Smart city with Chinese characteristics against the background of big data: Idea, action and risk

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ABSTRACT

Chinese urbanization has generated great impacts on the world since the reform and opening up. However, urban problems, e.g., environmental pollution, resources shortage, and traffic jam, have been more and more serious for urban management and development. Smart city has been put forward as an effective approach to achieve better urban management recently. Smart city aims to realize the integration of municipal service, business, transportation, water, energy source and other urban sub-systems through close combination of human wisdom and information communication techniques (ICTs). As a result, the link and synergy of information could be ultimately established with ICTs, e.g., internet, internet of things, cloud computing. Yet, few studies have been conducted to systematically link smart city with big data in China. This paper aims to put forward a development framework of smart city with Chinese characteristics against the background of big data. Key actions, including rational planning of city infrastructures, the establishment and improvement of long-acting mechanism, the effective performance of city managerial function, are proposed to realize the development idea. Meanwhile, this paper also investigates the risks embedded in development of smart city with Chinese characteristics, e.g., information safety, weak emergency responding capacity and poor independent research and development capacity of core technology. This study can facilitate Chinese local governments to systematically plan smart city before clinging the hot concept in a rush.

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1. The introduction of smart city

Urbanization is the only access to modernization, and has become a general trend of social and economic development around the world. Over the past 60 years, the global urbanization rate has risen 21%, more than 50% of the world population lives in urban area today. Meanwhile, the ratio is predicted to be close to 60% by 2030 (United Nations, 2015). China has witnessed a rapid urbanization since the reform and opening up policy (Shen et al., 2012; Wu et al., 2012; Wu et al., 2016). As shown in Fig. 1, by 2015, Chinese urbanized population has reached 0.77 billion, accounting for 56.1% of the total population of China (National Bureau of Statistics of PRC, 2015). The number of urbanized population is almost 4.47 times as much as that in 1978. Due to the mutual promotion between urbanization and economic development, urbanization has become one of the powerful engines and important driving forces for the healthy and sustainable development of Chinese economy.

Similar with what western countries has experienced, China has been challenged by various urban problems during the rapid urbanization. These problems may include irrational transformation of rural land to urban land, large number of land-lost farmers as a underprivileged group, rural-urban conflicts, environmental pollution, traffic jam and frequent public safety incidents (e.g. Yu et al., 2014; Yu et al., 2015; Peng, 2015; Peng et al., 2015; Bao and Peng, 2016). Meanwhile, urbanization results in a considerable economic disparity between urban and rural areas in developing countries, which has had a consequent significant impact on CO_2 emissions (Wu et al., 2016; Wu, 2016; Hong et al., 2016). In other words, a higher urbanization rate, energy carbon emission coefficient and energy intensity will lead to increased carbon emissions. Therefore, innovation and improvement on cleaner production are

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The increase of Chinese urban population from 1978 to 2015
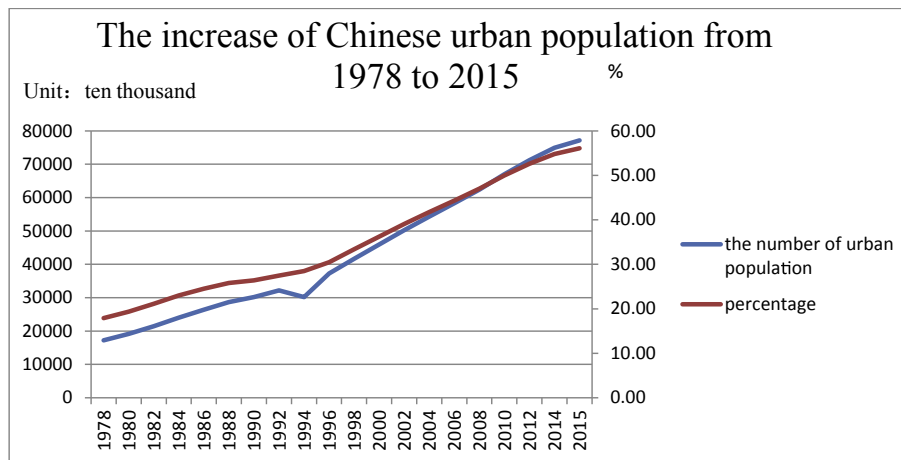
Unit：ten thousand   %

Fig. 1. The increase of citizens in China.

of much importance when facing the increasingly intensified environmental problems in urban areas. Smart city is proposed as a new way that can efficiently integrate various resources based on the collection, store and analyze of big data, by which the optimization of resources distribution can be realized, and the CO_2 emissions can be efficiently reduced. More examples and cases can be found in Section 3. Besides, the difficulty of obtaining and processing large amount of information and transferring such information to better decision-making on urban development and management has also worsen these problems.

The advanced information techniques are changing the world and bring possibilities to solve such urban problems. Internet has exerted a far-reaching and continuous impact on economic and social development since its emergence in the 1960s. In recent years, mobile communication and internet has been organically combined, due to the positive user experience, innovative marketing mode and competitive techniques, the number of mobile internet users first time outnumbered that of PC internet users in 2012 (Luo et al., 2011). Nowadays, shopping on TaoBao (a famous on-line shopping platform in China), taking taxi by Fast Taxi (an app like Uber), enjoying various group-buying or reserving train ticket from 12306 (the official website of Chinese Railway ticket service) are more and more popular and integrated in the daily life in China. In addition, after computer, internet and mobile communication, as another achievement of industrial revolution, internet of things makes various things connected, integrating the physical space and informational space (Sun et al., 2010), prompting the digitalization, informationization and gridding of all things. The burgeoning internet of things, systemized by technologies of computing and service, internet and communication, perception and identification, management and support, endows things with intelligence (Wang, 2009). With the integration of such advanced information techniques and the spatial monitoring tools, e.g. GPS, GIS and RS, it is possible to concert and record the spatiality of human behaviors as big data, by which provides a new thought for the future urban planning and management.

Big data is a fantasy concept around the world. Although it lacks a consensus on the definition of big data, volume, variety, and velocity, or the three 'Vs', which emphasize large amount of data, many formats of recording data, and the high speed of generating data, are usually used to characterize big data (McAfee et al., 2012; Lu et al., 2015). The continuous development of internet, internet of things, and big data analytics makes it possible to build smart city. In fact, smart city is an idea born with intimate relationship with data. In 1980s, with the popularization of LAN and the anticipation of the coming of WAN and internet, people became zealous in equipping city with network technique, and this thought was clearly expressed in *Wired Cities*, a book that was edited and published by Dutton et al. (1987). Before the publication of *Wired Cities*, much concern about the huge challenge that cities would confront from network technique in the future had been put forward in Martin's book, *The Wired Society* (1977) (Martin, 1977). No matter what names are, wired city or wired society, both of them could be seemed as the original conception of smart city. By the middle of 1990s, people found that library, welfare service and many other daily services provided by government could be realized by WAN. Since then, the technique of information and communication has been also applied in fields of emergency service, ambulance, fire control and waste treatment, etc (Batty, 2012). IBM formally stated the concept of smart city. In November 2008, Mr. Samuel J. Palmisano, the former CEO of IBM, firstly stated the conception of Smart city and mentioned the word, "Smart city" during his speech on the forum of business leadership of IBM (Palmisano, 2008), which was held in Istanbul, Turkey. In July 2009, the global business services of IBM held a press conference, during which smart city was formally stated in a research report named t*he Vision of a Smart City*. This research report defined smart city as a city that could maximize the payment with limit input of resources by the use of techniques to improve urban services, civilian, business, transportation, communication, water, sources and other urban core systems (Dirks and Keeling, 2009).

Led by IBM, Cisco and other suppliers of network technique, the wave of building smart city has swept the globe (Woods and Goldstein, 2014), in which China is no exception. National New Urbanization Planning (2014–2020) (The Xinhua News Agency, 2014) explicitly requests to promote the development of smart city, and unify the material resource, informational resource and intellectual resource for urban development. The internet of things, cloud computing, big data and other new information and communication techniques (ICTs) are suggested to be innovatively integrated for the social and economic development of cities. National New Urbanization Planning (2014–2020) also points out the direction of Chinese smart city, including broadband access of network, informationized planning and management, smart infrastructures, convenient provision of public service, modernized industrial development and elaborate social governance. Since entering the era of big data, how to build smart cities with Chinese characteristics attracts much attention from governments at all

levels, network suppliers and civilians. Big data could be either an unprecedented opportunity or a severe challenge for the development of smart city. However, few studies have been conducted to investigate how to develop smart city with Chinese characteristics against the background of big data. This study aims to propose such development framework with specifying the key actions and potential risks. The remaining parts of this paper are arranged as follows: Ideas for developing smart city with Chinese characteristics against the background of big data will be presented in the second part. The third and fourth sections will present the key actions and risks respectively. Section 5 concludes this study with specifying the future studies.

2. Ideas for developing Smart city against the background of big data

One of the most remarkable characteristics of smart city is the integration of techniques and strategic policies. The preset goals, such as sustainable development, enhancing civilian's welfare, and economic growth can be achieved through such integration. In the past decades, investment is one the most important drivers to the development of Chinese economy. There was a 4 trillion investment plan launched by the central government of China in 2008 in order to deal with international financial crisis. As a result, the social fixed investments increased by 30.1% in 2009, which led to the rapid development of infrastructure, affordable housing, and high-end manufacturing (Wen, 2010). Driven by the investment-oriented economic growth, the ICTs are developing rapidly and entering the era of big data. Armed with big data, either the internal or the external operation mechanism of city can be dramatically changed to develop smart city. The following sub-sections would present the ideas of how to develop smart city with Chinese characteristics against the background of big data.

Human beings, as one of the smartest beings in this world, are constituted by delicate organs and a variety of complicated systems. Through cooperation among the system of human body, it can offer timely perception of information and appropriate responding to the perceived information. As a result, the needs of human bodies can get satisfied efficiently. Correspondingly, the smart city is proposed to act like human bodies, which can be illustrated from two aspects, a perceptive city and the system of systems.

2.1. A perceptive city

A real smart city is a city which can be understood and managed, in other words, a city with perception (Kitchin, 2014). Smart city can be realized only by the extensive application of ICTs in the urban management system. As shown in Fig. 2, the perceptive layer of smart city management system is analogous to the limbs and sense organs of human, which is responsible for information collection. Internet, internet of things and mobile communication network technologies constitute the supporting system which is just like the nervous system of human. Combined with spatial techniques of GIS, GPS and RS, the supporting system can replace the traditional data with spatial data, ultimately, realizing the transfer and store of information. Although the information techniques, such as internet, internet of things, and mobile communication network, play an important role in collecting, transmitting, and storing big data, the data could not directly tell the truth behind. The development of smart city is of more dependence on mining the useful information embedded in the collected big data. Therefore, big data analytics or data mining is necessary to facilitate decision-making on urban governance, e.g. identifying the locations needing police resources through mining information from a

suite of cameras and live incident logs (Kitchin, 2014). As Fig. 2 indicated, the platform layer can analyze the real-time perceived data with the help from cloud computing and data center. The platform can provide more efficient, accurate and scientific analysis than the traditional approach, so the platform layer is analogous to the brain of human. Finally, city administrators can make decisions at the behavior layer, by which the foundation of smart detection and management for city can be established.

2.2. A system of systems

City works on the basis of a series of core systems with various functions, including systems of service, civilian, business, transportation, communication, water, and energy. The relationships among these core systems are illustrated in Fig. 3. The city service system is the operation system, which comprised of municipalities and various services that are coordinated by the municipality. Civilian system concerns public safety, health and education, which determines whether civilians can have high-quality of life. Business system refers to the environment of policy and regulation of commercial activities. Civilian system and business system are the customer system, and the rest four systems make up the urban infrastructure system.

All systems mentioned in smart city should be instrumented, interconnected and intelligent so that these systems could be integrated as a system of systems (Dirks and Keeling, 2009). It is worth noting that isolated operation of any core system is inefficient, only when all systems are integrated as a whole, could the operational efficiency be dramatically enhanced, and the city, as a result, could be smarter.

3. Key actions for developing smart city with Chinese characteristics against the background of big data

3.1. Rational planning of infrastructure

Created by the close combination of human wisdom and ICTs, smart city possesses various characteristics including high intelligence, interconnected integration, exchange and sharing, and associated application (Xu, 2012). The core of smart city is the high integration of informationization and urbanization. In other words, the utilization of internet, internet of things and cloud computing provides opportunities for the establishment of close link between human behaviors and its relationship with space, and for the realization of mass data calculation. Through such link, the problems existing in the process of urbanization can be resolved and an innovative idea of city planning would be brought in.

Western countries are the foregoers and have obtained a series of achievements. For example, in 2009, cooperated with IBM, the government of Dubuque, a city in Iowa of United States of America (USA), started to build a USA-leading smart city. The local government installed numerical control meters for every residential and commercial house to collect the consumption data of electricity and water. With these meters the real-time monitoring on the consumption of electricity and water can be realized. Thereby, the consumption characteristics of each district can be understand, which is helpful to the improvement of urban management and allocation of infrastructure (IBM, 2015). The government of Los Angeles invested a lot on the transportation management system. In 2013, Los Angeles was the first city in the world that realized the synchronous working of 4500 traffic lights, which means 12% driving time could be saved when you drive on the main roads in Los Angeles (DuBravac, 2014). Stockholm of Sweden installed various sensors in urban roads, including radio frequency identification, laser scanning, and automatic photographing. These sensors
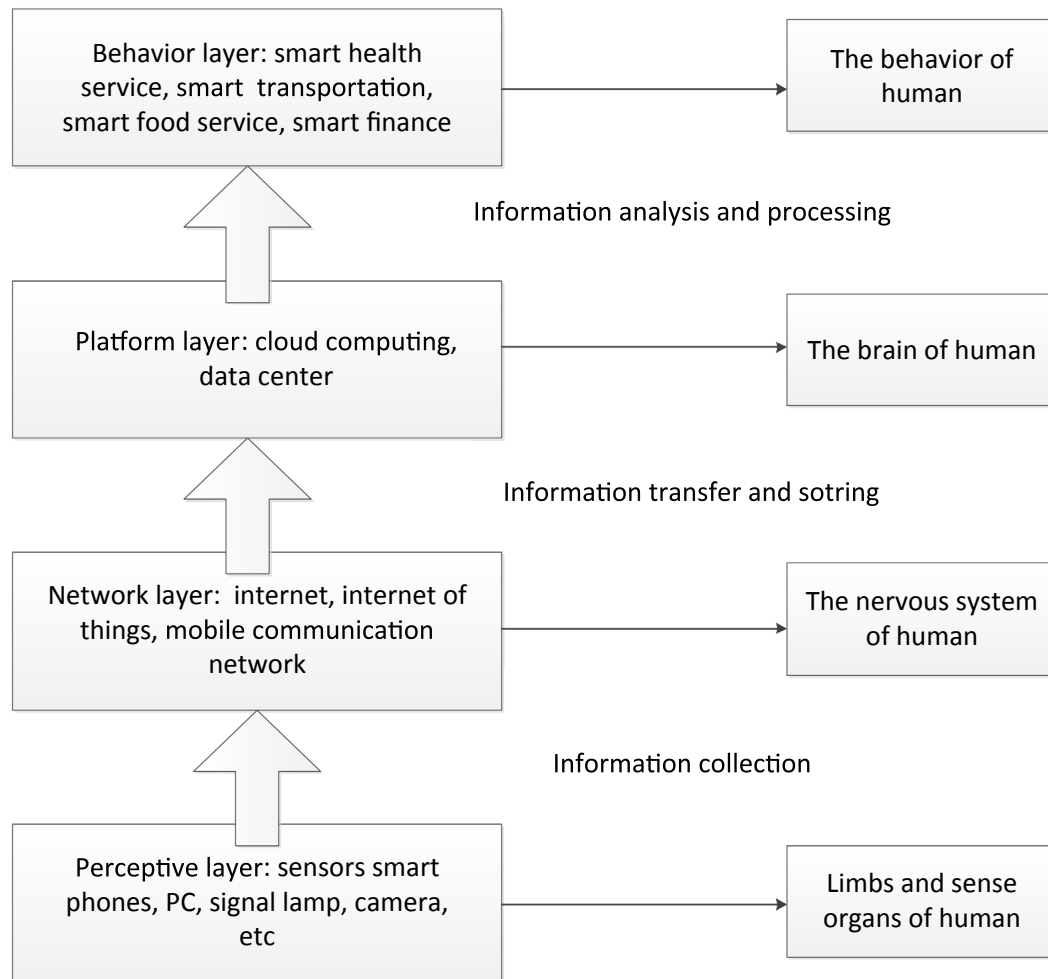
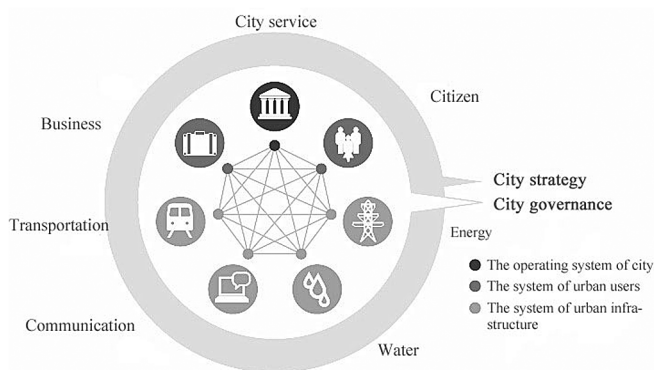**Fig. 2.** The urban management system of smart city.

Fig. 3. Relationship among each core system of city. (Source: Dirks and Keeling, 2009).

can monitor the inflow and outflow of cars in downtown area at rush hours. Based on such information, special tax can be imposed on these cars in order to alleviate traffic jam and reduce emission of greenhouse gas (Letaifa, 2015). Copenhagen, known as the city of bicycle, analyzed the transportation of each district to establish a rational planned transportation network based on the spatial big data. Such approach ensured every citizen would be served by rail transit in the circumference of 1 km from residences (DeMaio, 2009). In addition, many other countries have obtained great achievements in respect of developing smart city, such as South Korea, Japan and Singapore (Neirotti et al., 2014).

It is evident that smart cities built by developed countries provide better social service for civilians, or contributed a lot for the energy saving and emission reduction of greenhouse gas, or promote the diversified development of city. However, the priority of developing a smart city for China is whether the smart city can help to balance the supply and demand of infrastructure. To take a simple example, the passenger flow of different lines, regions and periods can be estimated by analyzing the swiping times of bus IC card. Then, these estimated passenger flow can be analyzed with spatial information by using GIS technique. Finally, bus stations and lines would be planned according to the passenger flow and the traveling preference of residents. In addition, the crowded places, like living areas and transportation hubs, would be equipped with more relevant infrastructure. The example shows that by using terminal sensors, the spatial big data of people's daily behaviors can be captured. Based on these captured data and the utilization of internet of things, cloud computing, GIS and other new ICTs, the urban transportation, education, medicine, water & electricity, and other infrastructure can be better provided.

3.2. The establishment and improvement of long-term mechanism

Smart city just sprang up in recent years, but the essence of which, informationization of urban management has had a long

history. Many cities in China have tried to develop smart cities, as *Insight on 2014 ICT* showed (Telecommunication Research Institute of the Ministry of Industry and Information Technology (2014)) that 100% of sub-provincial cities and above, 89% (241 cities) of prefecture-level cities and above, 47% (51 cities) of county-level cities and above were putting forward the development of smart cities. It is evident that smart city has been an irresistible trend of the future urban development. However, for developing smart city in line with local conditions and coordinated development, the establishment and improvement of a long-term mechanism would be a key point.

The system of smart city is comprised of organization, procedure, management, ethic and many other aspects. The mechanism of smart city system can connect various urban affairs with a certain operational pattern and make them work cooperatively (Zhang, 2013). Specifically speaking, there are three mechanisms for smart city. The first is the information management mechanism. The information mechanism requires government to establish a unified and normative system. There are many participants and various data involved in the development of smart city. The stakeholders include government, enterprises, non-profit organizations, individuals and so forth. The data includes government affairs, business and many others. Therefore, a scientific and rational information management system, which is normative and open, is necessary for the development of smart city. The second is the incentive, restraint and feedback mechanisms, which would ensure the well-organized and normative development of smart city. Different with traditional urban management, innovative managerial patterns should be encouraged, such as adopting incentive mechanism for integrating the power of government and enterprises, and encouraging social capital to participate in the construction and operation of smart city. Meanwhile, the development of smart city needs to be real-time monitored, the restraint and feedback mechanisms would play an important role in early-warning and policy adjustment. The third is the guarantee mechanism. It is important to improve the citizens' recognition and understanding about smart city in order to get their supports on development of smart city. In addition, the sustainable development of smart city should be continuously strengthened by a healthy and comprehensive organizational system and advanced techniques.

Due to the healthy and comprehensive mechanism, Government, as the main participant involved in the development of smart city, can strictly control and supervise the top-level design. Instead of indiscriminately using other countries' successful experience for reference, the development of each city should be based on a strategic planning and its local condition. The integration of national economic and social overall development planning, development priority zoning and other relevant special planning should be emphasized during development of smart city. Driven by mechanism, platform and technology and oriented by service, the new pattern of public affairs management and urban development management could be ultimately established.

3.3. The effective implementation of city managerial function

The three most prominent characteristics of smart city include intelligence, interconnection and synergism. The seamless connection of information between things and things, or human and things could be realized in smart city. When dealing with the information mentioned above, it is necessary for us to take human as the priority, that is, highlight the idea of people-orientation. Aristotle said that people gathering in city for living, for living a happy life, they gathered. People suffered various problems caused by rapid urbanization. The high techniques have been chosen to

solve such urban problems, so high tech needs to be closely fit for the demand of people. Therefore, the practice of urban management must base on the demand of citizens, and provide a good social environment for realizing better human life.

In order to effectively implement managerial function of smart city, the highest priority is the innovation and reform of traditional management approach. Cities will compete to develop smart city without considering their local conditions, which will wastes human, material and financial resources. Instead of taking the development of smart city just as an access to promote officials' performance, the development of smart city should be oriented by improving citizens' life, and the citizen should be the core of city planning and development. The service structure of smart city is comprised of basic service, administrative service and intellectual service (Shi, 2011). With these services, combined with the real-time function of big data, the real-time urban management can be realized. For example, based on navigation, location and other traditional functions, combined with the real-time monitoring of transportation flow, the electronic MAP (Gao De Map in China) can characterize the traffic situation of main road on mobile terminals. Therefore, drivers can choose a better route according to the real-time traffic situation so that the driving time can be saved, and the traffic jam can be alleviated. The public bicycle program, led by Hangzhou, has achieved partial preset objectives. However it is still embarrassed by a situation that in some regions all bicycles are borrowed out, yet in some other regions, the situation is quite the contrary. Big data is helpful for administrators to understand the imbalance allocation of public resources and to adjust the number of bicycles in different regions. In addition, by establishing online one-stop municipal service system, and using electronic medical record to connect patients' information with departments of hospitals, citizens' daily life would be more convenient and the urban management would be more efficient.

The development of smart city would bring huge "developmental dividend" to cities, and form a "blue sea" which is appealing to enterprises. First of all, the managerial efficiency of city itself can be improved. Meanwhile, if we can take the strategy of developing smart city as the basis to realize the optimization of industries and to create a new urban growth pole, it would be another driving force for the urbanization.

In conclusion, the key actions for developing smart city in China based on big data can be summarized from three aspects, rational planning of infrastructure, establishment and improvement of
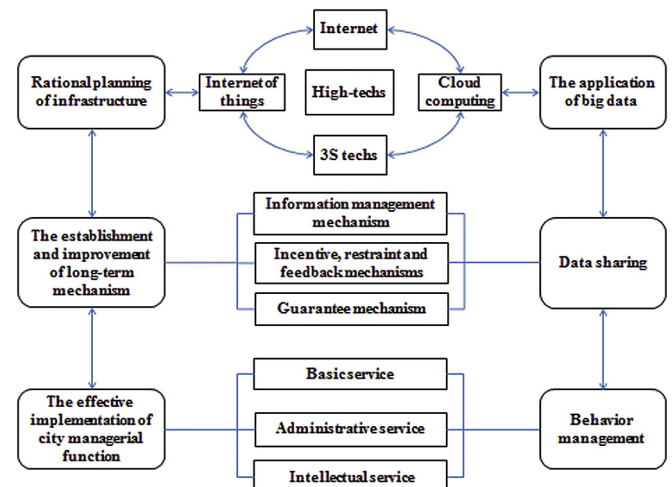

Fig. 4. The basic operational framework of each action.

long-term mechanism, and effective implementation of city managerial function. Fig. 4 is an illustration of the operational framework of each action. The logic behind the organization of mentioned actions is to satisfy the demands of citizens as much as possible. Smart city has been recognized as a potential solution to the problems emerging in urbanization, so smart city needs to be closely fit for the demand of citizens instead of as an access to promote officials' performance. However, the urbanization rate of China has exceeded 50%, it is hard to satisfy individual citizens with various demands at present. Hence, priority should be put on the rational planning of infrastructure in order to meet the public demand recently. As the practical condition of China and aims of smart city are confirmed, a set of long-term mechanisms should be taken into consideration subsequently, by which the development of smart city can be healthy, orderly and conform to the China's characteristics. The city managerial function can further be effectively implemented by satisfying the demands of citizens with improved infrastructure and convenient public services embedded in smart city.

4. The risks of building smart city with Chinese characteristics on the background of big data

Currently, many countries and cities are vigorously trying to develop smart cities, and have obtained great achievements in fields of smart commercial environment, smart health-care, smart transportation, smart communication, smart energy and others. In addition, all of these achievements have not only contributed to the informatization and intellectualization of urban management, but also spurred new industries and commercial activities. However, there are still some potential problems existing in the development of smart city.

4.1. The risk of information safety

Developing smart cities by using internet, internet of things, mobile communication network and other advanced techniques need to constantly improve the mechanism of information collection and exchange & sharing. During such process the first risk is information safety (Martínez-Ballesté et al., 2013). From the perspective of personal privacy, large amount of information related to citizens' preference for transportation, consumption, health-care, finance are obtained by terminal sensors through constantly scanning, picturing, locating and tracing. Such personal commercial and municipal data is important for development of smart city. Without reasonable restriction, it is difficult to guarantee personal privacy and thus personal information safety is endangered. As a result, when cooperation happed between enterprises and enterprises, governments and enterprises, or even governments and foreign organizations, the protection of confidential data would be of great importance.

Meanwhile, smart city establishes a public management and service platform which bears multiple participants, and realizes the multi-level inter-connection and resource sharing between human and human, human and things, as well as things and things. The leak of information from any joint would possibly be utilized by hackers to invade systems and stole confidential data by programming malicious code. This information leak will lead to the collapse of the whole system and much more serious consequences.

4.2. The risk of incapability of dealing with emergency

Similar with an ecosystem that has many subsystems, the subsystems of city are inter-connectedly and interdependently integrated. The original attention of developing smart city is to provide a decision-making basis for urban management through the connection and cooperation of each urban subsystem by using advanced technologies. Smart city is helpful to the early-warning of natural disasters. The early warning accuracy of natural disasters can be improved through the analysis of historical data and the supervision on real-time data. However, it is worth noting that smart city has a strong dependence on network communication, when disasters happened, systems collapsed, and relevant information obstructed, the cooperation of urban ecosystem would be seriously damaged, which will lead to social chaos.

Therefore, facing with natural disasters, accident disasters (traffic accident, mining accident, etc), public heath accidents (infectious disease, chemicals leaking, etc), and social security accidents (terrorists attack, group crime, etc), smart city is supposed to improve the capability of dealing with emergency. Contingency plan should be established in advance for better operation of the emergency system.

4.3. The risk of lack of independent research and development on core technologies

Rapid advancement of ICTs endows urbanization with infinite possibility. But due to the lack of core technologies of information system, database management, and operation solutions, China is still dependent on the support from foreign countries when building smart cities. This kind of dependence restricts the development of smart city in China, and creates much uncertainties and potential risks concerned with the leak of confidential information. For instance, in 2011, the information stored in Google's cloud server but belonged to European Information Center was handed over to US intelligence agency by Google, which seriously threatened the information safety of Europe (Whittaker, 2011). Likewise, digital city, as an important part of smart city, provides services for urban management through the sharing of spatial information obtained by the use of spatial technology (e.g. GIS, GPS, and RS), but such technologies are still dominated by western countries. In other words, once western countries shut down the GPS location system, many data would become unavailable immediately.

Consequently, the promotion of independent innovation has been the key point for comprehensive national strength. While fully using global scientific and technological resources, it is important to strengthen the integrated and independent innovation which focuses on breakthrough products and new industries (Xu, 2005). The development of smart city still needs to be supported by good policy environment for nurturing independent innovation, enhancing capability of research and development concerned with big data, cloud computing and other core technologies. In addition, the establishment of researching and innovative system with Chinese characteristics is also important during the development process.

5. Conclusion

The competition among cities ultimately aims to attract more migrates, business and tourists, which means cities have to constantly provide high-quality life and vigorous economic atmosphere. Although faced with challenges like limited budget, scarce resources and problems left over from history, government still has a chance to change challenges into opportunities by the use of new technologies. The more smart individuals are, the more they are attractive, so are cities. Against the background of big data, being smarter by rational use of technologies has been an effective approach for cities to win competitions.

With the rapid development of urbanization, problems such as

inefficient use of land, traffic jam, and environmental pollution have been gradually emerged. Supported by internet, internet of things and mobile communication network, smart city can efficiently integrate and analyze the key information of each urban subsystem by using big data, cloud computing and other measures. Smart city is an innovation for resolving problems resulted from urbanization, which has obtained great achievements in smart power grid, smart transportation, smart energy and other fields. This paper analyzes the origin of smart city and conceives the development of smart city with Chinese characteristics against the background of big data. Meanwhile, key actions for developing smart city have also been provided including the rational planning of infrastructure, the establishment of long-term mechanism as well as the effective implementation of urban management function. Finally, this paper presents potential risks existing in the development of smart city. Measures to cope such risks have also been suggested including the strengthening of information supervision, the improvement of emergency management, and the enhancement of independent research and development. This study can facilitate Chinese local governments to better understand smart city and systematically plan smart city before clinging the hot concept in a rush.

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