-depth studies usually cover a relatively much smaller area.

To resolve this problem, we have proposed the development of methodology capable of maintaining both a fine resolution and capable of conducting research at the national or regional scale (Long & Shen, 2014). The mega-model is an effective tool for quantitative research, driven by the availability of big/open data and implemented through straightforward modelling approach (Long et al., 2014b). The resulting capability presents a new paradigm of urban and regional study (Hunt et al, 2005; Wegener, 2004; He et al., 2012). The subjects of mega-modelling are usually urban systems containing several cities, but by using this modeling method we can examine both the development of individual cities as well as the networking among cities, to achieve comprehensiveness.

Here we present two applications of the mega-model methodology. The first is the MVP-CA (Mega-Vector-Parcels Cellular Automata) Model which has produced detailed estimates of urban growth of all Chinese cities at the parcel scale. The full Model simulates the growth of all 654 cities in China in the next five years under various developmental scenarios (Long et al., 2014a).

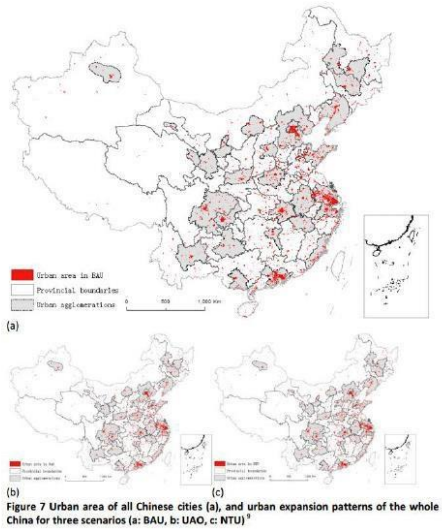

Figure 7 Urban area of all Chinese cities (a), and urban expansion patterns of the whole China for three scenarios (a: BAU, b: UAO, c: NTU)[9]

Table 3 The simulated results in the BAU scenario for typical cities

Zhengzhou	Beijing	Jinan
Nanjing	Hangzhou	Shanghai
Chengdu	Chongqing	Nanning

Fig 1 Urban growth simulation of all Chinese cities under various scenarios

The second application of MVP-CA generated land use maps for 297 cities using street maps and POI (Point of Interest) data. This project was undertaken because to the unavailability of open land use data in China and aims to provide free and open land use data for researchers. The layouts, land use functions, urban boundaries, densities, and degrees of land use mix are all identified as a result of the modeling. (Long & Liu, 2013; Long & Shen, 2014; Long & Liu, 2015).

In our methodology, OSM data are used to identify and delineate parcel geometries, while POIs are gathered to infer land use intensity, function, and mixing at the parcel-level. To be more specific, five steps are involved. First, parcel boundaries are delineated with OSM. Second, land use density is calculated as the ratio between the counts of POIs in/close to a parcel to the parcel area and then standardized to range from 0 to 1. Third, urban parcels are identified from all generated parcels with a vector-based constrained cellular automata (CA) model. Fourth, urban function for individual parcels is identified by examining dominant POI types within the parcels, which refers to the POI type accounting for more than 50% of all POIs within the parcel. The last step, the results are validated against both conventional manually collected parcel data and Ordnance Survey data.

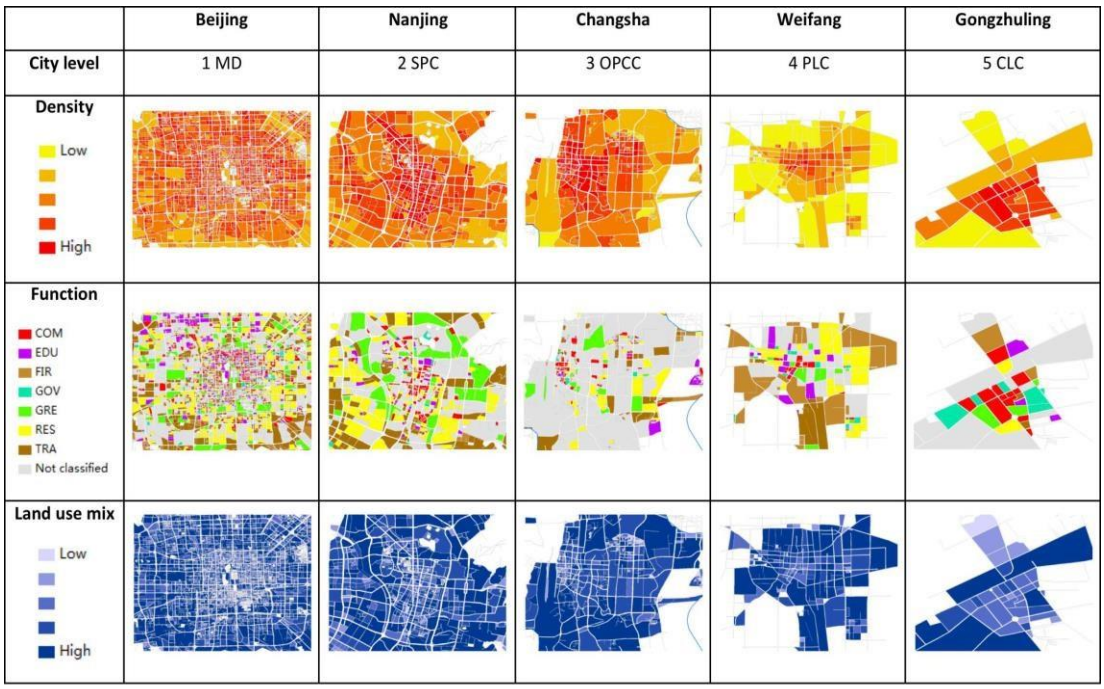

Fig 2 Derived land use map of 297 cities using MVP-CA

2.2 Transformation in temporal scale

Another breakthrough use is the dynamic analysis of urban development. The data sources of conventional urban study and planning are mainly governmental statistic annals and self-conducted surveys, which are cross-sectional data at a single time-point. Moreover, due to the limited sampling technique, the spatial coverage of data is also limited. On the contrary, the big data, such as bus/metro card records and taxi GPS traces, are able to reflect the dynamics of the urban system in minutes and seconds, which are obviously advantageous in consistency, wide coverage, and comprehensiveness. By combining these big data sets the limits of conventional urban study and research are solved (Long et al., 2012; Bagchi & White, 2004; Joh & Hwang, 2010; Jang, 2010; Roth et al., 2011; Zhou et al., 2007; Dong et al., 2009; Peng et al., 2007; Yang et al., 2009).

After being accumulated for a certain period, the big data are also able to reflect the long-term changes and trends of urban development and life style over time. For instance, Long (2012)'s research on a week's bus card record of Beijing residents involves more than 10 million card holders and more than 100 million records, with which the commute pattern and the urban structure of Beijing are identified. The research indicates that more than 95% of full-time jobs are longer than six hours a day and 99.5% people start their daily travel from their own homes. It also demonstrated that the influential area of the CBD is much larger than either the Shangdi technological cluster or the "Financial Street". A further comparison of the records in 2008 and 2014 shows that the total bus trips are reducing and being replaced by the metro rail trips. Moreover, we identify lower income people from related socio-economic surveys and find that they usually spend more time on bus and

transfer more; 80% of these people move their homes within the six years and 87% change jobs, which means that they live quite an unstable life. It therefore reminds us to give more consideration towards this group of people in “urban village” regeneration, public housing design, and urban design.

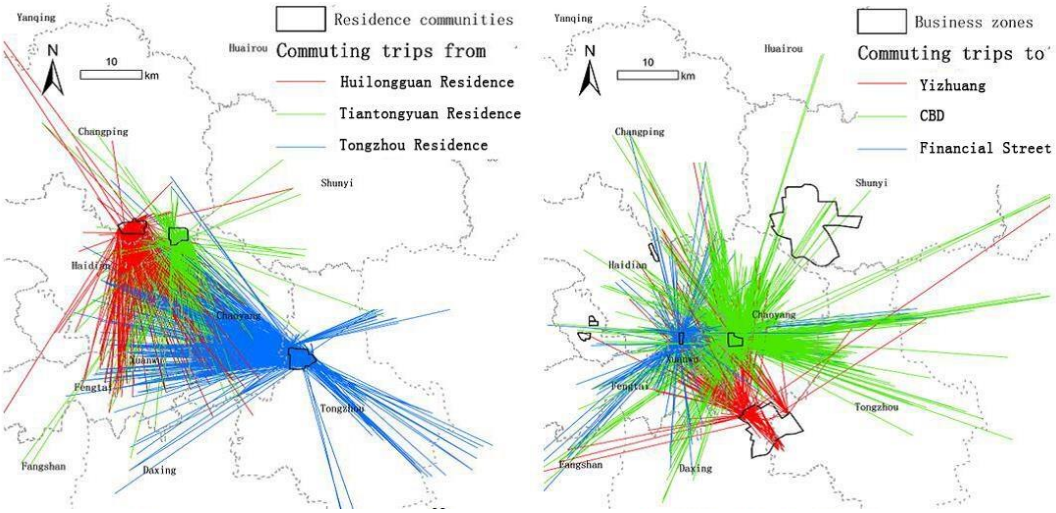

Fig 3 Commute pattern in typical areas

2.3 Transformation in granularity

The new type of urbanization is defined to be human-oriented urbanization, which lays much emphasis on the human scale and the granularity of research. On the contrary, lots of conventional urban planning and policy making was “building-oriented”, which led to various social, economic and environmental problems caused by extensive development. In response to the situation, many Chinese cities have put forward plans of smart growth and replaced the large expansion projects with small-scale urban regeneration and redevelopment projects. In such circumstance, planning techniques that function at large spatial scale are less useful, which gives rise to the need to develop planning information at finer scales.

An example of research with higher granularity is our research on the dynamics of nationwide population density at the town/sub-district scale. According to the research, one third of the country’s land is sparsely populated, due to the aggregation towards big cities and city centers. Besides the well-known phenomenon of decaying village (Liu et al., 2009), we also find a trend of decaying taking place in 180 cities of all 654 Chinese cities. The finding is informative for planning practice in China, which was always based on the expectation of population growth. With the recognition of the decaying trend, the goal of planning in those 180 cities should no longer be land expansion, but the enhancement of residents’ living quality. Another related issue is the so-called “ghost city” caused by over-construction in lots of Chinese cities in the past decade, which can be identified through evaluating the intensity of activity using Baidu map (Chinese version of Google map) and Weibo (Chinese twitter) data. The housing vacancy rate can be thus calculated for all cities with big data, from which the influencing factors and certain rules of urban development can be derived as reference for policy making.

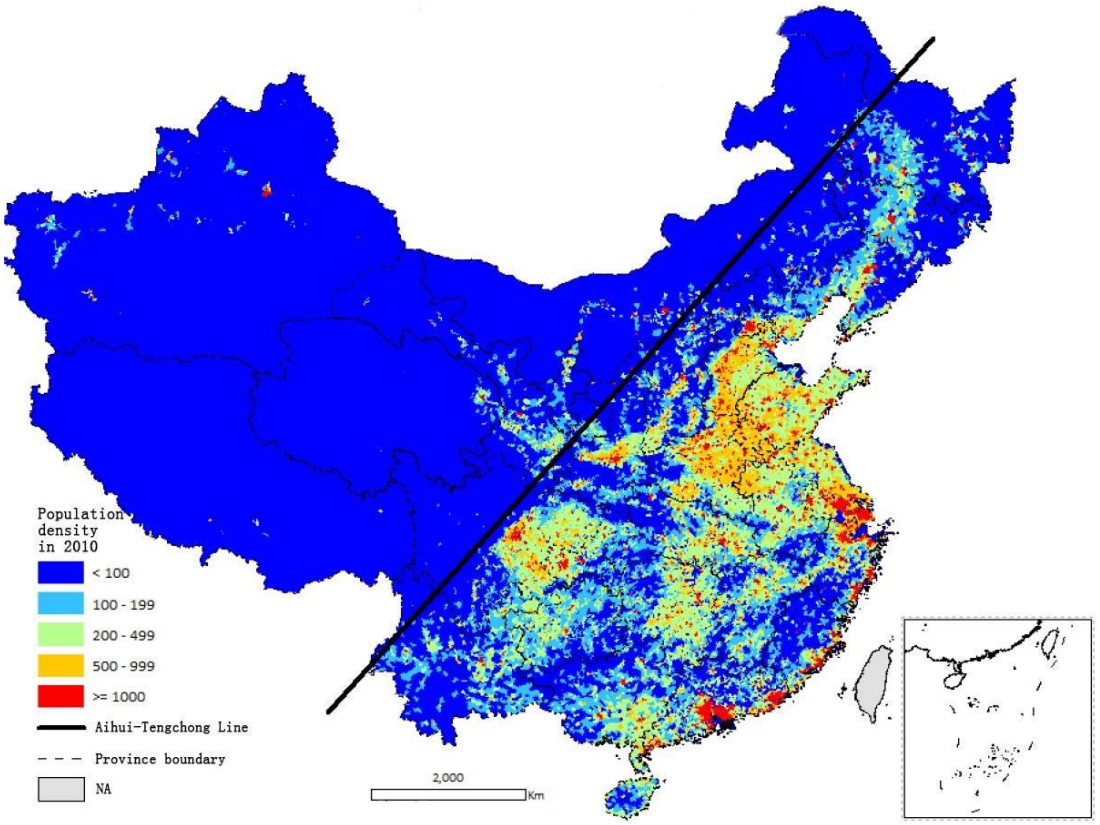

Fig 4 Distribution of population density at sub-district level in 2010

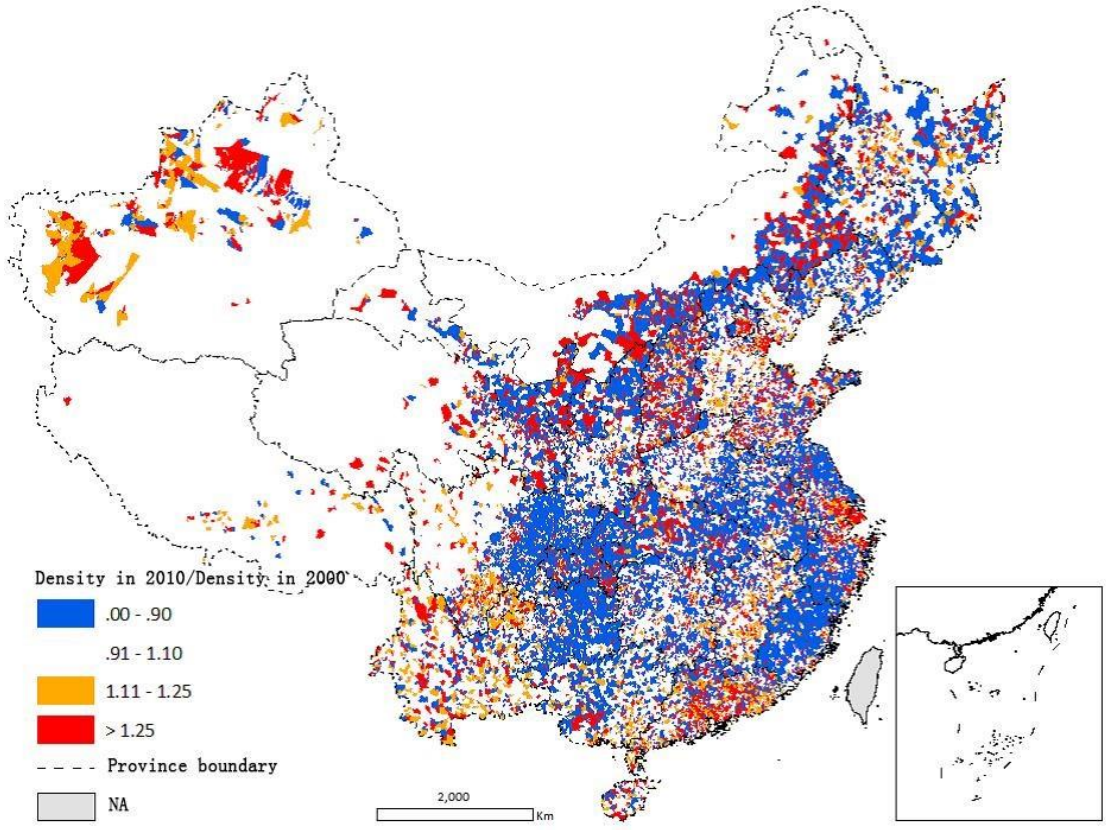

Fig 5 Population density ratio between 2000 and 2010

Another study on the implementation of land use plan shows that 50% of all developments in Beijing are informal or illegal, with no planning permission; while, on the other hand, 95% of people's activity and mobility is still within the planning boundary. It indicates that the planning control is quite effective in the social sense, despite of ineffectiveness in the physical sense.

Fig 6 Ratio of shrinking of Chinese cities between 2000 and 2010

The third example is a nationwide sub-district-scale analysis on the exposure to PM2.5 pollution. We find that Xingtai City in Hebei Province is the most exposed city to PM2.5, and Beijing, Wuhan, and Chengdu suffer similar numbers of overexposure days.

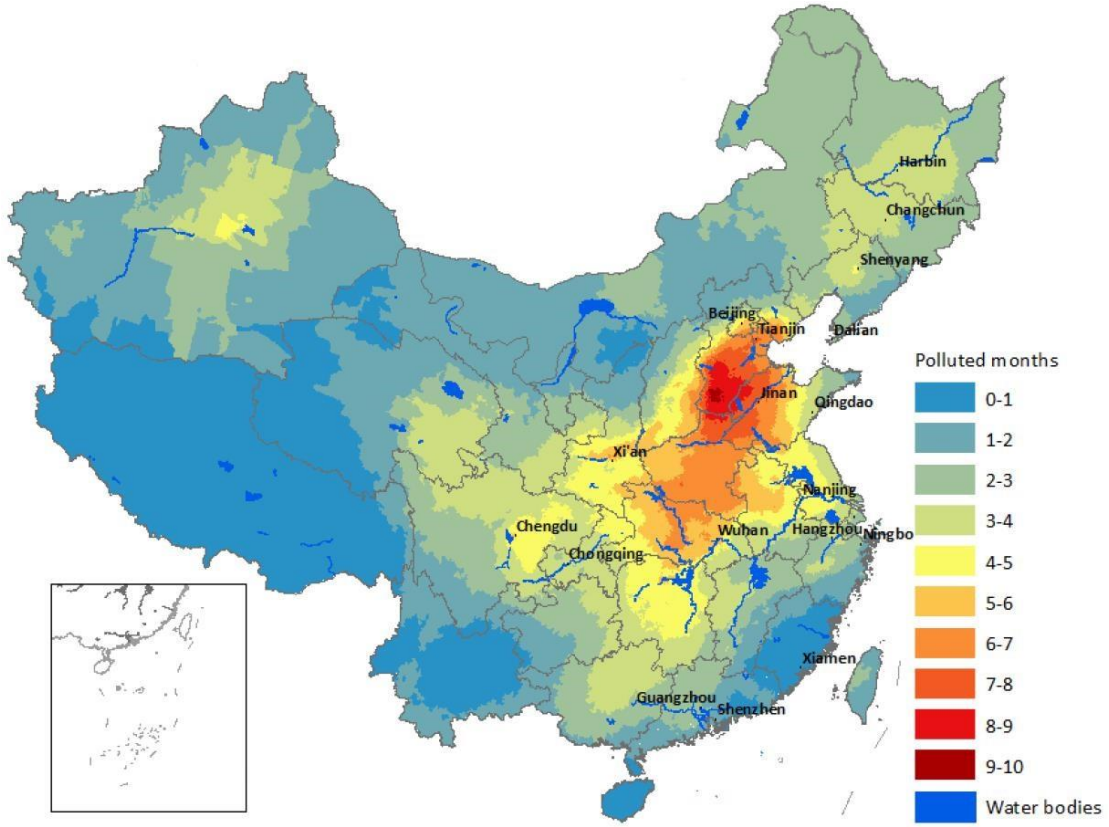

Fig 7 Urban environment at fine spatial scales: The number of polluted months in a year for each Chinese sub-district violating national PM2.5 standard.

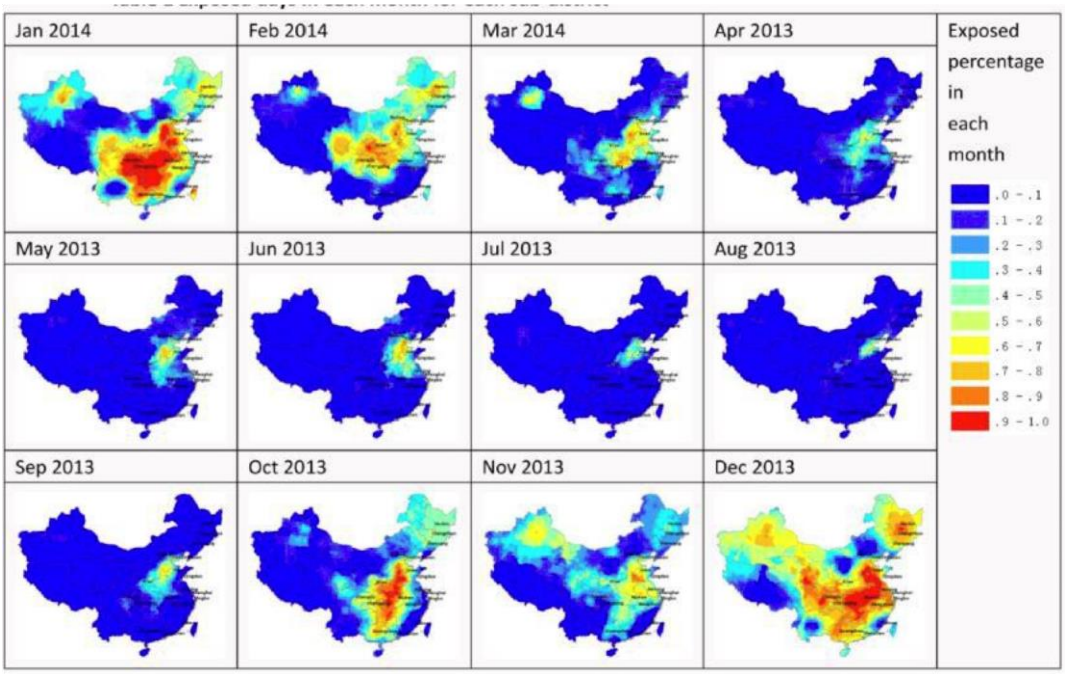

Fig 8 Exposed days in each month for each sub-district

2.4 Transformation in methodology

Similar to the trend of crowdsourcing in data collection (VGI), there is also a trend of crowdsourcing in terms of urban research. For instance, it is almost impossible for a single research group to conduct detailed socio-economic and spatial transformation changes field work in all 180 shrinking Chinese cities in shrinking cities. Therefore, we propose the use of crowdsourcing as a new research paradigm. BCL has proposed several crowd-sourcing projects including the field survey in shrinking cities and counties, and the verification of the urban growth simulation by MVP-CA.

3 Concluding remarks and discussion

In this short report, we present several major changes and challenges in assembling big/open urban datasets for Chinese cities, and showcase our attempt at applying big/open urban data to understanding China's urbanization. The new data environment has been drawing more and more attention from both researchers and planners, since it enables detailed observation on individuals' activities in the urban space. These detailed data could be applied to provide helpful information for the decisions on heated topics such as urban regeneration, shrinking city, public participation, etc., as well as provide new developing opportunities for urban study, planning and design, construction, and commercial consultancy, which correspond to the human-oriented development strategy to the central government's New Type Urbanization policy.

Several Chinese urban research and planning institutes have started to conduct quantitative urban research, including the works by Beijing City Lab. Recognizing that the new data are able to cover large geographic area in fine resolution, we proposed the mega-model, a new regional and urban research paradigm. Meanwhile, we have also identified four transformations in quantitative urban research, namely transformation in spatial scale, in temporal scale, in granularity, and in methodology, which are all centered on the improving people's quality of life. However, there are also several issues that we need to pay attention to.

3.1 Dealing with data bias

This issue has been repeatedly discussed since the emergence of new data. For instance, the studies on urban residents' happiness using geotagged Weibo are suffering from data bias on several aspects, including the duplicity of Weibo senders, the limitations of natural language processing technology, the representativeness of Weibo senders, and the black box of Weibo API, all of which bring doubts to the reliability of such studies. There are a few strategies to tackle this problem. The first strategy is to make use of the data bias. For instance, recognizing that low-income people are more likely to travel by bus frequently, we studied the travel behavior and the change of residence and work locations of low-income people from 2008 to 2010 with smart card data (SCD). The second strategy is to study the behavior of special groups, such as our study on the travel behavior of university students and four extreme social-economic groups in Beijing. The third strategy is to combine these data with other data on studying the same issue to improve the stability of research results.

In another research, we combined SCD, travel survey data, social website check-in data, and taxi GPS data in evaluating the planning implementation of Beijing, which indicates that more than 95% people conduct their daily life within the planning boundary. The last strategy is to use more than one dataset to complement each other, thus depicting the whole urban system.

3.2 Short term data visualization vs Long term data exploration

Most data used in current research are collected in less than one week instead of years. Moreover, some research is merely data visualization. Comparing with the new data, conventional data, such as yearbook data, can reflect the transformation of the urban system over the years. However, the situation would change a lot with the accumulation of new data, which could lead to quite different research results. For example, the one-day record of credit card can be applied to identify the patterns of consumption, while one-month's record can help identify the influence of festivals and years' records can further manifest the impacts of technological progress on consumption, which will change the current situation of lack of long term research and theoretical breakthrough. Such a research trajectory is reflected in our research with SCD from 2008 to 2014.

3.3 Current situation analysis vs Future planning support

Up to now, there is more existing research aiming at analyzing the current situation of urban systems than evaluating their future development, which needs to be changed. In order to provide effective guidance to urban planning and design with the new data and research methods, we have proposed a new methodology named Data Augmented Design/DAD.

DAD is a planning and design method based on quantitative urban analysis, which provides whole-process tools for field survey, information processing, design, and short-term and long-term evaluation. DAD aims at enhancing the scientific base of design, as well as evoking the creativity of planners and designers. To be more specific, DAD is not betrayal from art and design, but a new design method that emphasizes the inspiration power of quantitative analysis. We expect DAD to reduce the working load of designers and thus let them focus on creation instead of repetitive work, and at the same time improve the measurability of design. Moreover, DAD is simple and straightforward, which makes it convenient to be generalized but also sensitive to the specialty of each project.

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