China's Digital Twin City and its Implications

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1. Introduction

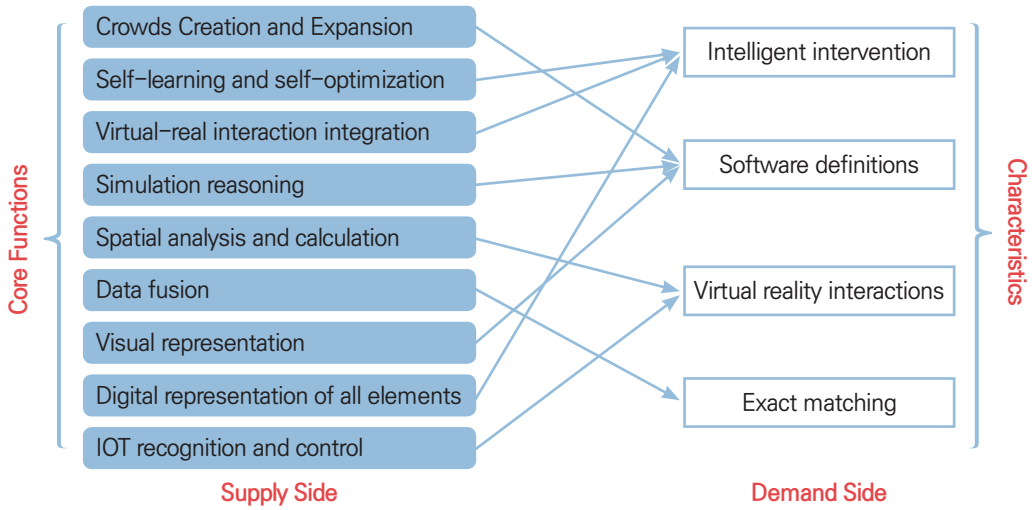
The construction of new infrastructure by the Chinese government promotes the development of digital twin city. The digital twin city is an important component of the new infrastructure, and the construction of the new infrastructure accelerates the emergence of the digital twin city. New infrastructure is part of China's new development strategy and is expected to help drive the new Chinese economy, especially in sectors like new consumption, new manufacturing and new services.[1] Many local authorities have announced related policies, and some policies include provisions for digital twin city. Along with a set of policies, the technologies supporting digital twin city such as 5G, the Internet of Things (IoT), edge computing, cloud computing and AI are expected to mature. This paper explores the concept and current status of China's digital twin city, which are rapidly developing in recent years, and describe the implications they carry.

2. The Concept of the Digital Twin City in China

The digital twin city is a complex and comprehensive technology system that supports the construction of a new smart city, and is a state-of-the-art advanced model for innovation in intelligent urban management. It is a future development model of a city in which a real city in the physical dimension and a virtual city in the information dimension coexist. This technological system simulates, monitors, diagnoses, predicts and controls processes through accurate mapping, identification, real-time analysis, scientific decision making and intelligent and accurate execution. Described in detail, a twin city is a digital city that imitates its actual counterpart in the digital space, monitoring and di-

1 "Economic Watch: 'new infrastructure' to bring digital opportunities for Chinese economy", *Xinhuanet* , March 2020.

Figure 1. Relationship between Core Functions and Characteristics of Digital Twin City



Source: CACIT (2020), Digital Twin City Research Report.

agnosing all urban systems in real-time through digitalization and virtualization, accurately predicting behaviors and reactions through 3D simulations. These capabilities support intelligent urban management. Such a system addresses complexities and uncertainties in urban planning, design, construction, management, and closed-loop processes. In addition, it improves the distribution and operation efficiency of urban material, intellectual and information resources, and strengthens the endogenous development engine of smart cities. A digital twin city is based on an information technology system and urban information model featuring digital identification, automatic recognition, network connection, comprehensive computing, intelligent control and platform services. The main features of digital twin city include: accurate mapping, virtual reality interaction, software definition and intelligent intervention.[2] The core functions of digital twin city are as follows: IOT recognition and control, digital expression of all elements, graphical portrayal, data fusion, spatial analysis and calculation, simulation reasoning, virtual and real interaction integration, self-learning and self-optimization, and crowd creation and expansion.

3. China's Policy to Foster Digital Twin City

1) Central Government Policy

Recently, the central government announced policies to promote the development of technologies, industries and applications related

2 CACIT (2018), Digital Twin City Research Report.

Table 1. Digital Twin City Policies of the Central Government

Date	Authorities	Contents
October 2019	NDRC	The Catalogue for Guiding Industry Restructuring (2019) designated CIM and BIM-related technology development and applications based on big data, IoT, and GIS as an incentive industry
November 2019	MNS	The Overall Framework of Natural Resources Informatization presented a 3D natural resource map
December 2019	MHUR	Proposed establishing a CIM platform system as one of nine key missions in 2020 for the three levels of government: central, local, and city
February 2020	MIIT	Three year action plan for the digital transformation of Intelligent Manufacturing in the building materials industry (2020-2022) mentioned BIM technology, computer modeling, real-time detection, and simulation technology
April 2020	NDRC and CCAC	The Implementation Plan for Promoting the Actions of Migrating to Cloud, Using Digital Tools and Enabling Intelligence emphasizes innovative application and integration of next-generation digital technologies such as big data, AI, cloud computing and digital twin city, etc
September 2020	MHUR	Technical guidelines for CIM basic platforms regulate the construction of CIM basic platforms in each region

Source: CACIT (2020), Digital Twin City Research Report.

to digital twin city. The National Development and Reform Committee (NDRC), the Ministry of Science and Technology (MST), the Ministry of Industry and Information Technology (MIIT), the Ministry of Natural Resources (MNR) and the Ministry of Housing, Urban-Rural Development (MHUR) promulgated policies to support the construction of digital twin city. These include the City Information Model (CIM) and Building Information Model (BIM). The NDRC and the Central Cyberspace Affairs Commission (CCAC) announced a plan promoting migration to the cloud and the use of digital tools to stimulate economic development. This plan refers to digital twin city as key fields in the digital transformation, alongside big data, AI, cloud computing, 5G, IoT and block-chain. In order to reinforce innovation capacity, it emphasizes the development of a digital twin innovation plan, strengthening cooperation among industry-academia-research institutes, digital infrastructure, standardized software and application environments. The MHUR and the MNR announced standards and guidance on the application of technologies related to BIM and CIM, respectively, and guided the construction of the CIM platform standard. The NDRC, MST, and MIIT set relevant policies and research objectives, respectively, and encourage the development of CIM-related industries and technological innovation.

2) Local Government Policy

After the demonstration of a digital twin city in Xiong'an New District, the digital twin concept has been incorporated into new smart city and new infrastructure plans in various regions. In an official release, the Shanghai municipal government explored the construction of a digital

twin city. The Hainan Provincial government announced a plan and suggested that Hainan Province will build a digital provincial twin by 2025. Zhejiang Province proposed the establishment of a digital twin community. City governments in Guiyang, Nanjing, Hefei, Fuzhou, and Chengdu also proposed the construction of new smart city based on digital twin city.

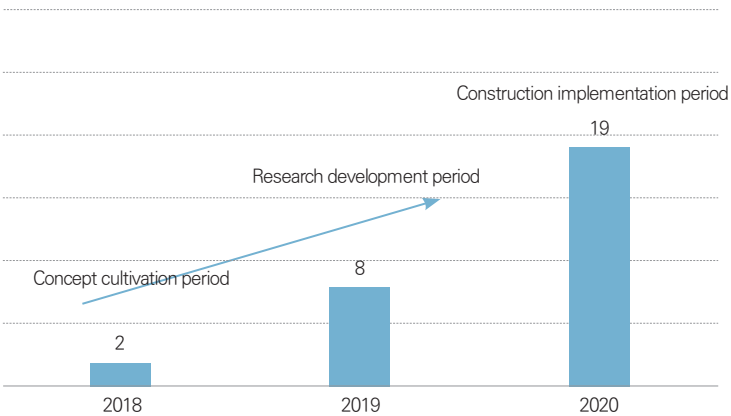
4. The Status of China's Digital Twin City

1) Digital Twin City no Longer Conceptual

The number of CIM-related projects, a key element of a digital twin city, has increased significantly, laying the foundation for the construction of a digital twin city. Since the digital twin city concept was first introduced in 2017, local governments and industries have planned and implemented related projects. According to CAICT[3], there were only two CIM-related bidding projects in 2018, but eight in 2019 and 19 new projects as of October 2020. This rapid growth means that CIM has already entered the large-scale implementation phase. According to public statistics, the total cost of the CIM public bidding projects has exceeded 800 million CNY, and the trend of promoting digital twin city has intensified based on CIM.

Some cities have already announced specific plans for building digital twin city. Huamu Street in Shanghai implemented a digital twin city construction project, and improved the efficiency of community governance through digitalization. In Beijing, the Central Business District has a plan to build a spatio-temporal information management platform and a digital

Figure 2. CIM-related Projects (2018-2020)



Source: CAICT (2020), Digital Twin City Research Report.

3 The China Academy of Information and Communications Technology.

twin CBD (Central Business District). The government authority of Guiyang Economic and Technological Development Zone will invest about 60 million CNY to carry out the construction of digital twin city safety infrastructure. The government of Wuhan announced plans to invest 350 million CNY and develop a smart city platform to build a digital twin city, IOT platforms and application and support platforms.

2) Growing Body of Research on Digital Twin City Technologies

Recently, universities (Peking University, Tsinghua University, and Beihang University) and academic institutions such as IACAS (the Institute of Automation of the Chinese Academy of Sciences), have focused research efforts on digital twin city and related industrial applications. According to CNKI[4] statistics, the number of publications on the subject of digital twin city has soared from single digits in 2017 to more than 60 in 2020. The number of thesis publications has increased significantly, from just two 2017 and four in 2018 to 47 in 2019 and 63 in 2020. More than a dozen of these research papers were supported by the National Natural Science Fund and the National Focused Research and Development Plan. Research fields include information technology, macroeconomic and sustainable development, computer software and application programming, architectural science and engineering, physical geography, and surveying and mapping. Scholars in a variety of academic fields are paying attention to digital twin city.

Main research areas include: understanding digital twin city, twin city technologies and practical applications. From the perspective of cybernetics, IACAS proposed the concept of a parallel city that with three main functions: providing an accurate depiction of the real city, making intelligent predictions and providing active guidance. Research by Peking University scholars focused on R&D of digital spatial analysis technology and proposed a digital twin urban spatial network framework. To achieve multi-source heterogeneous data aggregation, correlation, and efficient computing, Grid Data System (GDS) data platform technology has been developed. Researchers at Beihang University, which have conducted research on digital twin manufacturing technologies, proposed a five-dimensional model connecting physical and virtual objects in addition to twin data and services, gradually expanding their theory into smart city-related fields such as city management and safety. CACIT has jointly built a digital twin city prototype system with partners from various industries. These partners include internet companies, geospatial information companies and modeling and simulation companies. The institution has analyzed and sought ways to build and utilize digital twin city.

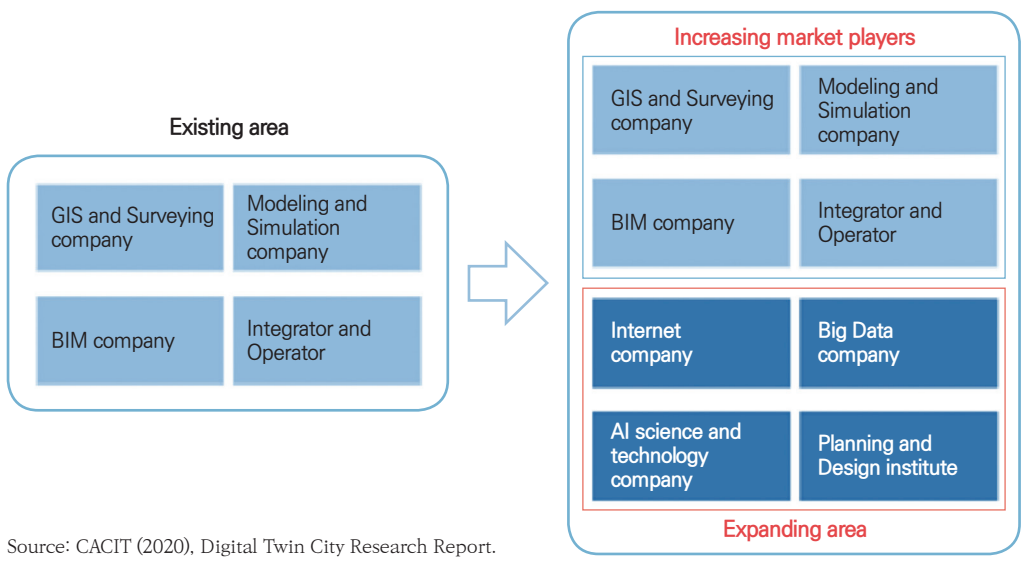
4 China National Knowledge Infrastructure.

3) More Market Players are Reorganizing Technological Solutions Around Digital Twins

Developments in the field of digital twin city continue unabated as more types of enterprises actively enter this new arena. As interest in digital twin city grows, it has steadily expanded in four areas: geographic information and mapping, BIM, modeling and simulation, and integrators and operators. NavInfo combines the advantages of high-precision maps and geospatial data, and applies digital twin technologies to traffic operation and urban refinement. KQ GEO supports application services such as urban planning, construction and management integration, and real estate registration through a functional digital twin city platform based on the KQGIS series platform. China Telecom has built several digital twin parks using IOT platforms and data with 3D models, sensors and operational history. Big data companies including Sefonsoft and Minglamp have built deep data knowledge maps, visually analyzing various types of city data supporting the integration of multiple application programs. Twin technology based on independent and controllable 3D graphic engines and spatial computing technologies provides high-quality digital twin services to smart cities as well as industries in aerospace, marine plant and education. HDEC[5] and other urban planning and design organizations have applied digitalization technology to all urban processes in constructing future communities and building a CIM platform tailored to the community.

Existing leading companies working in smart city-adjacent fields have reorganized and opti-

Figure 3. Expanding Digital Twin City Fields and Attracting Market Participants



Source: CACIT (2020), Digital Twin City Research Report.

5 Huadong Engineering Corporation Limited.

mized smart city solutions to expand their businesses to digital twin city industries. iFLYTEK integrated digital city, intelligent scenes, and Ultrain platforms using big data, AI and image recognition technologies, targeting digital twin city based on the experience of Urban Ultrain. It has also built a digital twin city platform with deep learning capabilities. Tencent Cloud built its CityBase platform by leveraging experience in smart city construction, government work, education and healthcare. Its Tencent Solutions project is based on digital twins. JD Digital has built a smart city operating system that supports real-time data processing and data convergence across fields, sectors and regions and is supported innovative environment and energy consumption applications.

Many companies have created a digital twin city cooperative ecosystem. The construction of a digital twin city is a complex, system-wide project between various industrial sectors. With the advancement of digitalization, corporate relationships have become less competitive and more symbiotic. A consensus has been reach on the integration of industrial ecosystems. Major ICT companies and internet companies have led the construction of the ecosystem, and technology service companies specializing in spatial information, BIM, simulations and AI are active participants. Enterprises across the industrial ecosystem including operators, technology providers, integrators and equipment suppliers are actively cooperating in the development of application scenarios, the modeling of digital twin city and the creation of open function platforms at a rudimentary level. Tencent Cloud, along with spatial information vendors such as Feidu Technology and Aoge Intelligence, lead the construction of CityBase, a CIM-based industrial internet platform. In cooperation with leading companies in various industries such as Daxiangyun and Ariake Cloud, it designed a dozen application scenarios for smart factories, smart construction and urban emergency situations. JD Digital built a database and other technologies for digital twin city based on a smart city operating system, and has cooperated with cloud service companies, smart hardware companies and solution companies. Huawei built an urban digital platform based on object recognition, 5G and AI, and improved the basic resource coordination function. With Fuhui AI as an engine, it has worked with scientific research institutes, application developers and solution integrators as digital twin joint venture partners and designed Baihuaqifang application scenarios.

4) A Digital Twin Inspires Various Industries to Shorten the Path to Digitalization

A digital twin city accelerates the process of industrial digitization and creates new pathways and models for industrial applications. The digital twin city construction model can be rapidly disseminated and replicated in transportation, energy, water conservation, factories, healthcare and other fields. The city government of Beijing has built a local traffic digital twin simu-

lation system. It improved the visualization and interaction capabilities of micro-simulations on Xisanhuan Road, and provided program evaluation and comparison tools to improve transportation. The Beijing Chaoyang District Fire Rescue Detachment adopted digital twin technology to practically and effectively conduct emergency drills for various fire prevention plans based on the construction site of the management area. A hospital in Western China has collected medical treatment data and physical symptom data for cardiovascular patients with smart wearable devices in real time, and built a digital twin treatment system that provides real-time warning and pre-diagnosis through combining the experiences of experts and scholars with AI algorithms. The Langfang Thermal Power Plant has digitized the entire production process and realized intelligent management, and the diagnosis and prediction rate of Class I and Class II defects through this system is over 85 percent. Yunnan's Fuxian Lake created a digital twin lake and has accessed water recognition data to accurately understand sewage outflows and underground river inflows. It enables visualization, controllable monitoring and simulated projections of river and lake management data.

Initial efforts to apply a digital twin to a small spatial area has greatly improved governance services at an intelligent level. Due to the high construction cost of digital twins, this technology is well-suited to applications in resource-intensive, densely-populated areas such as parks, communities, ports, and so forth, and can take full advantage of the delicate and precise governance functions. Huawei's Songshan Lake Park has used real-time access to the park's cognitive data to set up digital twin scenarios based on its real-time operational status, visualizing and analyzing park operations, connecting tasks and simulating decision-making. China Merchants' Qianhai Smart Port has used digital twin technology to track hundreds of thousands of containers, simulate the operation of terminal equipment, comprehensively evaluate operation scheduling and accurately control loading and unloading operations to enhance intelligent port operation and shipping management.

5. Implications

As interest in digital twin city increases, related projects have multiplied. But there are cases in which these trends are blindly followed. The construction of a digital twin city requires complex and comprehensive technologies and a deep understanding of urban management. Some projects exhibit inchoate purpose, lack depth and fail to demonstrate an adequate grasp of the application scenario in question, in turn failing to meet actual demand. Considering management mechanisms, data coordination and technology costs, construction of digital twin city should gradually expand to include entire cities, starting with demarcated areas such as communities, parks, campuses and ports.

Technical solutions for building digital twin

city are still being studied. Extant technical issues include redundant CIM platforms and lack of spatiotemporal data standards. Directions for building an integrated CIM platform should be clarified and an overall plan should be established, with clear directions for the development of the digital twin city with integrated goals and demands. To reduce redundant developments, an organizational system and management mechanism for overall planning and development should be established, integrating common requirements and accommodating an appropriate CIM structure.

Core technologies such as measurement, mapping, identification and recognition, collaborative computing, expression of all elements and simulation should be developed indigenously, without relying on foreign companies. The maturity level of large data loading, cloud computing collaboration and simulation technologies is not high and most software design is led by foreign companies. Core technology independence is insufficient. Basic research should be strengthened and a breakthrough in basic software innovation must be achieved by establishing an open source software ecosystem. It is critical to actively develop integrated application programs.

The digital twin city is a huge intellectual project integrating knowledge, technology, data, algorithms, tools and applications. It requires strong industrial ecosystem cooperation and intensive support. Private sector actors, academia and research organizations should extensively cooperate on strategies, technologies, standards and markets, strengthen joint efforts and conduct collaborative research to apply basic common technologies. The government should open up data resources and establish support policies so that technology plans and applications can be continuously developed and tested. To promote the modernization of urban governance, government mechanisms must be reformed and governance structures adapted to the digital twin technology architecture must be established. Overall, the comprehensive promotion of the CIM platform, compatibility of data normative standards, the fostering of application environments and market demand, and the establishment of ecological cooperation mechanisms are expected to determine the level of development of digital twin city in the future.

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