Research on Evaluation Index System of Smart City based on Four Helix Theory

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Abstract: The development of smart cities is conducive to the promotion of urban economic development, optimization of industrial structure, and is also an important driving force for China's urbanization development. Therefore, it is particularly important to establish a reasonable and effective smart city evaluation system. This research is based on the concept of innovation 2.0, with urban users as the center and openness and collaboration as the basic modes, and constructs a smart city evaluation index system based on the four-helix theory, including four first-class indexes of smart infrastructure, smart governance, smart economy and smart people's livelihood, 10 second-class indexes of perceived network construction level, broadband network construction level and database construction level, and 33 third-class indexes of smart grid coverage rate, sensor number and 3S equipment coverage rate, so as to provide decision-making basis for the sustainable development of Chinese cities.

1. Introduction

With the rapid development of the new generation of information technology and its innovative application in the economic and social fields, the intelligent city proposed by IBM has become the focus of international attention in the 21st century. Promoting the construction of intelligent city has become a new goal of urban development. Developing smart cities is conducive to promoting urban economic development and optimizing industrial structure, and is also an important driving force for the development of urbanization in China. Therefore, it is particularly important to establish a reasonable and effective evaluation system of smart cities. Research institutions at home and abroad have carried out a lot of research on the evaluation system of smart cities. The Intelligent Cities Forum (ICF), founded by the World Telecommunications Association of the United States, proposes to build an economic system with broadband construction as the main body to enhance urban competitiveness. The evaluation indicators include broadband connectivity, knowledge workforce, innovation, digital inclusion, marketing promotion and annual theme [1]. The European Union Intelligent City Evaluation System is proposed by the Evaluation Center of the Regional Science Center of the University of Vienna in Austria, the University of Lubina in Slovenia and the Architectural and Urban Mobile Research Institute of the University of Teft Technology in the Netherlands. The index system includes the Intelligent Economy, the Intelligent Public, the Intelligent Governance, the Intelligent Action Force, the Intelligent Environment and the Intelligent Life. The Ministry of Industry and Information Technology China Software Evaluation Center, the Ministry of Housing and Construction and Shanghai Pudong Institute of Intelligent Cities have proposed 13 kinds of intelligent city evaluation systems [2]. Domestic scholars mainly focus on infrastructure, government management, economic development and public services in smart city evaluation model [3-9]. Intelligent city is a new generation of information and communication technology as the support, oriented to knowledge society Innovation 2.0 urban form [10]. However, the evaluation model constructed by the above literature has not been based on the theory of innovation 2.0. Therefore, this study is based on the concept of innovation 2.0, centered on urban users, and based on the basic model of openness and collaboration, to construct an evaluation index

system of smart cities based on the four-helix theory[11-13], with a view to providing decision-making basis for sustainable urban development in China.

2. Four Helix Theory of Smart City

2.1 Composition and Function of Quadruple Helix

From the current practice of the construction of smart cities around the world, the joint participation of government, industry, universities, scientific research institutions and the public constitutes the main body of the implementation of the construction of smart cities. Although the main body of implementation of smart city construction in different countries is basically the same, the roles they play in the process of construction are different. The key difference lies in the relationship between government and other organizations. The common implementation modes are government-led four-helix development mode, enterprise-led four-helix development mode, technological innovation experimental four-helix development mode and mixed four-helix development mode [14].

The four-spiral development model of smart city is composed of government, industry, universities, scientific research institutions and the public. The government-led four-spiral development model is the inevitable choice of the implementation model of smart city construction. Although the government, industry, universities, scientific research institutions and the public are the main bodies of the implementation of smart city construction, their respective fields of activities are different, and their roles in the implementation of construction are also differentiated (Table 1).

Table 1. The Four Helix Composition and Function of Smart Cities

Subject Composition	Effect
Urban Government and Its Functional Departments	As the leading force in the construction and implementation of smart cities, there are seven aspects of this leading force: ①The organizer of the construction and implementation process; ②Representatives of the ownership of state-owned assets; ③Major Investors in Construction and Implementation； ④The decision maker of construction project implementation; ⑤The coordinator of each implementation subject; ⑥The main supervisor of the construction and implementation process; ⑦One of the executors of project implementation.
Industry (IT industry, investment and financing industry, infrastructure industry, etc.)	As the executive force of smart city construction and implementation, enterprises are the main executors of construction projects and the main investors of construction and implementation.
Institutions of higher learning and scientific research	As a supplementary force for the construction and implementation of smart cities, universities and scientific research institutions can participate in the construction process by providing technical advice and scheme design, and give full play to their advantages and characteristics to contribute to the construction of smart cities.
public	The public is an indispensable supporter of the implementation of smart city construction. At the same time, the public is also a decision-making participant, a supervisor participant and an executive participant in the implementation of smart city construction.

2.2 Construction of Four Helix Model

The government, industry, universities, scientific research institutions and the public constitute the main body of the implementation of the four spirals of the smart city. They complement each other, each has its own functions and functions, and form a complete system of the four spirals of the development of the smart city. In the practice of smart city construction, there will be some deviations from their roles, such as the absence, offside and inadequacy of individual implementation subjects, which will affect the implementation effect of smart city construction. Due to the deviation of the implementation subject from its own role, it will stimulate the contradictions among the various subjects, lead to the functional imbalance of the implementation subject system, and cause the construction of smart cities not to meet expectations. Therefore, in order to ensure the smooth implementation of smart city construction, it is necessary to establish an effective coordination mechanism among the implementation subjects in order to build a four-spiral development model of smart city construction [14].

In order to improve the degree of tightness and orderliness of cooperation among the main bodies, it is necessary to establish effective coordination mechanism for the implementation of smart city construction, that is to say, to improve the degree of coordination among the main bodies. The main synergy mechanism of this model includes four aspects: open choice mechanism, interest coordination mechanism, institutional normative mechanism and information communication mechanism (Table 2).

3. Intelligent City Evaluation Index System

Innovation 2.0 is the core concept of the development of China's smart city. Based on the concept of innovation 2.0, smart city is the convergence of mass city management and service innovation with urban users as the center and openness and collaboration as the basic mode. Therefore, the construction of evaluation index system of smart city should follow the following principles: 1. Emphasizing people-oriented urban development, emphasizing user innovation and deepening it. Public demand analysis is the forerunner of smart city development; 2. Emphasizing on creating good environment and resource allocation, emphasizing innovative environment and system, cultivating market and guiding the direction of smart city construction is the foundation of smart city development; 3. Emphasizing multi-subject participation in urban development, emphasizing collaborative innovation, and making public-private partnership development in the new technological environment the key of smart city development.

According to the above principles, this study builds the evaluation index system of smart city based on the four-helix theory. According to the four-helix theory, the main body of a smart city includes the public (users), the government, enterprises and universities (or scientific research institutions). In the process of smart city development, it is a process of cooperation or game among the four main bodies (Fig. 1). According to Figure 1, there are 4 independent innovation activities and 11 collaborative innovation activities in four categories (Table 3). (1) Four kinds of independent innovation activities of the government, industry, universities, scientific research institutions and the public; (2) six kinds of collaborative innovation activities of the government-industry, government-university and research institutions, government-public, industry-university and research institutions, industry-public, universities and research institutions-public; (3) Government-Industry-University and scientific research institutions, government-industry-public, government-university-university Collaborative innovation activities with scientific research institutions - the public, industry - universities and scientific research institutions - the public; and (4) collaborative innovation activities with government - Industry - universities and scientific research institutions - the public. Therefore, the evaluation index system of smart city includes four first-level indicators (Table 4), namely, smart infrastructure, smart governance, smart economy and smart people's livelihood.

Table 2. Synergy mechanism of four-helix model in smart cities

Type of mechanism	Content
Open Choice Mechanism	The main body of the implementation of smart city construction should be highly open and selective, both of which activate the competitiveness between the main bodies and bring vitality to the implementation of smart city construction. A high degree of openness facilitates the selection of subjects in the process of coordination and cooperation to achieve the best matching. A reasonable open mechanism provides a favorable environment for the optimization of the selection among subjects.
Interest coordination mechanism	The coordination mechanism between the main bodies must be based on the principle of mutual benefit, construct a good interactive interest adjustment mechanism among the main bodies, balance and coordinate the interests of all parties, and form a benign interactive pattern of all stakeholders' co-construction, sharing and multi-win.
Institutional normative mechanism	In the implementation of smart city construction, the key to the orderly operation of cooperative mode is to increase the supply of institutional resources and improve the game rules among different stakeholders. In order to realize the division of labor and cooperation among the subjects, we should comprehensively analyze the nature and function of each subject, scientifically locate the functions and functions of each subject, and determine the behavior and relationship through the system. There are three aspects to coordinate the main body of safeguard implementation through the system: the coordination of policies and laws, the coordination of planning and planning, and the coordination of contracts.
Information communication mechanism	Ensuring the smooth communication of "synergetic information" among the main bodies is one of the keys to realize the efficient synergy of the main bodies in the implementation of smart city construction. The construction of information communication mechanism can promote extensive exchanges among various subjects, enhance trust, form consensus, reduce transaction costs and realize information sharing. At the same time, the process of communication is also the process of learning. The subject's learning behavior creates its adaptability. Improving the subject's learning ability in communication is an effective means to enhance its adaptability to complex systems. Establishing interactive, dynamic and concurrent information communication mechanism is an important way to improve the synergy of the main body in the implementation of smart city construction.

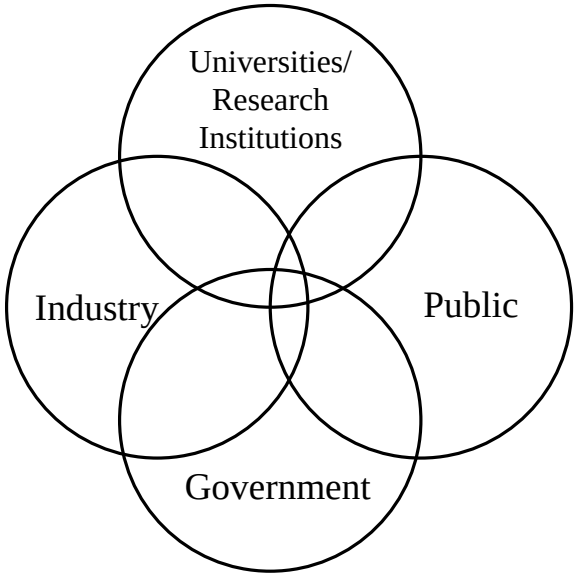

Fig. 1 Four Helix Model of Intelligent City Construction Subject

Table 3. Intelligent City Evaluation Indicators and Collaborative Innovation Types

Index	Collaborative Innovation Types
Intelligent Infrastructure	Government, Government-Industry, Government-Universities and Scientific Research Institutions, Government-Industry-Universities and Scientific Research Institutions, Government-Industry-Universities and Scientific Research Institutions-Public
Intelligent Governance	Government, Government-Industry, Government-Universities and Scientific Research Institutions, Government-Public, Government-Industry-Universities and Scientific Research Institutions, Government-Industry-Public, Government-Industry-Universities and Scientific Research Institutions-Public
Intelligent Economy	Industry, Government-Industry, Government-Industry-Universities and Scientific Research Institutions
Smart people's livelihood	Government, Government-Public, Government-Universities and Research Institutions, Government-Universities and Research Institutions-Public

3.1 Intelligent Infrastructure

The infrastructure of smart city is a collaborative innovation of five types: government, government-industry, government-university and scientific research institution, Government-Industry-University and scientific research institution, Government-Industry-University and scientific research institution-public. According to the development of smart city, various network information facilities such as transportation, sanitation, gardens, pipeline network, environment and disaster prevention are built in the city. Including the level of perception network construction, broadband network construction and database construction. Among them, the construction level of perception network reflects the construction level of modern information technology perception network environment, based on real-time optimization of communication network configuration, improve work efficiency and innovate management procedures. Perception network construction level indicators include smart grid coverage, sensor number, 3S (RS, GIS, GPS) equipment coverage. Broadband network construction level indicators include optical access coverage, wireless network coverage and wireless WLAN coverage. The index of database construction level includes the sharing degree of database information, the coverage rate of basic database and the number of database per capita.

Table 4. Evaluation Index System of Smart Cities

First-level indicators	Secondary indicators	Three-level indicators
Intelligent Infrastructure	Perception Network Construction Level	Smart grid coverage
		Number of sensors
		Coverage Rate of 3S (RS, GIS, GPS) Equipment
	Broadband Network Construction Level	Optical Fiber Access Coverage
		Wireless network coverage
		Wireless WLAN coverage
	Level of database construction	Sharing and Sharing Degree of Database Information
		Basic database coverage
		Number of databases per capita
Intelligent Governance	Online Office	Website Construction Rate of Government Departments
		Download Rate of Government Information Online
		Government Online Purchasing Ratio
		Network Rate of Administrative Examination and Approval
	social management	Digital Urban Management System Coverage Rate
		Construction Rate of Enterprise Supervision System
		Construction rate of social emergency management system
		Construction Rate of Socio-economic Detection System
Intelligent Economy	Urban Economic Development Level	Per capita GDP
		Per capita disposable income of urban residents
	intelligence Industry Development Level	The Gross Output Value of High-tech Industries as a Proportion of GDP
		Contribution Rate of High-tech Industry
		The proportion of investment in Informatization Transformation of traditional industries to GDP
Smart people's livelihood	Wisdom Community	Coverage Rate of Safety Monitoring in Residential Areas
		Coverage Rate of Community Information Service System
	Wisdom Life	Convenience of medical treatment
		Satisfaction degree of convenience of network information acquisition
		Satisfaction with Transportation Convenience
		Satisfaction with Convenience of Public Sector Services
	Intelligent environment	Wastewater treatment rate
		Greening rate of built-up area
		Excellent rate of air quality
		Proportion of automatic monitoring of environmental quality
		Proportion of Key Pollution Sources Monitoring

3.2 Intelligent Governance

Intelligent governance is a collaborative innovation of seven types: government, government-industry, government-university and scientific research institution, government-public,

Government-Industry-University and scientific research institution, government-industry-public, Government-Industry-University and scientific research institution-public. It uses modern information technology to strengthen the reform of the internal system of government, optimize administrative procedures and improve the governance model, to improve the government's management. Efficiency and Intelligent Management Level [15]. Intelligent governance includes two kinds of indicators: online office and social management. Online office includes government department website construction rate, government information online download rate, government online procurement rate and administrative approval network rate and other indicators. Social management includes the coverage rate of digital urban management system, the construction rate of enterprise supervision system, the construction rate of social emergency management system and the construction rate of social economic detection system.

3.3 Intelligent Economy

A complete and true form of knowledge economy should have two important characteristics, that is, innovative knowledge dominates knowledge and creative industry becomes the leading industry. The national innovation system and the national entrepreneurship system together constitute the main form of the smart economy. Together, they make the innovation drive from the growth mode to the economic form. Intelligent economy promotes urban economic development through three types of collaborative innovation: industry, government-industry, Government-Industry-University and scientific research institutions. Therefore, the indicators of intelligent economy include two indicators: the level of urban economic development and the level of intelligent industry development. Among them, the level of urban economic development includes per capita GDP, per capita disposable income of urban residents and other indicators. The development level of intelligent industry includes the proportion of total output value of high-tech industry to GDP, the contribution rate of high-tech industry and the proportion of investment in traditional industry informatization transformation to GDP.

3.4 Intelligent People's Livelihood

The construction of intelligent people's livelihood is a systematic project utilizing a variety of modern high and new technologies. Through four types of collaborative innovation, namely, government, government-public, government-university and scientific research institute-public, government-university and scientific research institute-public, the construction of intelligent people's livelihood can realize the happiness and well-being of residents' lives by using modern intelligent technology. Smart people's livelihood includes three aspects: smart community, smart life and smart environment. Among them, the intelligent community is an innovative mode of social management in the new era, relying on the Internet of Things, cloud computing and other data technology, building intelligent management systems such as home, monitoring, nursing and lifestyle. Including the coverage rate of security monitoring in residential areas, coverage rate of community information service system and other indicators. Intelligent life refers to the public service departments which are closely related to people's lives, such as medical treatment, transportation and so on, using modern intelligent technology to realize the convenience and intelligence of people's lives. Including the degree of medical convenience, the satisfaction of accessibility to network information, the satisfaction of transportation convenience and the satisfaction of convenience of public services and other indicators. Intelligent environment includes wastewater treatment rate, greening rate of built-up area, excellent rate of air quality, automatic monitoring proportion of environmental quality and monitoring proportion of key pollution sources.

4. Conclusions

In the era of big data, smart city, as a new type of urban management, is an effective management mode to deal with and solve a series of social problems arising from the rapid development of urbanization. The construction and implementation of smart cities need not only strong information

technology support and perfect network infrastructure, but also wise and scientific decision-making by city managers. Only by combining hard and soft can the quality of public life brought about by the development of smart cities be further improved and the development of cities be continued. At present, the research on the evaluation of "smart city" in this paper is limited to the qualitative research stage, and needs to carry out quantitative research on evaluation model and empirical evaluation in the future.

References

[1] Yan Jianghui, Liu Jinping. Building a framework of intelligent city evaluation system based on self-organizing system [J]. Macroeconomic Research, 2018, 1:121-128.

[2] Gong Bingzheng. Discussion on the Evaluation Index and Method of Smart City [J]. Journal of Office Automation, 2015, (1).

[3] Deng Xianfeng. [J] Research on the Evaluation Index System of "Smart City". Development Research, 2010, (12).

[4] Chen Ming, Wang Qianchen, Zhang Xiaohai and other "Smart City" evaluation index system research - Take "Smart Nanjing" construction as an example [J]. Urban Development Research, 2011, (5).

[5] Li Xianyi, Deng Xiaoyu. Research on the evaluation index system of Smart City [J]. Telecommunication Network Technology, 2011, (10).

[6] Zhang Zhenggang, Zhang Xiaojuan. Five-Dimensional Model Study of Smart City [J]. China Science and Technology Forum, 2014, 11:41-46.

[7] Cui Lu, Yang Kairui. Establishment of evaluation index system for smart city [J]. Statistics and decision-making, 2018, 6:33-38.

[8] Zou Kai, Bao Minglin. Evaluation of the development potential of smart cities based on grey relational theory and BP neural network [J]. Scientific and technological progress and countermeasures, 2015, 32 (17): 123-128.

[9] Liu Xiaoyin, Zheng Shurong. Evaluation of the Development Potential of China's Smart Cities Based on Principal Component Method - According to the Data of 11 Eastern Cities [J]. Research on Science and Technology Management, 2013 (22): 75-79.

[10] Song Gang, Hulun. Intelligent City from the Perspective of Innovation 2.0 [J]. Urban Development Research, 2012, 19 (9): 53-60.

[11] Huang Yao, Wang Ming. Triple Helix" to "Four Helix": Evolution of Dynamic Mechanism of Knowledge Production Model [J]. Research on Educational Development, 2018, 1:69-75.

[12] Wu Weihong, Chen Gaoxiang, Zhang Aimei. An Empirical Study on the Four Helix of Collaborative Innovation of Government-Industry-University-Research Funds from the Perspective of Mutual Information [J]. Scientific and Technological Progress and Countermeasures, 2018, 35 (6): 21-28.

[13] Wu Qi, Shen Zhongqin. Research on the Construction of Innovation Platform for Technology-based Small and Micro Enterprises - Based on the Four Helix Model [J]. Scientific and Technological Progress and Countermeasures, 2014, 31 (3): 84-87.

[14] Zhao Dapeng. Research on China's Smart City Construction [D]. Jilin: Jilin University, 2013.

[15] Myrica rubra. Challenges and Countermeasures of government wisdom governance in the era of big data [J]. Theoretical discussion, 2015, (2).