China –IoT Nation

Smart Cities

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Dansk resume

Formålet med denne ICDK OUTLOOK er at belyse udviklingen af "Internet of things" (IoT) i Kina og inspirere virksomheder og universiteter til at se mod Kina for IoT partnerskaber og markedsmuligheder. Rapporten er en del af en todelt rapportserie kaldet *China IoT Nation*. Denne rapport dækker Kinas Smart City-strategier og -politikker. Den anden rapport dækker AI og Big Data og kan findes på ICDKs hjemmeside icdk.um.dk.

Politisk fokus

I senere år har IoT teknologi og Smart Cities været en vigtig del af Kinas nationale strategi, hvilket reflekterer regeringens ambitioner om at fremskynde den digitale urbanisering i Kina. Dette ses bl.a. i den 13. femårsplan, hvor det ikke alene understreges, at det er en politisk prioritet at udvikle 'smart cities', der er også en målsætning om at udvikle nye typer af 'smart cities', som i højere grad imødekommer borgernes behov. Smart City markedet forventes at have en værdi på 59.9 mia. US$ i 2023.

Anvendelse af Smart City-teknologi

Smart City-teknologi benyttes forskelligt på tværs af sektorer og byer. I transportsektoren bruges IoT bl.a. til at kontrollere trafik i realtid og sikre en sikker og effektiv infrastruktur. I Hangzhou har Alibaba implementeret Smart City-systemet City Brain, som bl.a. har mindsket trafikpropper med 15% siden sin start.

Inden for offentlig ledelse er forbindelsen mellem borger og kommune blevet forbedret. F.eks. giver Shanghais Citizen Cloud øget adgang til offentlige services.

I energisektoren bruges IoT til at reducere energiforbruget. I Hangzhou har man bl.a. formindsket energiforbruget til gadebelysning med 30% ved at lade et Smart City-system styre, hvornår gadelamperne er tændte.

Med hensyn til forurening er high-tech byen Shenzhen førende. Her har digitale løsninger såsom IoT, GIS 3D simulationer, og andre teknologier, der gør lokalregeringen i stand til at forudsige luftkvalitet i realtid, hjulpet med at reducere luftforurening med ca. 50% på mindre end et årti. I affaldssektoren har Tianjin digitaliseret bortskaffelsen af affald, mens Beijing har effektiviseret sin affaldsindsamling gennem intelligente systemer.

I denne rapport uddybes ovenstående cases sammen med en lang række andre eksempler. Til sidst præsenteres de fire største virksomheder inden for udvikling af Smart City-teknologi sammen med de vigtigste start-ups.

Executive summary

The purpose of this ICDK OUTLOOK report is to shed light on the development of the Internet of Things (IoT) in China and inspire corporates and universities to look to China for IoT partnerships and market opportunities. The report at hand is part of a two-part report series entitled *China IoT Nation*. It covers China's Smart City strategy and policies, and includes a variety of application examples from different Chinese cities. The other report covers AI and big data policies, and use-cases. Both reports can be found on the website of ICDK Shanghai: icdk.um.dk.

Relevant policies

In recent years, IoT technology and smart cities have held an important place in the Chinese national strategy. This reflects a desire by key stakeholders in government and business to accelerate the digital urbanisation of China. The smart cities market is expected to reach a value of US$ 59.9 bn by 2023, which is partly due to national policies having smart city development high on the agenda.

In the 13th Five-Year Plan, the plan is to develop 100 cities into "new-type smart cities", which differ from traditional smart cities by putting people-oriented development above informatisation. A timeline for the development of China's smart city strategy can be seen in Figure 1.

To answer the call from the national government, many municipal governments in China have are making their own plans for developing smart cities and have launched a number of local projects, some of which are included in the report.

Applications of Smart City technology

Smart City technologies are deployed differently across different sectors and in different cities. Within the transportation sector, IoT technology is used to manage and control traffic in real time to ensure a safe and efficient infrastructure network. In Hangzhou, tech giant Alibaba has implemented a citywide Smart City system called City Brain, which improves fire safety and has reduced the number of traffic jams by 15% since the project was initiated. Meanwhile in Shanghai, Huawei has implemented a smart parking system, and in Wuxi, an "Internet of Vehicles" system has digitalised car traffic.

In the governance sector, the connection between municipalities and their citizens has been improved all across China. The example here is Shanghai where a cloud application called Citizen Cloud improves the accessibility to government services.
In the energy sector, IoT and Smart City technologies are used to reduce excessive energy usage, for instance in Hangzhou where energy usage for lighting has been reduced by 30% by implementing a smart energy system to control when streetlights are on.

In the area of pollution, the high-tech city of Shenzhen is a flag-bearer. Here, hardware and software solutions have helped reduce air pollution by approximately

50% in less than a decade. This is thanks to IoT, GIS 3D simulations and other technologies that now enable the city government to predict air quality conditions using highly accurate digital models based on real-time sensory data. In the waste management sector, the city of Tianjin has digitalised waste disposal while Beijing has implemented intelligent garbage collection systems to maximise efficiency.

In this report, each case study is presented in detail along with city-level case studies on Shanghai, Wuxi and Wuhan. Finally, four major corporations that are driving the Smart City technological development forward are introduced together with key start-ups.

Preface

According to the Chinese government, China missed out on the first three industrial revolutions, i.e. they were not front runners in inventing or introducing mechanisation, new energy sources, or electronics and computation on a mass scale in society. In the 21st century, the government is therefore fully committed to participating in, driving and benefitting from the fourth industrial revolution, i.e. smart automation.

Internet of Things (IoT) plays an important role in China's ambitions in the fourth industrial revolution. It provides the data that powers China's ambitions in artificial intelligence, it provides information for the systems that control China's increasingly smart cities and it monitors the health of individuals for the benefit of China's healthcare system. These are just a few areas where IoT is central to China's smart automation ambitions.
As is usually the case in China, the government has laid out its ambitions in numerous policies, which are important reference points and a good place to start if one wants to understand the direction of development within a certain field in China. As such, this report includes a section on China's national policies. However, the real impact is of course to be found in the implementation and, thus, we have made an effort to include several relevant use-cases as examples of China's endeavor to become an IoT Nation.

At the Innovation Centre in Shanghai, we have so far followed the development of China's IoT ambitions as part of our general surveying of the Chinese tech landscape. In some projects, for instance Nordic Sustainable Cities and various water-related projects, IoT is more prominent and we discuss new solutions with Chinese companies involved in these projects as well as exchange information about policy initiatives with government officials on different levels in the Chinese system.
The 'IoT Nation' reports, however, represent our first deep dive into the field of IoT. We have chosen to focus on two major IoT topics: big data and artificial intelligence in one report, and smart cities in the other.
We believe that both reports provide some valuable insights into these two important areas of IoT application. Furthermore, we hope they will inspire Danish stakeholders from corporates to start-ups, on the one hand, and universities to individual researches, on that other hand, to look towards China for inspiration, partnerships and market opportunities.

Innovation Centre Denmark in Shanghai is happy to support any China focused IoT initiatives that the two reports may inspire, and we are ourselves looking into ways of strengthening our capacity in this sector.

Enjoy the read!

Søren Boutrup, Executive Director
Martin Bech, Innovation Attaché

1. Introduction

Driven by population size and the desire for rapid urbanization, China's 'smart city' concept is a top 'national strategy' initiative for the government.[i] A key application area of the Internet of Things (IoT), the country's smart cities market is projected to reach US$ 59.9 billion by 2023, from US$ 30.4 billion in 2018.[ii] By examining and analyzing policy measures and applications from China's central government and the lower Yangtze River Delta, and corporate and start-up activity, this report seeks to define, identify, and investigate China's smart city initiatives.

Smart city initiatives refer to urbanized areas that utilize information and communication technologies (ICT), as a means to improve sustainability, increase efficiency levels, accelerate economic development and ultimately, create a better quality of life for city residents.[iii] Of the range of different ICT solutions smart cities rely on (including, but not limited to, blockchain, artificial intelligence, and robotics), one of the most important is IoT.[iv] IoT describes the ability to connect any Internet Protocol-enabled device (a smart device) to the Internet[v] for data-driven solutions; for example, an IoT-enabled thermostat that allows a user to remotely check on their home. Urbanized areas (cities) are where IoT can currently create the greatest value, in addition to a number of corresponding serious cybersecurity risks.[vi] IoT-enabled devices / smart technologies have the capability to leverage high-speed communication networks (for example, 5G) to bolster municipal services and infrastructure.[vii] Areas where IoT is/can be deployed include utilities, sanitation and waste management, urban mobility and public transportation, IT connectivity, public safety, and weather monitoring.[viii]

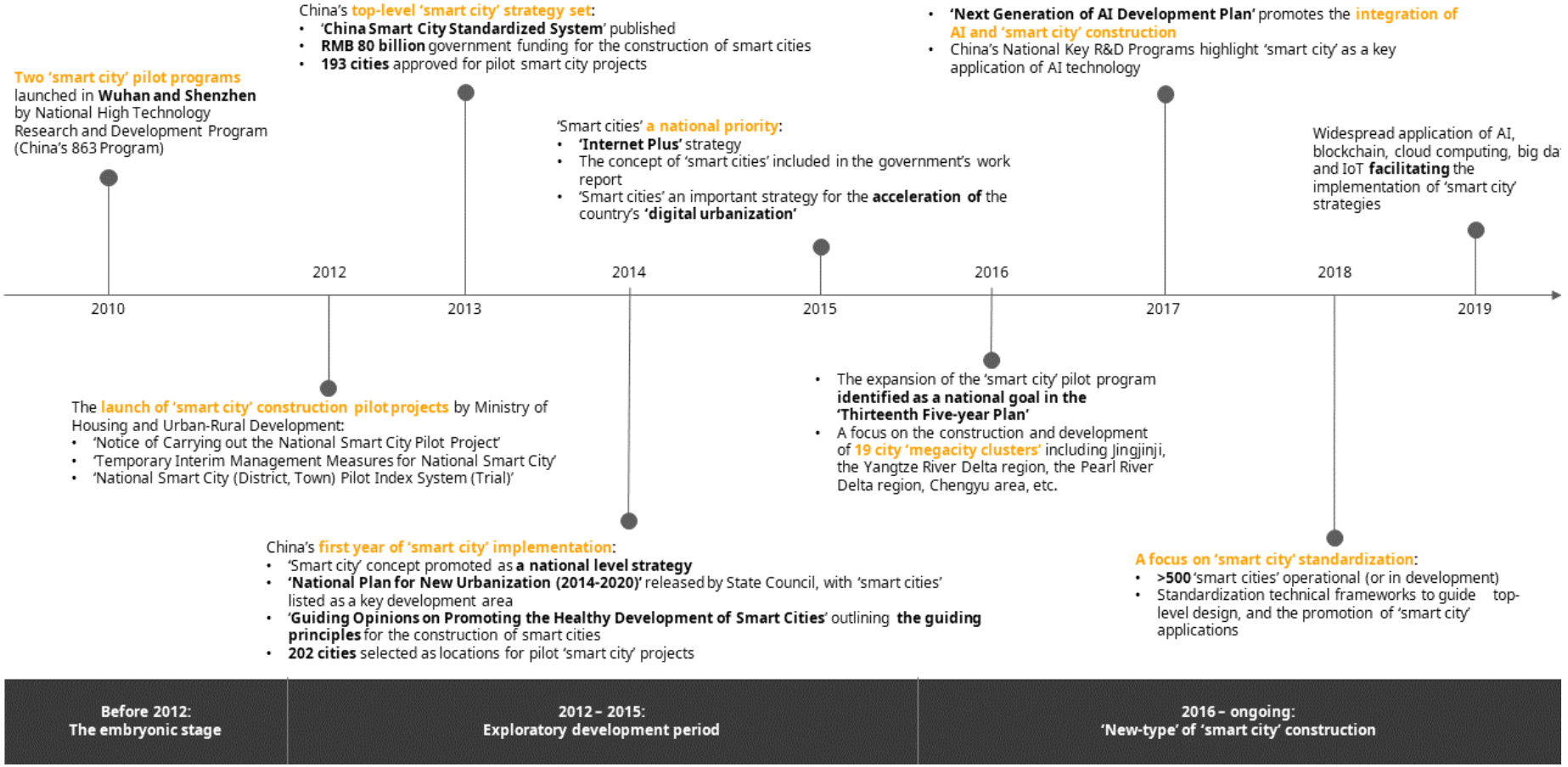


Figure 1: Timeline: The development of China's smart city strategy

2. Smart City Policies

2.1 China's Smart City Strategy

China views the smart city concept as a critical strategy for accelerating the processes of industrialization, informatization, urbanization and agricultural modernization. [ix] Through the country's smart cities initiative, China is focused on improving public services and enhancing the level of urban governance. [x]
Smart city strategies also present a clear value proposition. China's smart city market is expected to increase in value from US$ 30.4 billion in 2018 to US$ 59.9 billion by 2023.[xi] In order to accelerate smart city construction and implementation, China has adopted a batching approach to pilot projects. Currently, over 500 smart cities are operational (or in development). During the Thirteenth Five-Year Plan (2016-2020), 100 cities will be selected for 'new-type smart city' development.[xii]

2.2 National Smart City Policies

From top-level strategy to creating standards, driving technological developments to clarifying smart city operations, China sees the smart city initiative as a tool for the acceleration of the country's digital urbanization (i.e. the application of new technology to traditional fields). Cities are establishing extensive databases and sensor networks to collect, store, and analyze information related to transportation, electricity, public safety, and the environment.[xiii]

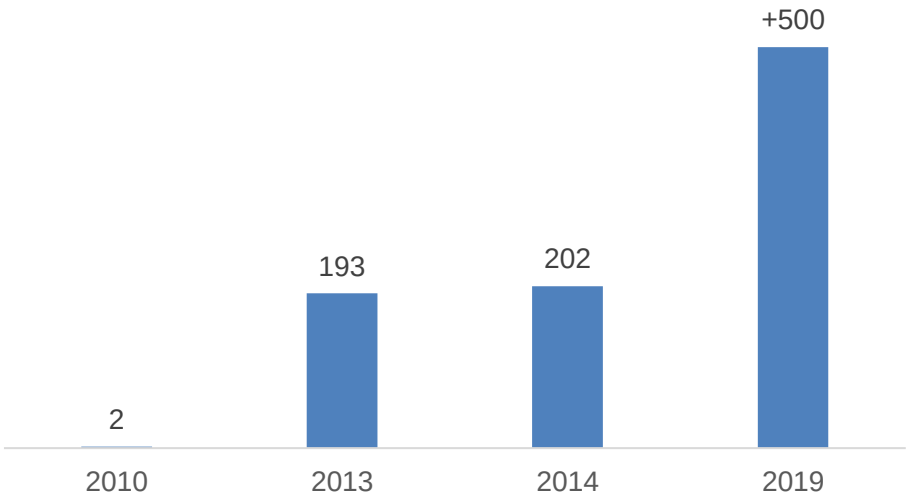


Figure 2: The growth of China's smart city pilot programs, 2010-2019

At all levels, China's approach to smart city development has been an iterative one. Beginning with formulating development plans and management processes, in 2010, the National High Technology Research and Development Program (China's 863 Program) launched two smart city pilot programs in Wuhan and Shenzhen.[xiv]

Increasing to 193 pilot smart cities in 2013,[xv] and 202 cities in 2014,[xvi] currently, over 500 pilot smart cities are operational or in development.[xvii] A national priority, the smart city initiative is integrated with technological agendas including 'Internet Plus', and China's artificial intelligence (AI) ambitions: in 2017, China's National Key Research and Development Programs highlighted smart city as a key application of AI technology.[xviii]

China's emphasis on governance and optimization applications is underlined by the continued top-level design of its smart city initiatives. President Xi Jinping's Xiong'an New Area initiative – considered China's number-one urban project[xix] – echoes the nation's focus on modernization. Successful development of Xiong'an will see it run on 100% clean energy[xx] and become an early adopter of self-driving car technology, smart city administration, intelligent infrastructure, and data asset management systems. China's technology giants and telecommunications providers are expected to establish branches and offer their services in the New Area. In pursuit of this smart city project, spending over the next few decades is estimated to reach US$ 580 billion.[xxi]

While China's earlier permutations of smart city strategies were more focused on 'informatization' and technological development (e.g. infrastructure, networks, and sensors), the nation's current 'new-type smart city' policy is more 'people-oriented'.[xxii] An evolving approach to smart city strategy, China is integrating the use of data analysis, data solutions, and AI technologies with the intention of creating more value for residents, local businesses, and governments. According to Nathan Lawes, Industrial IoT Ecosystem Development Lead at IoTOne, "In Europe, data is to be protected. In the US, data is to be commercialized. In China, data is to be controlled."[xxiii] Data is a critical asset for the government, particularly with respect to governance.

China is increasingly focused on technical standardization, a process that requires a deep technical knowledge capacity. Identified as a national goal in the Thirteenth Five-Year Plan, standardization plays an important role in guiding future strategies. Looking forward, the widespread application of AI, blockchain, big data and IoT are on the rise in China, which facilitates the implementation of smart city projects. In turn, the development of these urban intelligent ecosystems drives the growth and the adoption of these technologies. George Yan, Founder and CEO of Clobotics, outlined China's strengths in smart city development as "generous access to data and a widespread commercial mindset towards leveraging it." However, in spite of high levels of government investment in fundamental research, in terms of technological dominance, Yan states that China still has far to go.[xxiv]

2.2.1 Funding smart city projects: public-private partnerships (PPP)

The Chinese government has placed a high priority on the development of fundamental technologies – including semiconductors, 5G networks, AI, and cloud computing – that are the building blocks for smart city development. In addition to government funding, public-private partnerships (PPP) have emerged as a supplementary form of project funding, linking public and commercial interests.
China prefers PPPs because they consider them more 'efficient', with higher return on investment than 100% government-funded projects. As a source of capital,

commercial investments tend to be taken more seriously by beneficiaries, with a trend towards higher rates of successful, timely delivery.[xxv]

As of June 2018, there are 102 smart city PPP projects in China, with a total investment of RMB 87.9 billion. This includes:

- 56 top-level ('comprehensive') smart city projects (54.9%)
- 9 data center projects (8.82%)
- 5 smart municipal administration (4.90%)
- 5 smart security projects (4.90%)[xxvi]

Other areas include smart lighting, smart agriculture, smart environmental protection, smart industrial parks, smart energy, smart logistics, and so on.

2.3 City-level case study #1: Shanghai's smart city policies as a 'stepping stone' to greater national prominence

Shanghai's smart city strategy is intended to facilitate the city's aim of becoming a hub for economic, finance, trade, shipping, and scientific and technological innovation (Shanghai's "five centers" initiative).[xxvii] From infrastructure development to attracting tech firms, by 2020, Shanghai's municipal government intends for the city to lead China in the field of IT.

2.3.1 Timeline

2011-2013:
The Shanghai government publishes the 'Action Plan 2011-2013 of Shanghai Municipality for Building Smart City'. This plan focuses on the development of a fundamental IT and telecommunications infrastructure.

2013:

- 43 pilot smart community programs are launched
- RMB 1.06 trillion in e-commerce revenue
- RMB 1.09 trillion in total market size, IT industry
- 25 million people and 1.42 million companies covered by e-government services (e.g. access to social services like pension funds)[xxviii]

2014:
The government publishes the 'Action Plan 2014-2016 of Shanghai Municipality for Building Smart City'. In addition to outlining 50 smart city projects available for tender, the plan focuses on liveability (e.g. improved living environments, smart economic development, e-governance, etc.).[xxix]

2016:
Shanghai releases two policies: one reaffirms its commitment to improving the city's information infrastructure, IT industry, and network security systems, all fundamental for smart city development (the "Thirteenth Five-Year Plan for National

Economic and Social Development of Shanghai"), and the second outlines Shanghai's intentions, by 2020, to be a leader, both in China and globally, in IT-driven 'citizen services' (the "Thirteenth Five-Year Plan for Promoting the Construction of Smart Cities in Shanghai").

2019:
The implementation of smart city applications is a top priority for Shanghai (see sections 3.1.2, 3.2.1, and 4.2). Focus areas include improving the daily lives of residents, upgrading the economy via tech-enabled analysis, and improved government services.

2.3.2 Funding

As well as government-backed financing, Public-Private Partnerships (PPP) have also emerged as funding options. In the field of smart water management, Shanghai Pudong Veolia Water Company is a joint venture between Veolia, the French waste, water, and energy management specialist, and the Shanghai Water Authorities.[xxx]

3. Application areas and use cases

Key focus areas of China's smart city applications include public services (including utilities and bill payment), government services (e.g. waste management, healthcare, education), and urban management (e.g. traffic management).

3.1 Traffic management

In spite of affordable public transportation options and anti-traffic legislation in many cities, as China rapidly urbanizes, residents have had to adapt their lives to daily traffic challenges. Smart city applications include centralized real-time traffic infrastructure management and control, via more integrated and interconnected platforms, which allow for better information collection and sharing, enabling both operators and end users to make more informed decisions. Benefits include improved security and road safety, and significant reductions in travel time.

3.1.1 Case study #1: Hangzhou: Alibaba's "City Brain" and improving traffic flow

In response to Hangzhou's traffic congestion – previously ranked fifth among China's most congested cities[xxxi] – Alibaba launched its AI-driven "City Brain" project in 2016. In 2018, Alibaba Cloud, the cloud computing unit of Alibaba, launched "City Brain 2.0", an expansion of its Hangzhou urban traffic-management system.[xxxii] The upgraded system integrates the use of AI and cloud computing technology for traffic and transport management. Future plans include expansion to other areas of public services, for example, emergency fire safety.[xxxiii]

Hangzhou's City Brain system extends across 420 square kilometers in the downtown city center.[xxxiv] Using cameras systems and sensors placed across the city, the City Brain collects real-time data on road conditions. This data is then sent to an AI data processing center for analysis. As of September 2018, the system regulates traffic signals at over 1,300 intersections via analysis of real-time traffic flow and weather data (as of September 2018).[xxxv]

Since its inception, the City Brain project has contributed to a 15% reduction in traffic jams.[xxxvi] Currently, in 2019, Hangzhou is the fifty seventh most congested Chinese city, moving fifty two spots down the list since 2010.[xxxvii] According to Alibaba, the City Brain has helped fire trucks and ambulances (and first responders) reduce their travel time to emergencies by 48.9%.[xxxviii] When ambulances are on their way to hospitals, the system changes all traffic lights to green, enabling patients to receive emergency care faster.[xxxix] A 4.6 minute reduction in travel times on highways has also been attributed to the City Brain.[xl]

Hangzhou's traffic police are also benefiting from Alibaba's system. As a result of the

increased availability of data, police are able to respond to traffic violations quicker and arrive at accident sites earlier.[xli] As of 2019, traffic violations are being reported with 95% accuracy.[xlii] "The City Brain can detect accidents within a second, and we can arrive at the site in five minutes," said Zheng Yijiong, China's first traffic policeman to control traffic flows with an AI partner.[xliii]

3.1.2 Case study #2: Shanghai: Huawei's smart parking solution

Demand for available public parking spots has grown in step with China's increase in car ownership, which has led to an increase in road traffic. In 2016, Huawei, one of China's tech giants, launched a smart parking network in Shanghai.[xliv] Chip-sets embedded under parking spaces in over 300 parking lots across Shanghai collect and transmit real-time information on the occupancy rate of parking lots to car drivers through an app.[xlv] By enabling drivers to directly reserve parking spaces, the system alleviates traffic congestion by reducing the number of drivers on the road looking for parking.

3.1.3 Case study #3: Wuxi: the world's first city-wide application of the Internet of Vehicles (LTE-V2X) for improved traffic flow and safer rides

In 2018, with strong support from the government, Wuxi launched the world's first city-level Internet of Vehicles (IoV) LTE-V2X (vehicle-to-everything) application demonstration project.[xlvi] Built on the LTE-4G cellular network, LTE-V2X is a wireless telecommunication technology that enables high-bandwidth, low-latency, and high-reliability communications of V2X, including vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-pedestrian communication.
By implementing IoV as a tool to coordinate communication between vehicles and roads, Wuxi aims to build an intelligent transportation system that will improve traffic flow and ride safety. In addition to the economic benefits of IoV, this initiative echoes China's drive to lead in technology-enabled urbanization and development.

V2X is widely considered the key to intelligent traffic systems, a fundamental building block for fully autonomous driving. The scale of the global V2X market is projected to reach RMB 614 billion by 2020, of which RMB 200 billion will be in China.[xlvii] Industry investment has kept pace with Wuxi's strategy: in September 2017, the Wuxi government, in partnership with China Mobile, Huawei, the Traffic Management Research Institute of the Ministry of Public Security, and the China Academy of Information and Communications Technology, initiated the city's pilot LTE-V2X project. Automobile industry players, including Audi China, FAW and Zotye Automobile, participated in technical tests of LTE-V2X solutions.[xlviii]
IoV systems consist of a network of roadside units (RSUs) installed on open roads. Each RSU is connected to road traffic facilities (including traffic lights, cameras, road signs, and speed limit reminders). In Wuxi, RSUs work with T-Box technology (from Huawei), which transmits vehicle information that allows for real-time remote tracking and services related to vehicle status.[xlix]

With over 30 application scenarios, Wuxi's stated applications for IoV include:

- Car speed guidance (e.g. based on environmental factors, advising drivers to drive faster or slower)
- Allowing emergency service vehicles priority road use

- Reducing traffic conflicts at crossroads (by detecting oncoming traffic and notifying drivers)

Timeline of development

- 2018: Wuxi's IoV LTE-V2X coverage extends over 170 square kilometers, encompassing the city's core urban area, Taihu New City. 240 IoV-enabled traffic crossroads were completed, including five elevated freeways.
- 2019: full LTE-V2X coverage is expected to be applied throughout Wuxi. The government intends to focus on infrastructure upgrades.

2020: Wuxi intends to be a leading test case in the V2X industry, whose potential successes could be scaled throughout Jiangsu province. Benchmarks include installing 200,000 access terminals, including RSUs.

3.2 Governance

Large investments in ICT infrastructure, together with highly-integrated public services, are helping major Chinese cities such as Shanghai, Guangzhou, and Beijing rapidly scale their smart city projects to millions of citizens.

3.2.1 Case study #4: Shanghai: Citizen Cloud: greater accessibility to government services via cloud platforms

Citizen Cloud, a cloud-based platform and mobile app, is the Shanghai government's effort to digitalize access to government services for their residents.[l] The platform aggregates, and facilitates easy access to, over 1,200 government services for Shanghai residents, including healthcare records, medical treatment, senior care, and legal services.[li] As of February 2019, over one-third of Shanghai's population, approximately ten million people, are registered users.[lii]

Shanghai has also developed the Shanghai Data Exchange, a big data exchange platform. Companies are allowed to purchase open data collected from the city's cameras and sensors. The purchases are intended to enable companies to develop public information tools and services for the benefit of Shanghai residents.[liii]

3.3 Energy

China's commitment to both reduce its carbon emissions and increase its use of renewable power means smart city solutions are a necessary part of the nation's energy transformation strategy. Professor Wang Haoyu, Assistant Professor and Director of ShanghaiTech University's PEARL research group, states that energy - and energy security - is critical for the successful implementation of smart cities.[liv] With power systems increasingly integrated into intelligent energy networks, access to information on consumption and availability facilitates a more sustainable use of resources. This is particularly relevant for cities, where due to high population density, energy consumption is high.

3.3.1 Case study #6: Hangzhou - smart lights enabled by new technology

In 2017, Zhejiang province established the country's first smart lighting project, an applied use case for standardized NB-IoT (Narrowband Internet of Things) technology.[lv] Cheap, and with low data rates, NB-IoT is a Low Power Wide Area Network (LPWAN) radio technology standard that is optimized for extensive coverage and low power consumption applications. In spite of its advantages, China's telecommunications operators are concerned about the lack of standardization of NB-IoT.[lvi]

Hangzhou intends to install China Telecom's NB-IoT communication technology in each street light pole, allowing them to be integrated into a unified management platform. The platform saves energy by managing the brightness of each street lamp. There will be 56,000 street lamps in the main urban areas of Hangzhou equipped with sensors collecting and transmitting data by the end of 2019.[lvii] By 2020, lighting energy consumption per kilometer on highways and in tunnels is expected to be reduced by 30%, according to the "Notice on Issuing the Thirteenth Five-Year Plan on Energy Consumption in Zhejiang province".[lviii]

3.4 Pollution

China's rapid urbanization has contributed to multiple types of serious environmental pollutants (e.g., air, soil, and water). Smart city initiatives, where sensors provide real-time updates – like those used to monitor air pollution in Shenzhen (see case study #7) – allow for accurate environmental monitoring.

3.4.1 Case study #7: Shenzhen - integrated solutions for smart environmental protection

The base of hardware and garment production, Shenzhen has long been challenged by pollution. Currently, it is considered one of China's most sustainable cities. According to city authorities, in less than a decade, Shenzhen has reduced its air pollution (PM2.5 levels) by approximately 50%.[lix]

An early adopter of smart environmental protection solutions, Shenzhen is both highly responsive and anticipatory. Since 2009, the city has employed hardware and software technologies, including IoT, cloud computing, 3D simulations via GIS platform, online environmental monitoring, and ecological resource estimation, to reduce its environmental impact.[lx]

The Shenzhen government uses a digital platform for centralized management: the "Shenzhen Environmental Geographic Information Platform".[lxi] An important component of Shenzhen's Environmental Supervision and Early Warning Information System, the platform can model real-time simulations of pollution, conduct impact assessments, and evaluate air pollution control strategies.[lxii]

3.5 Waste

With high population densities, rising consumption, and the refuse associated with both, for Chinese cities, waste management is an essential service. Via smart waste applications, cities can create better, more efficient waste collection systems.

3.5.1 Case study #8: Tianjin: app-based waste disposal for greater convenience

In 2017, a waste management app called Biandoubang was trialed in Tianjin. Through the app, residents classify their waste, and then are informed where the closest appropriate disposal sites are located on a map.[lxiii]
Users looking to dispose of large items can also schedule appointments via the app for door-to-door recycling. To encourage user interest, in exchange for participation, citizens are given credits that can be used to make purchases at participating vendors.[lxiv]

3.5.2 Case study #9: Beijing: experimenting with a smart garbage collection system for improved waste management

In 2016, 378 smart garbage collection sites were installed as a pilot project in Beijing's Jinsongzhong community. All of the garbage cans are equipped with waterproof NFC (near-field communication) tags.[lxv]
Via sensors, site managers can remotely assess real-time data on garbage cans in the area, including can location, can identifying numbers, cans' assigned garbage category, garbage collection time, collection weight, and corresponding collection vehicles. This real-time information can be accessed at any time, enabling optimization of waste collection and management.[lxvi]

3.6 City-level case study #2: Wuxi - the 'capital of IoT'

Selected by the State Council as the designated national sensor network, Wuxi's local government has leveraged policy and technological developments as a means to transform and update the city. Wuxi's expansive IoT infrastructure has enabled the city to quickly implement the smart city concept.

Known as the 'capital of IoT' in China, in 2009, Wuxi was designated the first nationwide hub for IoT development. The city is the test site of the nation's first implementation of in-car entertainment, smart medical care, smart home technology, game competitions, financial insurance, and virtual reality, all using the IoT-enabled sensor network.[lxvii]

Economically, Wuxi's 2,000-plus IoT companies generated a combined income of more than RMB 243 billion (US$ 35.5 billion) in 2017, half of the total income made by IoT companies in the province, and 25% of the national total. The economic security of the city's residents is tied to Wuxi's smart city (and IoT) initiatives: currently, over 180,000 people work in the city's IoT sector, 2.74% of the city's 6.57 million population.[lxviii]

3.6.1 Wuxi's 'IoT towns'

Three towns in Wuxi are leading in IoT development, each with a specialized focus: Hongshan Town (IoT R&D), Huihaiwan Town (sensor manufacturing and technological breakthroughs), and Xueland Town (utilizing IoT to upgrade traditional industries). These towns illustrate the government's level of commitment, 'all in' strategy, and iterative approach towards smart city project implementation.

Hongshan, China's first IoT town, was designed as a model for future large-scale IoT applications.[lxix] Almost all of Hongshan's public services (in collaboration with Alibaba Cloud) are equipped with smart devices for data collection and online smart management. According to Wang Jinjian, Party chief of the district, over 10,000 sensors collect data on water systems, environmental protection systems, energy, and transportation.[lxx]

3.7 City-level case study #3: Wuhan - accelerating urban upgrading via smart city strategies

Wuhan is a leader in smart city implementation, using IoT to bridge traditional and digital infrastructure. As central China's most populous city (approximately 10 million residents as of 2017), Wuhan's economic potential and historical role as a logistics hub make it a strong candidate for upgrading via smart initiatives.
As China's largest water, land, and air transport hub among the country's inland cities[lxxi], Wuhan was formally recognized by the National State Council in 2016 as the nation's most important shipping center.[lxxii] With tier two cities (including Wuhan) considered key drivers for China's future economic growth, national development policies are increasingly being directed at them. Wuhan has benefited from the national 'Rise of Central China' programme, launched in 2004 and now in its second ten-year phase.[lxxiii]

Wuhan was among the first cities in China to pilot the nation's smart city program, and the first city in the world to hold an open tender to global companies for intelligent city designs. Wuhan's pilot smart city projects are predominantly centered around public service applications:

- Sewage management: a trial integrated real-time data system for sewage management.
- Road management: electronic toll collection for several of the city's bridges and tunnels, and a nascent smart parking scheme.
- Connectivity and access to information: Wi-Fi is being extended on the bus network, which will also enable real-time service information.

Infrastructure development: investment into Wuhan's cloud-based GIS information platform has facilitated administrative decision-making and the development of smartphone apps.[lxxiv]

4. Corporates and Start-ups

4.1 PATH: Ping An, Alibaba, Tencent, and Huawei

China aspires to lead in the global realm of smart city development. In support of this vision, Ping An, Alibaba, Tencent, and Huawei (collectively known as PATH) launched a smart city initiative in China. They intend to (continue to) apply their technological capabilities to Chinese cities working on implementing smart city strategies.[lxxv]

A close collaboration between industry and government is mutually beneficial. With over 500 cities throughout the country committed to developing smart city applications, companies (including PATH) are able to test their solutions in the world's largest smart city testing ground. For governments, clear policy directives guide industry players, improving the likelihood of timely execution of smart city strategies. Gains for industry, government, and residents build on layers of technology; for instance, China Unicom, one of China's largest telecommunications provider, will set up NB-IoT networks for 300 Chinese cities as part of the nation's smart city push.[lxxvi]

While PATH is collaborative, a competitive spirit remains. In 2018, Ping An stated its goal to become a top public cloud provider in five sectors: finance, healthcare, smart city, real estate, and automobile. As of 2018, the country's top cloud service provider, Alibaba owns close to half of China's public cloud market, with Tencent holding approximately a 10% market share.[lxxvii]

4.1.1 Ping An

Leveraging China's smart city initiative as an opportunity to expand on its core technologies, Ping An released a white paper in 2018 on smart city strategies, with respect to biometrics, blockchain, AI, big data, and cloud computing.[lxxviii] The paper is the result of ten years of planning and research, and RMB 50 billion in funding.[lxxix] Ping An's smart city applications have been implemented in over 200 Chinese cities, with their online platform facilitating access to over 2,000 services. Strategic partnerships with Shenzhen, Tibet, Chongqing, and Nanning reinforce Ping An's role in implementing top-level design.

4.1.2 Alibaba

An illustration of the necessary close ties between industry and government, in November 2017, the Ministry of Science and Technology appointed Alibaba as one of four 'national champions' leading China's AI development in smart cities.[lxxx] Alibaba's "city brain", a platform which gathers data from sensors, analyzes data in

real time, and identifies potential solutions (see section 3.3.1).

Alibaba Cloud launched Ali Government Cloud in 2017, a platform to help governments integrate different platforms to enable e-government services. Citizen services include, traffic prediction and tax management. In Hangzhou, approximately 36 billion data files from 59 government departments have been integrated into the government's e-service platform, built by Alibaba Cloud. Citizens can access 296 services on this platform by using their ID cards.[lxxxi]
Alipay, Alibaba's largest FinTech solution, is enabling quicker and easier financial transactions that intersect with smart city initiatives. Water, electricity, and gas bills are to be paid through Alipay, the company's online payment platform. As of 2015, city services provided by Alipay covered 19 provinces and 124 cities, with over 4,000 businesses and 100 million users.[lxxxii] With respect to transportation, Alipay has launched a unified payment service that enables the users of the Shanghai, Nanjing, Hefei, and Hangzhou metro systems to replace use of multiple traditional transportation cards with their individual Alipay accounts.[lxxxiii]

4.1.3 Tencent

Tencent will continue to leverage its communication platforms for e-governance, its technological capabilities for more efficient transportation systems, and its cloud computing capabilities via Tencent Cloud.[lxxxiv]

Digital government services:

- "One-stop" government services (e.g. doctors' appointments) are increasingly being integrated into WeChat, through mini apps and official accounts. As of 2015, WeChat-enabled public services covered 12 provinces and 69 cities, serving 200 million users.[lxxxv]
- New business models are being developed to facilitate the reach of digital government services. In October 2017, Tencent, with China Unicom and China Telecom, co-founded Digital Guangdong Network Construction Co., Ltd. The company's focus is to establish digital government services for Guangdong province as a means to eliminate data isolation and utilize more urban information. More than 1,000 systems of 56 provincial government departments in Guangdong province and 21 local government information systems will be migrated to the cloud with the help of Digital Guangdong Network.[lxxxvi]
- New partnerships are being formed with municipal governments. In August 2018, Tencent signed an agreement with the Shanghai Municipal Government to promote smart city projects and facilitate the development of Shanghai's Citizen Cloud system.[lxxxvii]

Applied cloud computing:

- Tencent Cloud's city "super brain" system is creating cost- and time-savings. Via Shenzhen's pilot smart policing project, Tencent's city super brain system saves citizens 4.28 million hours and about RMB 100 million in service costs per year. The system also helped the fire department of a Ningbo town eliminated 79 fire hazards during the 2018 Spring Festival.[lxxxviii]

Transportation:

- Tencent has been developing FinTech payment solutions for greater efficiency in transportation. Working with local governments, bus, and subway companies, Tencent is promoting QR code payment for buses and flights, smart travel assistant, and bus hailing services.[lxxxix]
    - In 2017, Tencent launched the "Tencent Passenger Ride Code" in Guangzhou. Instead of swiping public transportation cards, users scan a QR code via a smart phone app.[xc] The program has since expanded to more than 100 cities including Hefei, Zhengzhou, Sanya, and Chongqing, with approximately 50 million users in total.[xci]
    - The option to pay by WeChat payment is now available at more than 20,000 gas stations, increasing payment efficiency by up 100%.
- Easier bus hailing: In addition to payment systems, Tencent is also piloting a bus hailing service in central China's Zhengzhou city.[xcii]
- Enabling greater connectivity on trains for more access to services: Tencent and Geely set up a joint venture in June 2018 to operate Wi-Fi platforms on Chinese high-speed trains.[xciii]
- Combining solutions and capabilities: Based upon its cloud computing, big data, and AI capabilities, Tencent hopes to build cloud platform services for use in logistics systems, aviation, the metro, bus, and airport. Across all scenarios, Tencent aims to provide precise marketing and data analysis as a means to enable smart solutions.[xciv]

4.1.4 Huawei

Huawei manufactures hardware critical for use in smart city implementation, such as smartphones and T-boxes - an in-vehicle communication module that enables cars to connect to a network and transmit data.[xcv]

The company's smart city platform is one of its key smart city initiatives for use both in China and around the world. An open solution platform, it combines technologies including sensors, AI, hybrid cloud, and IoT. This enables officials to utilize the data available from video and data sensors in real-time live 3D maps, which can be used to identify potential problems such as traffic jams.[xcvi]

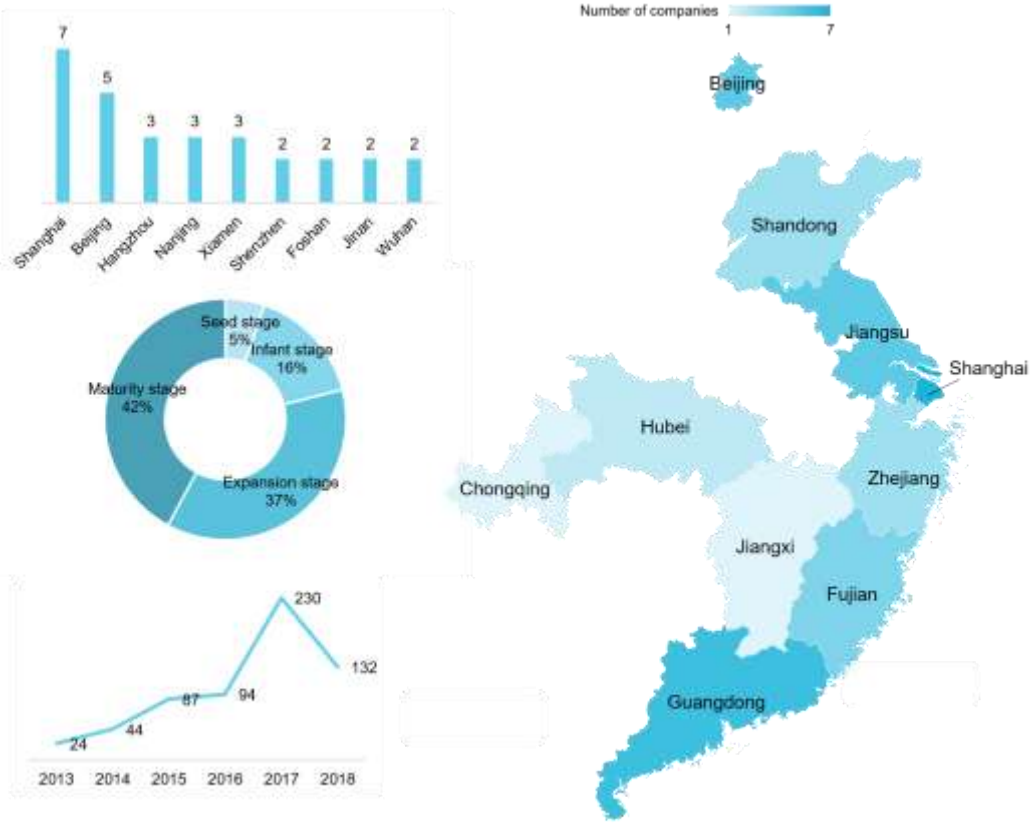
4.2 Start-Ups

In China, it is mainly the tech giants that are leading smart city initiatives, for example, Baidu's facilitation of the Shanghai government's smart transportation solutions, and Alibaba's close collaborative relationship with the Hangzhou government (see section 4.1). Few start-ups have a singular focus on smart city solutions: most applications developed by start-ups are usually one of multiple product application areas. In the past three years, over 30 smart city-related companies have received investment capital, much fewer than those specializing in big data (over 200 companies, as of 2019).[xcvii]

However, there are still several noteworthy Chinese start-ups with smart city product applications. Key players include SenseTime, Horizon Robotics, and Yitu Technology. A 'unicorn' valued at US$ 6 billion (after series D financing),[xcviii] SenseTime is sought after by governments for its vision recognition solutions. Collaborating with several cities, the company recently signed a strategic cooperation agreement with Sanya city to improve the city's smart travel solutions.[xcix]

Horizon Robotics, a high-profile start-up founded by the former head of Baidu's AI unit and backed by Intel, views the smart city as one of their main application scenarios.[c] Horizon is developing embedded AI processors and algorithms for autonomous vehicles (AV). Together with AVs, this technology will also enable ICV (intelligent connected vehicles) infrastructure to optimize traffic flow on the city level.

Figure 3 (anticlockwise): Bar chart: Chinese cities with the greatest number of smart city-related companies that received investment capital (2016-2019). Pie chart: Number of companies (related to smart city initiatives) that received investment capital, by different investment stages (2016-2019). Line chart: Annual number of investment deals (related to smart city initiatives) in China (2016-2019). Heat map: Number of smart city-related companies that received investment capital (2016-2019).



Smaller start-ups, such as Xinyi Information Technology, which received an RMB 10 million investment in its series A funding round in December 2018, are rising players in smart city applications.[ci] A Shanghai-based start-up, Xinyi produces NB-IoT chips that can be deployed in waste management systems, smart lighting, pest control, environment monitoring, and other use cases.

Another start-up, Zillion, produces IoT sensors for environmental and water monitoring. Currently, it has established strategic partnerships with Huawei, Alibaba Cloud, and MXCHIP. In terms of water monitoring, Zillion's sensors and terminals, combined with big data analysis, enable real-time operational monitoring of a water system, from source to faucet to sewage outlet.[cii]

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