Disaster Risk Reduction
Methods, Approaches and Practices

Jinling Hua
Bismark Adu Gyamfi
Rajib Shaw *Editors*

Considerations for a Post-COVID-19 Technology and Innovation Ecosystem in China

Springer

Disaster Risk Reduction

Methods, Approaches and Practices

Series Editor

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Disaster risk reduction is a process that leads to the safety of communities and nations. After the 2005 World Conference on Disaster Reduction, held in Kobe, Japan, the Hyogo Framework for Action (HFA) was adopted as a framework for risk reduction. The academic research and higher education in disaster risk reduction has made, and continues to make, a gradual shift from pure basic research to applied, implementation-oriented research. More emphasis is being given to multi-stakeholder collaboration and multi-disciplinary research. Emerging university networks in Asia, Europe, Africa, and the Americas have urged process-oriented research in the disaster risk reduction field. With this in mind, this new series will promote the output of action research on disaster risk reduction, which will be useful for a wide range of stakeholders including academicians, professionals, practitioners, and students and researchers in related fields. The series will focus on emerging needs in the risk reduction field, starting from climate change adaptation, urban ecosystem, coastal risk reduction, education for sustainable development, community-based practices, risk communication, and human security, among other areas. Through academic review, this series will encourage young researchers and practitioners to analyze field practices and link them to theory and policies with logic, data, and evidence. In this way, the series will emphasize evidence-based risk reduction methods, approaches, and practices.

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ISSN 2196-4106 ISSN 2196-4114 (electronic)
Disaster Risk Reduction
ISBN 978-981-16-6958-3 ISBN 978-981-16-6959-0 (eBook)
https://doi.org/10.1007/978-981-16-6959-0

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

Although China was the first country to be affected by COVID-19, it was possibly the first country to recover as well. During the COVID-19, China has utilized a significant number of emerging technologies to monitor and reduce the impacts of the infection. The COVID-19 management system of China is based on a strong hierarchy governance mechanism, which provides the guarantee for prevention and control.

The book has eleven chapters all together. The book starts with an overview and description of technology innovation ecosystem. This is followed by chapters on different types of technologies, like drones, social media, digital economy, big data, robotics, artificial intelligence, 5G and IOT/IOE. Finally, the book provides a road map for post COVID-19 technology ecosystem in China and its implications to the world.

Covering significant aspects of technologies for COVID-19 pandemic response, this book is intended for students, researchers, academia, policy makers and development practitioners in the fields of public health, emerging technology and policy of China, which has a strong relevance to Asia Pacific and beyond. It will help to better understand the historic growth of technology in China. We will be happy if the readers find this book useful and relevant.

Fujisawa, Japan

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About This Book

COVID-19 has made differential impacts to countries and communities around the world. China, where the COVID-19 started has utilized/used/developed different types of technologies to address the pandemic risks. Over last 10 months, there has been tremendous development in different types of technologies, in terms of both traditional as well as disruptive technologies. Also, there were many innovations of applying technologies in different context, during pandemic, as well as post pandemic recovery and preparedness aspects. This book will cover some of these technology development as well as its governance mechanism to develop a technology and innovation ecosystem in post COVID-19 context in China.

This book analyzes recent advances, trends, challenges and potentials of technology and its ecosystems in post COVID-19 China. Covering different aspects of technologies this book is a valuable resource material for students, researchers, academia, policy makers and development practitioners.

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Rajib Shaw is a professor in the Graduate School of Media and Governance in Keio University, Japan. He is also the Senior Fellow of Institute of Global Environmental Strategies (IGES) Japan, and the Chairperson of SEEDS Asia and CWS Japan, two Japanese NGOs. He is also co-founder of a Delhi (India) based social entrepreneur startup Resilience Innovation Knowledge Academy (RIKA). Earlier, he was the Executive Director of the Integrated Research on Disaster Risk (IRDR) and was a Professor in Kyoto University. His expertise includes disaster governance, community-based disaster risk management, climate change adaptation, urban risk management, and disaster and environmental education. Professor Shaw was the Chair of the United Nations Science Technology Advisory Group (STAG) for disaster risk reduction; and currently the Co-chair of the Asia Pacific Science Technology Academic Advisory Group (ASTAAG). He is also the CLA (Coordinating Lead Author) for Asia chapter of IPCC's 6th Assessment Report. He is the editor-in-chief of the journal "Progress in Disaster Science", and series editor of a Springer book series on disaster risk reduction. Professor Shaw has published 51 books and over 400 academic papers and book chapters.

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Chapter 1
Overview of Post COVID Scenario in China

Jinling Hua and Rajib Shaw

Abstract China was the first country to be affected by coronavirus (COVID-19) and was also the first country to initially recover from the disaster. While several other affected countries could have the opportunities to learn from each other, for China, it was its own efforts which made it stand out to overcome the disaster. A strong government protocol, severe surveillance, structured community group, disciplined citizens and use of innovative technologies are some of the reasons behind China's success to COVID-19. While the country is back to normal, and focusing mainly on the vaccine outreach, this chapter drew lessons of last one and half year of pandemic experience of China and brings out issues related to governance, technology and education/ public awareness.

Keywords COVID-19 · Centralized governance · Local governance · Citizen group · Technology and innovation

1.1 Introduction

COVID-19 was reported in Wuhan in China in December 2019, became a global pandemic in March 2020, and for last one and a half year (at the time of the writing of this chapter) had affected more than 160 million people globally with a death of 3.3 million in 190+ countries. This made COVID-19 as one of the severe-most disaster in century. The numbers of affected people, livelihood losses, economic disruptions are extremely high, and it is difficult to make a safe estimate. The psychological/mental stress arises during last one and a half year will have a longer repercussion. The ecological footprint of the disaster is also deep rooted. In spite of all these negative consequences, we have seen tremendous amount of innovation, both in terms of

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J. Hua et al. (eds.), *Considerations for a Post-COVID-19 Technology and Innovation Ecosystem in China*, Disaster Risk Reduction,
https://doi.org/10.1007/978-981-16-6959-0_1

technological, social and process-based approaches in many countries. While online education, work and health services becoming common in many developed countries, rural areas of developing countries with less digital connectivity feel the heat of the digital divide the most. World Economic Forum (WEF) Risk Outlook (January 2021) has put infectious disease as one of the greatest global risk in terms of impact, and fourth in rank in terms of likelihood. It is interesting to note that the same infectious disease was in the moderate likelihood and low impact risk in 2020 report (release in January 2020). Digital power concentration and digital inequality are some of the new risks which are arising in 2021, which was not there in the earlier WEF risk outlook. A strong north–south digital divide is arising, which is also prominent in urban rural areas. The digital divide is also prominent in age, gender, etc. Therefore, digital inclusivity is a key issue which needs attention globally, regionally, nationally and locally, depending on the context.

In this chapter, a brief outline of COVID-19 responses in China is provided, with specific focus on key governance and technology-related decisions and milestones. The chapter also sets the stage of different emerging technologies as arise in the post COVID-19 scenario in China. It provides a brief outline of different other chapters presented in this book.

1.2 COVID-19: China's Response

1.2.1 Overview

Looking back on China's COVID-19 strategy over the past one and half year, we can say that the prevention and control strategy has worked effectively for the country. The key to success lies in China's effective combination of the classical infectious disease strategy of "city closure" in combination with new technology. Since the closure of Wuhan City on April 8, 2020, although local infections have occurred in various regions, the number of new infections per day among the 1.4 billion people in China has been controlled below 400. China resolutely implements prevention and control work, aiming to control the number of infected people to zero (Fig. 1.1).

For the infected areas, China's implementation of a thorough strategy is a large-scale "city closure," at the same time, through new technology to effectively manage and serve the infected people. The fundamental reason for the flexible operation of this huge countermeasure mechanism lies in China's "community." Strong governance policies, strict regulations, full use of new technologies and close communication with communities and residents form a "Chinese way" of the COVID-19 response.

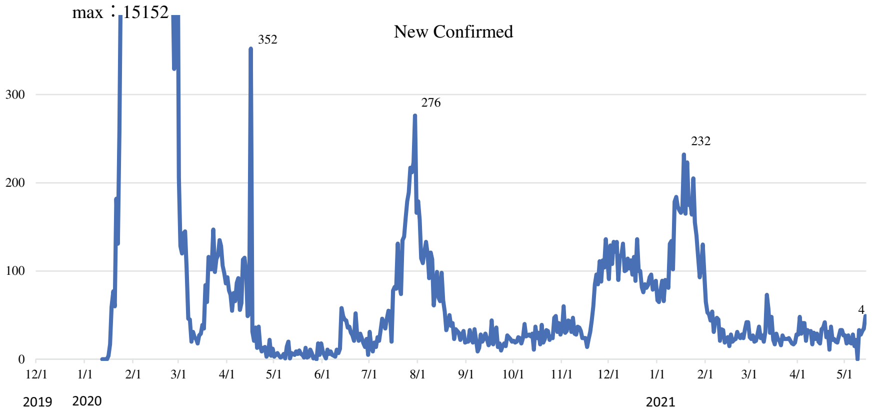

Fig. 1.1 COVID-19-infected numbers over timeline (*Source* This figure was prepared by the Authors using original data from Sina News)

1.2.2 Development of the COVID-19 Response System

The COVID-19 management system of China is based on a strong hierarchy governance mechanism, which provides the guarantee for prevention and control. After the outbreak, a system of provincial, municipal, district, county and township management evolved, where the central government played the key role, and ensured the governance and decision flow and its implementation in the lower level of governance structure. The Central Committee of the Communist Party (CCCP) of China established the command department of the prevention and control of COVID-19 to comprehensively coordinate and command the national epidemic situation. Provinces, cities, districts, counties and townships were asked to establish corresponding epidemic prevention and control headquarters in coordination with relevant government departments at all levels and to follow the overall arrangement of epidemic prevention and control of the government departments at the next higher level. Under the leadership of their respective epidemic control headquarters, each region took the community epidemic prevention and control leading group as the implementation center to implement the epidemic prevention measures. This "top-down" joint prevention and control system could concentrate national forces to fight the epidemic in a short time and effectively guarantee the party and the state's core leadership in the national epidemic prevention and control work.

1.2.3 Various Roles in the Community

In community organizations, the Party branch secretary is the leader, and the community residents committee, property service enterprises, volunteers, social organizations and other forces are fully mobilized to form a community epidemic prevention platform with multiple roles and responsibilities. The platform provided human resources for the development of epidemic prevention and control community team. Among them, the Party branch of the community, as the political core body of community epidemic prevention, plays a role of grasping direction, overall planning and organizing and coordinating. As an autonomous organization of community residents, community neighborhood committee is an important force to participate in community epidemic prevention. The smooth development of community epidemic prevention work cannot be separated from the human and intellectual support of the residents committee. Property service enterprises were professional community service providers. In the actual countermeasures, they mainly did community environmental improvement and management of people, which ensures the normal life of residents in different stages of epidemic situation. Volunteers were the reserve forces of community epidemic prevention, which inject a continuous vitality into the prevention and control of community epidemic, and fully mobilize the enthusiasm of community people to participate in community epidemic prevention. Social organizations had the characteristics of autonomy and non-profit, which made great contributions to coordinating social organizations in psychological health counseling and epidemic prevention materials management.

1.2.4 Functions and Management Mechanism of Community Epidemic Prevention Leading Group

Multisubject co-governance was the premise of community epidemic prevention work, and the cooperation and management mechanism between multi departments was an important guarantee mechanism for the smooth development of community epidemic prevention and control work. Throughout Wuhan City closure period and after the implementation of countermeasures in various regions, the community epidemic prevention leading group basically had the following functions and systems: (1) epidemic prevention counseling group, (2) epidemic information group, (3) epidemic prevention logistics group, (4) epidemic prevention rectification group and (5) epidemic prevention fund management group and other functional departments.

- *Epidemic prevention counseling group*: It is mainly to improve residents' awareness of prevention, guide residents to pay attention to authoritative information and stabilize residents' emotions to avoid unnecessary panic. It also provides door-to-door help services for special groups or people in need to help residents solve their problems during the epidemic prevention period and alleviate the social and psychological problems caused by the epidemic.
- *Epidemic information group*: The target of this group was to improve the basic information of community residents and comprehensively grasp the composition and flow of community personnel. Detailed statistics of community migrant information includes time, reasons, transport mode, peer information, etc. The group

cooperated with the property management enterprises to supervise the daily information of people in and out of the community, and timely update and submit the relevant data of community residents to the superior departments.

- *Epidemic prevention logistics group*: The group was responsible for ensuring the daily needs of residents and delivering goods to their homes. At the same time, as a link between residents and community organizations, the logistics group was also responsible for collecting relevant opinions and suggestions of community residents and accepting supervision.
- *Epidemic prevention and control group*: During the epidemic period, it was particularly important to ensure the living environment sanitation of community residents. The anti-epidemic environmental remediation group was established to be especially responsible for the remediation and disinfection of community environmental sanitation.
- *Epidemic prevention fund management group*: This group was responsible for the management of epidemic prevention funds, including the funds allocated by superior departments and social donation funds, so as to realize the special purpose of funds, the openness and transparency of fund use.

Hua and Shaw (2020) in their initial analysis for first three months of the pandemic have pointed out that although there was an initial delay in response, a unique combination of strong governance mechanism, linked to participatory community vigilance and engagement as well as citizen cooperation were at the core to the response mechanism. Added to it was the use for big data, digital and emerging technologies. At the initial stage, "*infodemic,*" as it is termed by WHO (World Health Organization) Director General, was the key issue to overcome with proper information sharing and reducing the fake news and misinformation about the risks. Over time, as we came to know about the different characteristic features of the virus and its nature, infection ways, protection measures, etc., gradually the *infodemic* risk became lower. Shaw et al. (2020) in a comparative analysis of China, Korea and Japan have also pointed out the unique combination of governance, technology use and citizen engagement in respective countries for effective response to the pandemic. The analysis emphasized the need of customized local responses of a global pandemic.

1.3 Relevance and Outline of the Book

COVID-19 has made differential impacts to countries and communities around the world. China, where the COVID-19 started has utilized/used/developed different types of technologies to address the pandemic risks. Over more than a year, there has been tremendous development in different types of technologies, in terms of both traditional as well as disruptive technologies. Also, there were many innovations of applying technologies in different context, during pandemic, as well as post pandemic recovery and preparedness aspects. This book covers some of these technology development as well as its governance mechanism to develop a technology and innovation ecosystem in post COVID-19 context in China.

The book has eleven chapters all together. The first chapter focuses on the COVID-19 responses in China and post COVID-19 technology development. The chapter also provides an outline of other chapters and provides a few post-scripts.

Second chapter focuses on historical development of Chinese technology ecosystem. Although this book is mainly covering on post COVID-19 technology development, we need to understand the historical perspective of Chinese investment in science and technology over last couple of decades. The Chinese government has placed emphasis through funding, reform and societal status on science and technology as a fundamental part of the socioeconomic development of the country as well as for national prestige. The twenty-first century has thus seen a series of central government initiatives designed to promote "indigenous innovation" and technological development more generally in China. These include the National Medium- and Long-Term Program for Science and Technology Development (2006–2020), the Strategic Emerging Industries initiative, the Internet Plus initiative, and the Made in China 2025 Program, among others. Today, China's science investment is largest in the world. Thus, China has developed an innovation and technology ecosystem, which has been nurtured by COVID-19, and further growth is expected in different existing as well as new technologies and its application in different ways. This chapter will throw light on the historical perspectives, while keeping in mind the future growth strategy.

Third chapter focuses on drones, also known as unmanned aerial vehicles (UAV). It is an unmanned aircraft operated by radio remote control equipment and self-carrying program control device. At present, drones have been widely used. By adding payloads, drones play an important role in agriculture and forestry operations, power line patrol, meteorological monitoring, aerial photography and other fields. Since the COVID-19 epidemic, drones have frequently appeared in the work of fight against COVID-19. In the detection stage, drone provides strong technical support for temperature measurement. In the prevention and control stage, drone effectively guarantees the safety of front-line medical workers. In terms of material supply, drones have improved supply efficiency. The importance of drones in the fight against pandemics highlights their advantages. It is expected that drones will usher in a rapid development stage in the industry in the future. This chapter studies the impact of drones on the prevention and control of the COVID-19 epidemic, analyzes the specific operations of drones during the epidemic prevention period and proposes ideas for the future development of drones in the post COVID-19.

Fourth chapter focuses on social media. As the world enters a post-epidemic society, the function of social media has highlighted its role in the spread of information during the COVID-19. This chapter is to introduce the impacts of social media in China during the COVID-19. It is divided into four parts. The first part is to introduce the development and progress of social media since 2000, and to understand its role in the spread of the incident. The second part is to introduce and evaluate the performance of social media in China during the COVID-19. The third part is to analyze the impact of social media in the epidemic in China through several case studies. The fourth part is to point out some of the problems of social media exposed in this epidemic, try to analyze it and make directions for handling of crisis events in the future.

Fifth chapter focuses on digital China. In the era of digital economy, whoever seizes the digital economy will seize the first opportunity. This chapter summarizes the development process of China's digital economy and the overall digital scale of the information industry so far. This chapter examines both the universal features and unique aspects of China's digitalization process. The concept of digital economy has four meanings: digital industrialization, industry digitization, digital governance and data value. Digital economy has become the key driving force of global economic growth. In 2019, the scale of digital economy in 47 countries around the world reached US $31.8 trillion, accounting for 41.5% of GDP, and the average nominal growth rate was 5.4%. Under the situation of increasing downward pressure on the global economy, the sustained, stable and rapid development of digital economy has become an important driving force for stable economic growth. In the future, with the continuous innovation of digital technology, accelerating the integration of traditional industries, the role of digital economy in promoting economic growth will become increasingly prominent. Big data, artificial intelligence, cloud computing and other new-generation information technologies are fully integrated into various fields of consumption at a faster speed. With the continuous acceleration of digitization, networking and intelligence, many new formats have been cultivated to accelerate the release of information consumption demand.

Sixth chapter covers big data. The big data is a new conception known by civilians in recent 10 years. However, we have discovered the important role of big data in China during the period of pandemic. To make a research on epidemic control in China during the last 10 months, the big data will be an essential point. We will firstly clarify what the big data is and its evolution in China in this chapter. Then, the big data applied for epidemic control will be divided to several typical types; their applications will be studied in the case of first wave from Wuhan and the case of Xinfadi market in Beijing. The important role of big data in economic recovery will also be analyzed, and based on the analysis, there will be a suppose for the future direction of big data in China.

Seventh chapter explores robotics, which have been a centric point for development in recent years. It is also an industry supported by Chinese government which had a certain scale before COVID-19. We could see the robotics have played an important role during the pandemic; it was also influenced by COVID-19. In this chapter, we will clarify at first the definition of robotics in China, then make an analysis of the special development ground and evolution of robotics in China. The centric part will be the analysis on practice of several typical robotics during COVID-19, and we will point out the deficiency of the robotics industry in China then create an outlook for its future development.

Chapter eight covers artificial intelligence. There are many ways authorities are using artificial intelligence (AI) to combat the deadly virus in China during this pandemic. I want to focus on the most crucial exploits, mainly, which are the use of the Facial recognition thermal scanners and Chest X-ray Pneumonia Classification. Facial recognition thermal scanners integrate body detection, face detection and dual-sensing via infrared cameras and visible light to help staff working at various open area locations to identify people who have elevated body temperatures swiftly. Chest X-ray imaging is one of the most widely used and cost-effective diagnostic methods for suspected thoracic diseases such as pneumonia, and of course, the COVID-19. Unlike tomographic imaging methods such as CT and MRI, the chest X-ray is a 2D projection of all soft and hard tissue structures in the chest. It typically has low contrast and superimposed overlying and underlying structures, making an accurate diagnosis and expert radiological tasks. Overall, this chapter aims to analyze the utilization of AI in preventing the epidemic in China and the rapid and accurate diagnosis of pneumonia caused by COVID-19. Moreover, this research identifies their positive impact on people's attitudes toward health and new technology, specifically, the implementation of artificial intelligence in the areas of medicine and public health. These literature reviews and analyses are essential to overview China's technology and innovation ecosystem's status amid the COVID-19 pandemic.

Chapter nine focuses on 5G. Mobile communication basically has a generation of ten years. The first few years before each generation starts is a mature process, and there are many version upgrades during each generation. It can be said that the technology is constantly improving. It is obvious that the technology is not mature when it is just commercial, especially 5G. The completion of 2G international standard was completed in 1987, and commercial use was in 1991. There was nearly four years in between. For 3G, 3GPP standard was completed in 1999, ITU was in 2000, and the earliest commercial application was in 2001. There was also more than a year or even two years. The completion of 4G standard and the earliest commercial use of 4G were 2009 and 2010 respectively, with an interval of one year. However, 5G commercial almost keeps pace with international standards. Therefore, in this sense, we can say that 5G is not mature enough, which is also true in foreign countries. In terms of the development of China's mobile communication, 1G is 6 years later than the international first commercial, 2G is 3 years later, 3G is 6 years later, 4G is 3 years later, 5G is synchronous. Therefore, it can be said that in the past few generations, the developed countries began to use commercial products several years later, and basically used foreign products. To 3G, China began to have some domestic brands, 4G has been greatly improved. By 4G, there is less risk of trial and error in China, because others are ahead. However, due to the later commercialization in developed countries, China has not only paid the market price, but also has to bear the increased product cost due to the lag of its own patent, thus the industrial chain has lost the opportunity to lead. The chapter will address: (1) what is the policy position of the 5G of COVID-19 in China's scientific and technological innovation, (2) how is it developed, (3) how does it drive China's economy out of the post COVID-19 era and (4) promote China's economic development? These series of questions would be the key topic of concern to the future world.

Chapter ten focuses on Internet of Things (IoT) and Internet of Everything (IoE). China's IoT has been booming since 2009 and has gradually become an important part of China's new social infrastructure and the key to supporting the development of China's digital economy. Its technology and application innovation emerge in endlessly and occupy an important position in the development of smart city. According to the latest data, the proportion of smart cities in China's IoT industry is the largest, followed by industrial IoT with 20%, smart home with 18% and IoV with 16%. Looking forward to the future IoT, IoV is an important part of national transportation development and personal travel. China's IoV adopts LTE-v2x cellular communication technology and gradually transits to 5G-V2X through NR-V2X. With the development of China's IoV, China has made great achievements in automobile manufacturing, communication and information, and road infrastructure construction. On the other hand, China is playing a more and more important role in the formulation of international C-V2X, 5G and other new-generation communication standards. By the end of October 2020, the total number of automatic driving patents in the world has exceeded 70,000, of which the overall authorization rate of automatic driving patents in China is close to 42%. In 2020, smart home accounts for 43%, IoV 11%, public health 8% and smart agriculture 7%. The most important connection center of personal IoT in family scene is mobile phone. The most important connection center of personal IoT in work scenario is PC. College students are mainly connected around personal intelligent products in the campus scene. In the scene of going out, users usually swipe their cards in public transportation and subway through personal intelligent products. About half of the people in sports choose to use smart bracelets/watches to improve their sports efficiency. China's IoT connection content is also constantly enriched, more and more toward the development of the era of IoE.

Chapter eleven covers the future role of technology in the global scenario. Timely, efficiency and accuracy are the many attributes widely associated with the performance, utilization and functionality of cutting-edge tools employed within the technology and innovation spectrum. The advancement of these tools has initiated a new norm of human life where artificial intelligence (AI), augmented and virtual reality (AR, VR), blockchain (BC), Internet of Things (IoT) and other sophisticated autonomous mechanisms have become part of the society and are deployed in complex, challenging phenomena initially deemed impossible. However, the urgency for workable management plans, monitoring and management of the current COVID-19 pandemic as well as the need for a swift development of vaccines are opening a new frontier to the applications that suggest that all options are must be put to their fullest, as well as maintaining existing societal regulations. To be able to understand and track the triggering events that is initiating technologies and societal changes, this chapter looks at the new societal norms in respect to pandemic control and the advancement in the application of destructive technologies and innovations. Using literation reviews technique, it is evident that the urgency to control the pandemic is creating a new society that where safety supersede all aspects of lives. However, it is revealed that this situation is gradually blurring the line between pandemic control and issues of ethical, security and human rights concerns. Therefore, if measures are not put in place for definite scope and boundaries of the application of the technologies, a post COVID-19 society could be marred with difficulties that may marginalize of bestow certain levels of excessive authority to managers of the technologies to the detriment of other stakeholders.

1.4 Postscript

It will be interesting to see the progress of technology and its application in China as well as other countries in the future. It is said that the COVID-19 has accelerated an innovation of 20 years into 1 year. However, high-speed technology development may create darker spots in terms of technology penetration. Inclusive technology innovation and application is the need of the hour. Therefore, it is very important that technology goes well with governance and people/community empowerment/participation/engagement. The next few chapters in the book cover overall governance decisions in historic perspectives, as well as specific technologies of drones, social media, digital China, big data, robotics, AI, 5G and IOT. In the interconnected world, China's technology development is linked to the technology application in the region as well as globally. Within China, the penetration of technology in the remote areas or in the rural areas are gradually increasing, and attempts are being made to reduce the gap of technology poverty. With the shared value and benefits of technology, it is important to move toward a safer, sustainable and people centric society. Possibly, we will be better prepared to cope with the next pandemic in future.

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Chapter 2
Innovation and Technology Ecosystem: Historical Perspectives

Jinling Hua and Rajib Shaw

Abstract Although this book is mainly covering on post COVID-19 technology development, we need to understand the historical perspective of Chinese investment in science and technology over last couple of decades. The Chinese government has placed emphasis through funding, reform and societal status on science and technology as a fundamental part of the socioeconomic development of the country as well as for national prestige. The twenty-first century has thus seen a series of central government initiatives designed to promote "indigenous innovation" and technological development more generally in China. These include the National Medium- and Long-Term Program for Science and Technology Development (2006–2020), the Strategic Emerging Industries initiative, the Internet Plus initiative and the Made in China 2025 Program, among others. Today, China's science investment is largest in the world. Thus, China has developed an innovation and technology ecosystem, which has been nurtured by COVID-19, and further growth is expected in different existing as well as new technologies and its application in different ways. This chapter will throw light on the historical perspectives, while keeping in mind the future growth strategy.

Keywords Strategic guidelines · Indigenous innovation · Technology ecosystem · Growth strategy

2.1 Introduction

The development of science and technology in China today is no coincidence. China's scientific and technological innovation achievements has a historical accumulation for the past 100 years. Tracing back history to 1895, that year, Tianjin Beiyang

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J. Hua et al. (eds.), *Considerations for a Post-COVID-19 Technology and Innovation Ecosystem in China*, Disaster Risk Reduction,
https://doi.org/10.1007/978-981-16-6959-0_2

Western learning school, the first modern university in China (Tianjin Beiyang Western learning school), was approved to be established, which is today's Tianjin University. During the half century from 1895 to 1949, domestic wars were incessant, and the working environment of colleges and universities at that time was very difficult. Before the founding of the people's Republic of China in 1948, there were 210 universities in the modern sense in China, which enrolled more than 150,000 students at that time. 150,000 is a rough equivalent to the number of students enrolled in the top two universities in China, which was the number of students enrolled in higher education at that time. By 1949, only more than 30 universities had survived. There are about 50,000 researchers in these research institutions (Xue 2018; MOST 2016).

After the founding of new China, China's scientific and technological development entered a stage of layout and catch-up. One month after the founding of new China, the Chinese Academy of Sciences was officially established. At that time, the central government sent a special working group to the Soviet Union to learn how to build a National Academy of Sciences. The Chinese Academy of Sciences, which focuses on basic research, soon entered normal operation. At the same time, many corresponding applied research institutes were set up in various industrial departments and provinces and autonomous regions (Xue 2018). In the past 70 years since the founding of the people's Republic of China, China's science, technology innovation and technology policy have gone through numerous practices and studies, to provide suitable strategic policy for China's development. China's science and technology has developed more rapidly in recent years and with the catalysis of the pandemic of COVID-19, it has invested and applied many of the new technologies that can be used in the epidemic prevention measures. From the first onset until its current stage, this paper examines this historical perspectives of the development of science and technology in China by dividing it into five periods according to its policy direction. They include technology import, integration of science technology and market, independent innovation, independent innovation-driven development, and catalysis of China's technological innovation ecosystem. This is an extremely long process of exploration and learning, and each stage of the five periods has its decisive role, so as to realize such a sound science and technology innovation ecosystem in China today.

2.2 The Development of Science and Technology Policy in China

This is an extremely long process of exploration and learning. Each stage of the five periods has its decisive role and represents today's technological innovation ecosystem in China (see Fig. 2.1).

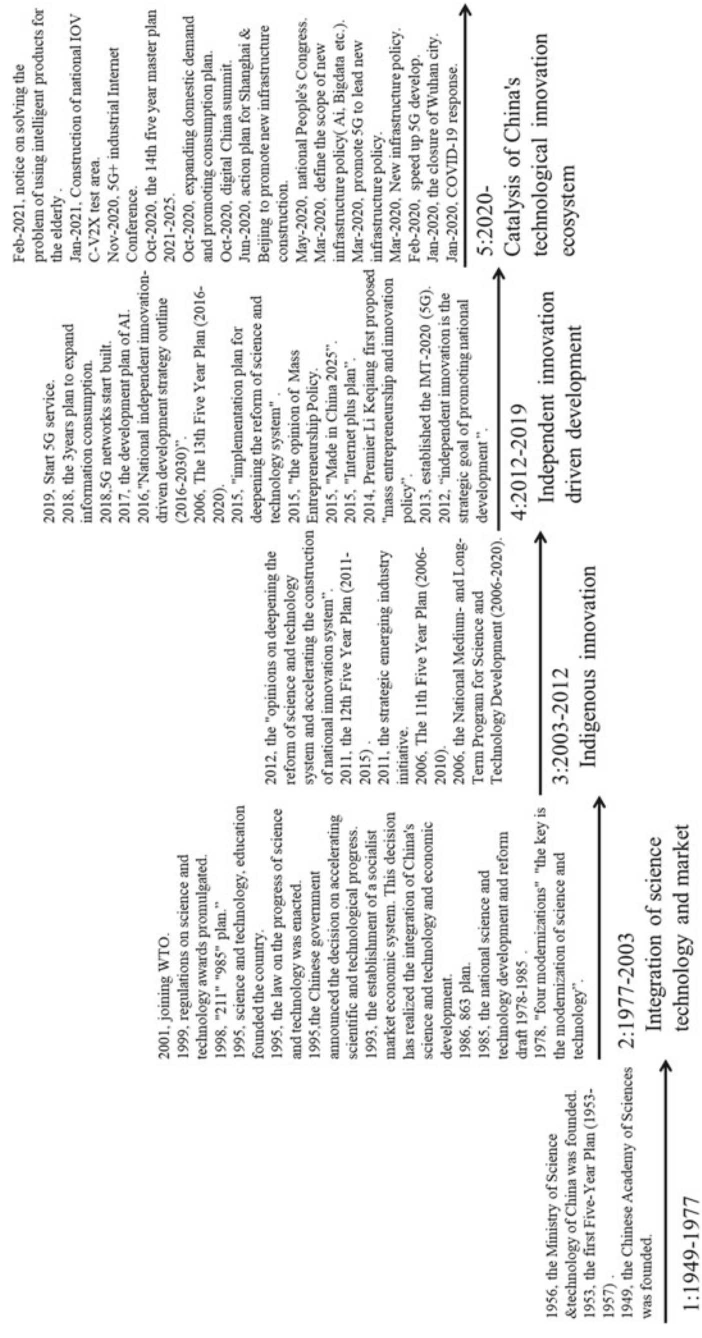

Fig. 2.1 Five stages of science and technology policy in China (*Source* This figure is compiled by the authors references and public materials)

2.2.1 First Period: Technology Import (1949–1977)

This is the early days of the founding of the people's Republic of China (September 1949). There are two points worth evaluating in this stage of science and technology policy. First, the scientific and technological development plan and the national management system were formulated rapidly. The first Five-Year Plan for Science and Technology development (1953–1957) was formulated. Secondly, they began to actively learn from the Soviet Union in the fields of science, technology and education. In the 1950s, China received 6.6 billion rubles of aid loans and 6.28 billion rubles of military aid from the Soviet Union and therefore, in 1951, China began to send students to the Soviet Union. In 1952, it set up a preparatory school for Soviet students in Beijing. By 1953, 63 Chinese universities had reached cooperation agreements with the Soviet Union so in 1956, they began to send university teachers to the Soviet Union. In the ten years from 1950 to 1960, about 90% of China's 9294 people went abroad to study and teach in the Soviet Union, although in 1956, the highest number was 2085 (Gu 2004). The Soviet Union's technical assistance covered all fields of China's national economy under the planned economy mode at that time, which included mining and industrial technology, agricultural technology, education, medical treatment, etc. The Soviet Union sent about 3000 engineers to China, and more than 20,000 Chinese went to the Soviet Union and Eastern Europe to study (Marukawa 2021a).

2.2.2 Second Period: Integration of Science Technology and Market (1977–2003)

The second stage is mainly to link the development of science and technology with the market economy through various regulations and policies, which has also laid a solid economic foundation for the development of the next nearly 30 years (MOST 2016). In March 1978, Deng Xiaoping put forward the "four modernizations" at the "National Science and Technology Conference" held by the CPC Central Committee to realize the comprehensive modernization of agriculture, industry, national defense and science. He reiterated: "the key is the modernization of science and technology" and "science and technology are the primary productive forces". He said: "we must break the rules, discover, create and develop talents, and train world-class scientific and technological experts as soon as possible." The national science and technology development and reform draft 1978–1985 was adopted at the meeting. The moment also witnessed the setting up of regulations of the people's Republic of China on encouraging invention, the regulations of the people's Republic of China on encouraging natural science, the regulations of the people's Republic of China on technological progress, and the patent law of the people's Republic of China were promulgated successively.

The National Conference on Science and Technology brought China's era of "the spring of science." After the "spring of science," the reforms on science and technology human resources, science and technology investment, scientific research institutions, industrial technology and many other aspects have been carried out. In November 1993, the Third Plenary Session of the Fourteenth Central Committee of the Communist Party of China announced the decision of the Central Committee of the Communist Party of China on several issues concerning the establishment of a socialist market economic system, which clearly put forward that, the reform of the scientific and technological system should be carried out simultaneously with the reform of the market economic system. This decision has realized the integration of China's science and technology and economic development. At the same time, various supporting policies have been issued one after another, which provide a strong institutional guarantee for the rapid development of science and technology in China in the next 30 years (MOST 2016; JST 2019a, b).

In May 1995, the Chinese government announced the decision on accelerating scientific and technological progress. China would then implement a strategy of invigorating the country through science and education, mainly to promote economic development and social progress through science, technology and education. In 1998, China launched the "211" higher education development plan and the "985" world-class university construction plan. In order to implement the scientific and technological achievements, the "opinions on venture capital" and "Regulations on national science and technology awards" were published in February 2009 to further encourage scientific research institutions and researchers to carry out innovative incentive measures. At the national scientific and technological work conference held in the same year, the decision on technological innovation, high-tech development and industrialization was also published (Liang 2019; MOST 2016).

In addition, the "100 Talents Program" aimed at cultivating the country's top talents began to be implemented in 1994 and then continued the "1000 Talents Program" (2009) and "10,000 Talents Program" (2012). This talent training policy has lasted for more than 20 years (JST 2019a).

2.2.3 Third Period: Independent Innovation (2003–2012)

Through the practice of reform and opening up and the introduction of foreign investment, more and more Chinese researchers realized that it is not enough for China to blindly catch up with the advanced countries. Hence, they started to explore and propose the necessary and specific development direction of independent innovation with Chinese characteristics. Therefore, the following directional guidance, plans and initiatives are put forward. In 2006, China published the National Medium- and Long-Term Program for Science and Technology Development (2006–2020), in which indigenous innovation was regarded as an important theme (Chen and Naughton 2016; Marukawa 2020). A series of policy documents clarified the goal of building a technologically innovative country, through relevant measures to support investment in scientific and technological resources, tax incentives, finance, government procurement, intellectual property protection, scientific and technological innovation bases and platforms, human resources, education and other 11 fields. A total of 78 supporting policies were issued (MOST 2016; JST 2019a, b).

At the Science and Technology Innovation Conference (2012), the "opinions on deepening the reform of science and technology system and accelerating the construction of national innovation system" was issued to ensure further improvement of science and technology system. According to this opinion, various departments of the State Council have issued more than 200 policy documents and implemented various reforms such as the formulation of scientific and technological innovation policies, the implementation and supervision of scientific and technological innovation policies in the new era. The policy focus during this period was "indigenous innovation" (Chen and Naughton 2016). According to Marukawa and Kajitani (2015), China has experienced technology transfer from the Soviet Union since its establishment and has been developing through the introduction of technology from developed countries and direct investment from foreign companies since the 1980s. China dreams of pushing the technology of Chinese domestic enterprises to the world stage through indigenous innovation in the future and "cultivating well-known enterprises competitive with international famous brands through independent intellectual property rights."

2.2.4 Fourth Period: Independent Innovation-Driven Development (2012–2019)

When entering the fourth stage, China has firmly established the strategic goal of promoting national development through independent innovation, so a large number of policy oriented plans and outlines are issued during this period. At the 18th National People's Congress in 2012, scientific and technological innovation was positioned as the core strategy to improve productivity and national strength. The central government formulated the development strategy by technological innovation and formulated important policies (MOST 2016). In February 2013, the Ministry of Science and Technology, together with the Ministry of Industry and Information Technology and the National Development and Reform Commission, established the IMT-2020 (International Mobile Telecommunications-2020, 5G) promotion group to gather the industry research force in the field of mobile communication, and started the basic work platform for the research and development of the fifth-generation mobile communication technology and international exchanges and cooperation.

In September 2014, Premier Li Keqiang first proposed "mass entrepreneurship and innovation policy" at the opening ceremony of the "Summer Davos conference" with the theme of "creating value through innovation" held in Tianjin (Li 2018). In March 2015, the "Internet Plus plan" was formulated in the "report on government activities" of the third session of the 12th National People's Congress. The plan proposes to make full use of mobile Internet, cloud and big data and IoT to promote the modernization of manufacturing industry, the healthy development of e-commerce, the sound development of Internet finance and promote the development and growth of Internet enterprises in the international market. In May 2015, the State Council announced the "Made in China 2025" (State Council of China 2015a). In June 2015, the State Council issued guidance on promoting "the opinion of mass entrepreneurship and mass innovation" (Mass Entrepreneurship Policy) (State Council of China 2015b). The opinions stipulate the development of fixed broadband network, new-generation mobile communication network and Internet, the acceleration of new infrastructure such as IoT and cloud computing, and the implementation of national new-generation information infrastructure construction projects. It is proposed that "Internet Plus plan" should be integrated with "Made in China 2025" (Liang 2019).

In September 2015, the "implementation plan for deepening the reform of science and technology system" was issued. In order to build technological innovation with Chinese characteristics and improve the innovation vitality of technological innovation subjects, 32 reforms and 143 policy measures were issued in 10 fields (Xue 2018). In May 2016, "National independent innovation-driven development strategy outline (2016–2030)" was issued. In the national science and technology innovation competition held in the month, general secretary Xi Jinping proposed a "three step strategy" for China's science and technology development, and declared to build a world scientific and technological power. Three months later, the 13th Five-Year Plan of national science and Technology (2016–2020) was announced (people's daily, November 28, 2017). In March 2017, Premier Li Keqiang instructed in the government work report to accelerate the development of artificial intelligence and related industries. In July of the same year, the State Council announced the development plan of AI (JST 2019a; MOST 2016).

2.2.5 Fifth Period: Catalysis of China's Technological Innovation Ecosystem (2020~)

China has experienced the previous four stages of development and gradually formed a good all-round technology and innovation ecosystem. It is mainly due to the policy support, strong national fund support, and the entrepreneurship and innovation trend of various industries over the years. These promote the vigorous development of new technologies in all walks of life in China, especially its use of new technologies in the response of COVID-19 in Wuhan and all over the country. That is, after the closure of Wuhan city on January 23, the city was the focus of attention of China and the whole world so two hospitals were quickly built in just 10 days. Through a rapid development, Chinese mobile operators laid 5G communication facilities to the hospital construction site, so that all stakeholders could share the construction progress of Wuhan hospital through a 24-h high-definition online live broadcast. In the subsequent COVID-19 response, the latest technologies such as AI, big data and robotics are widely used in hospitals, government agencies, transportation systems and various amenitized and services at public places.

For example, AI plays an important role in medical CT image automatic diagnosis system and online medical treatment. The AI scanning system developed by Fudan University and Shanghai government is used for the treatment of more than 93% of patients with COVID-19 in Shanghai. Baidu's big data effectively grasped the personnel flow in the early stage of COVID-19, around the Spring Festival and after the resumption of production and work. At the "World Internet Conference" on November 23, 2020, Zhong Nanshan, a Chinese epidemiologist said, "today, technologies such as big data, cloud computing and AI are accelerating the deep integration with transportation, medicine, education and scientific research, promoting the transformation and improvement of the whole society's informatization. Especially for the pandemic of COVID-19, information and communication technology strongly supports the work of COVID-19 response, especially in the aspect of disease epidemic discovery and management. It plays an important role in infectious investigation and judgment, information sharing and disease analysis." This statement leads to the following questions:

- At the critical moment of the outbreak of COVID-19, how did China respond in a timely manner?
- Why did China have so many new technologies that worked for the governance of cowid-19, and
- How did they develop to today's high level?

The answers reply on past China's science and technology innovation strategy, countless practical experience and continuous learning, which has led to the formation of today's sound and developing technology ecosystem in China. The following sections will shed light of some of these issues.

2.3 China's Unique Indigenous Innovation Policy

2.3.1 Characteristics of Indigenous Innovation-Related Policies

Looking back on the prosperity of China's scientific and technological innovation so far, the following scientific and technological policies are of great significance. The National Medium- and Long-Term Program for Science and Technology, the Strategic Emerging Industries Initiative, the Internet Plus initiative, the mass entrepreneurship and innovation and Made in China 2025.

- The National Medium- and Long-Term Program for Science and Technology Development (2006–2020) (2006): This outline puts forward the goal of building

China into an innovative country with world-class scientific and technological strength in the 15 years to 2020. Not only that, it also puts forward the specific implementation method to achieve the goal. The goal can be achieved by increasing the investment in research and development and strengthening the construction of key fields. The specific implementation method is also of great significance. On this basis, three plans have been formulated, the 11th Five-Year Plan of national science and Technology (2006–2010), the 12th Five-Year Plan of National Science and Technology (2011–2015) and the 13th Five-Year Plan of National Science and Technology (2016–2020).

- The Strategic Emerging Industries Initiative (2011): In July 2011, the strategic emerging industries initiative was formulated as part of the 12th Five-Year Plan (2011–2015). The 7 key industries proposed by the strategic emerging industries initiative are basically the same as the 6th content of the 9 strategic themes of "made in China 2025" (Marugawa 2020).
- However, in the "14th Five-Year Plan" (2021–2025) and 2035 long-term goal plan in October 2020, the term "strategic emerging industries" has been reviewed. Moreover, in 2011, all listed industries reappeared in their original form, adding aerospace equipment and marine equipment. In other words, the "strategic emerging industries" of the fourteenth Five-Year Plan is designated as an extension of the twelfth Five-Year Plan (Marugawa 2021b).
- The Internet Plus initiative (March 2015): The Internet Plus initiative defines the goal and specific policy of integration with the Internet. In this paper, the specific objectives of the four aspects of economy, people's livelihood, infrastructure construction and development environment are elaborated and presented as the following;

  i. It aims to improve the industrial structure of manufacturing and agriculture, improve productivity and the acceleration of e-commerce development.
  ii. Promote the development of Internet applications in the fields of health care, education and transportation.
  iii. Further realize the popularization of network, develop the next generation infrastructure such as cloud computing and Internet of things, and realize the industrialization of artificial intelligence.
  iv. Remove institutional obstacles that impede "Internet Plus," achieve substantive progress in data disclosure and credit information system and related legal construction in the public domain.

In the Internet Plus guidance, the ten-year development goal of 2025 was put forward, the industrial ecosystem of networking, intelligence, service and co-integration was basically built. According to this goal, 11 key projects have are put forward. Mass entrepreneurship and innovation later became the first of these 11 priority areas.

- Made in China 2025 (May 2015): In May 2015, the State Council issued "Made in China 2025." It is in accordance with the requirements of "improving the international competitiveness of industrial technology" in the 13th Five-Year

Plan of national science and Technology, striving to build and enhance the advanced manufacturing industry. According to the information released by the State Council of China, “Made in China 2025” proposes to strive to achieve the strategic goal of manufacturing power through “three steps.” The first step: strive to become a manufacturing power in 2025 within ten years. Step 2: by 2035, China’s manufacturing industry as a whole will reach the medium level of the world’s manufacturing power camp. Step 3: by 2049, we will be among the top manufacturing powers in the world. The main fields of manufacturing industry have innovation leading ability and obvious competitive advantage and build a global leading technology system and industrial system (State Council of China 2015a).

Made in China 2025 takes large manufacturing enterprises as the main target, formulates 5 major projects and 9 major strategies. Industrial technology research base construction, intelligent manufacturing, industrial base, green manufacturing and high-end equipment innovation projects. The nine strategies are as follows: 1. to improve the innovation ability of national manufacturing industry; 2. to promote the deep integration of informatization and industrialization; 3. to strengthen the basic ability of industry; 4. to strengthen the construction of quality brand; 5. to implement green manufacturing in an all-round way; 6. to vigorously promote the breakthrough development in key areas; 7. to further promote the structural adjustment of manufacturing industry; 8. to actively develop service-oriented manufacturing and production-oriented service industry; 9. to improve the international competitiveness The development level of urbanization (China’s State Council 2015b).

Marukawa (2020) said that “made in China 2025” is an important part of China’s effective industrial policy. Similar to the industrial policies of the 1990s, made in China 2025 adopts a tree structure, with policies and visions of each industry and theme suspended under a series of policy documents. The difference is that “made in China 2025” is more in-depth and comprehensive. From the perspective of policy objectives, he also pointed out that “made in China 2025” pays more attention to the improvement of policies for small- and medium-sized enterprises and is full of expectations for the development of high-tech industrial enterprises.

Another main purpose of “made in China 2025” is to improve the localization rate of China’s manufacturing industry. “Made in China 2025” is full of strategic atmosphere of import substitution of high-tech industries. Many high-tech industries listed in the document already exist in developed countries. China hopes to catch up with and surpass advanced countries in this aspect through “Made in China 2025” (Wübbeke et al. 2016). However, after COVID-19200, China’s localization direction began to rapidly turn to the strengthening of supply chain. In the fourteenth Five-Year Plan, domestic production will no longer appear. Instead, it is proposed to “improve the level of industry and supply chain.” In other words, “in order to achieve autonomy, controllability, safety and efficiency, we will strategically design and select the supply chain of each industry to promote the improvement and upgrading of all industrial chains.” It can be said that the policy of improving domestic productivity has turned to the policy of improving the security and flexibility of supply chain (Marukawa 2021b).

- The mass entrepreneurship and innovation (June 2015): commonly known as "entrepreneurship and innovation," this was proposed by Li Keqiang at the Davos Forum in the summer of 2014, and then included in the government work report in 2015. In June 2015, the State Council issued the opinions on several policies and measures to vigorously promote mass entrepreneurship and innovation, aiming to improve the ability of individuals and small and medium-sized enterprises with shortage of funds. These measures include tax breaks, supporting the venture capital, subsidies for start-ups, innovation demonstration zones and assistance mechanisms for SMEs (China's State Council 2015a).

This is a highlight of China's science and technology, especially innovation policy. From the perspective of policy orientation, mass entrepreneurship and innovation are mainly aimed at individuals or small- and medium-sized enterprises. Mass entrepreneurship and innovation aims to create a new enterprise by promoting the improvement of the environment and using ICT technology, so as to commercialize good business ideas in time and change and influence the industrial structure. It aims to promote the innovation of individual emerging enterprises or start-up, trying to cultivate a new generation of BAT (Baidu, Alibaba and Tencent). Mass entrepreneurship and innovation is positioned as a new engine of China's economic development.

In order for the public to support entrepreneurship, Chinese government departments cooperate to provide the public with coworking space. By subsidizing entrepreneurs' online expenses, providing relevant software for free, and simplifying enterprise registration procedures, the threshold of entrepreneurship can be reduced. In addition, the system of part-time researcher and the system of students' entrepreneurial leave have been implemented. When the patent is granted, more than half of the income is owned by the researcher, and the entrepreneurship support education plan for researchers and college students has been set up. In addition, it also attempts to build a national entrepreneurial ecosystem by introducing new investment systems such as Internet crowdfunding, technology loan mortgage system and stock mortgage system.

This series of entrepreneurial support has a strong sense of establishing a competitive advantage in science and technology entrepreneurship, which is different from the general entrepreneurship. Many ministries and agencies are involved in supporting entrepreneurship. In August 2015, the State Council held a coordination meeting between ministries and agencies to prevent vertical management. The meeting is held twice a year to coordinate various ministries and agencies to support start-ups. For important issues, the adjustment must be reported to the State Council (JST 2019a). Li Keqiang also proposed that this should be integrated with related innovation work, such as "Made in China 2025" and "Internet Plus" (Li 2018). In this policy, 96 measures have been launched in nine major areas. On this basis, more than 1000 entrepreneurship support measures have been implemented (62 policies of the State Council, 258 policies of various ministries and commissions, and 713 policies of local governments). This led to the development of a number of new companies. The government even requires large Internet enterprises and telecom enterprises to open platform connectivity, data, computing power and other resources to small- and medium-sized enterprises and emerging enterprises, and provide tools, enterprise management, marketing and other support and services. Among them, Tencent has been actively involved in providing various kinds of assistance to emerging enterprises, opening up free commercial instant media WeChat apps, WeChat payment and WeChat official account to many new companies. As a result, many emerging companies have developed rapidly with this platform, including the Chinese version of Uber and Didi Kuaiche (Li 2018).

2.3.2 Positioning of China's Indigenous Innovation—Related Policies

The (a–e) policies in 3.1 above are sorted out according to their level and time (see Fig. 2.2).

(a) The National Medium- and Long-Term Program for Science and Technology Development (2006–2020) (2006)
(b) The Strategic Emerging Industries Initiative (2011)
(c) The Internet Plus initiative (March 2015)
(d) Made in China 2025 (May 2015)
(e) The Mass entrepreneurship and innovation (June 2015).

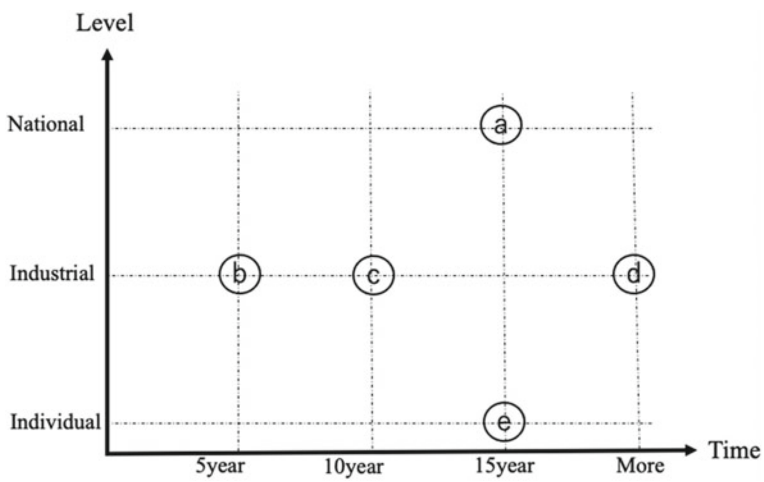

Fig. 2.2 Level and time of (a–e) policies (*Source* Sorted out by the Authors)

These policies are divided into three levels: national, industrial and individual. The implementation time is divided into 5, 10, 15 and more years. According to the direction of the policy, (a) clearly put forward the national medium and long-term goals, the 15-year goal is divided into 3 stages, and the specific implementation guidelines are formulated. (b) Finally, the content of the mentioned industrial fields is summarized in (d). (c) The development strategy of Internet-related industries in all aspects has been formulated. (d) Detailed "action plans" and "implementation guidelines" for various industries have been implemented, and policies for small and medium-sized enterprises have been adjusted. (e) Put forward policies to promote mass entrepreneurship and innovation. Premier Li Keqiang pointed out that the significance of promoting mass entrepreneurship is not only to increase employment and income, but also to improve the mobility among social strata, which helps to realize fairness and realize the dream of equality and freedom for all. The mass entrepreneurship and innovation policies has greatly promoted the establishment of start-up company.

From the national medium- and long-term planning objectives to the industrial field, and then to the formulation of science and technology innovation matrix policy based on mass entrepreneurship is a major feature of China's science and technology policy, is also a process of continuous exploration and correction learning.

2.3.3 Framework of China's Science and Technology Innovation Policy System

Since China's reform and opening up in the 1980s, the reform of China's science and technology system has continued to advance, constantly strengthening the support of science and technology for social development, people's livelihood, ecological environment and national security. Especially after the 18th people's Congress of the Communist Party of China, science and technology innovation was placed at the core of the overall national development, innovation-driven development strategy has been vigorously implemented. Furthermore, science and technology system reform has been continuously promoted. The main structure of science and technology system has been established, and the pattern of reform-driven innovation and innovation-driven development has been basically formed.

At present, China has gradually formed a set of scientific and technological innovation policy development path and policy measures continue to improve. It has basically formed a science and technology innovation policy system with wide coverage, complete categories and diversified tools (He 2011, 2019; Sun et al. 2016; Chen et al. 2013; Fan et al. 2012; Yang et al. 2020). MOST (2016) and some researchers have classified China's science and technology innovation policy system (He 2020; Zhou et al. 2012; Fan et al. 2012). This chapter makes a further summary as follows.

In China's science and technology innovation policies, 8 types of policies can be formed for the elements, subjects, linkages, industries, regions, environment, openness and feedback of the innovation system. The first is the innovation factor policy, which mainly includes talent, investment and technology facilities policy. The second is the main body of innovation policy, including enterprise innovation policy, colleges and universities. Third is about innovation related policies, including the transformation of scientific and technological achievements, the combination of science and technology and finance, and the policy of civil military integration. Fourth includes industrial innovation policies and innovation policies for specific industries, such as new energy vehicles, IC and mobile phone localization policies. Next is regional innovation policies, such as science and technology parks, high-tech areas and so on. The sixth is to innovate environmental policies, including innovation governance and ecological policies. The seventh is the policy of opening up and innovation, including the policy of international science and technology cooperation and opening up and the eighth is systematic feedback policy, including science and technology evaluation and supervision.

Need to pay attention to here is that different industries have different innovation modes, and we need to take different innovation forms in different regions according to the characteristics of regional economy. For example, the establishment of independent innovation demonstration zones, high-tech zones and so on. After the initial development, there is the need a set of reasonable innovation governance system to promote the formation of innovation ecology, and innovation needs good environmental protection. It needs the cooperation of governments at all levels or international cooperation. Finally, information feedback such as science and technology supervision and evaluation is needed to further promote the sound development of innovation system (see Fig. 2.3).

2.3.4 Chinese Investment in Science and Technology

According to OECD (2018) data and Progressive research service (2020), global R&D expenditure in 2018 was US $2.107 trillion. The USA is the world has the largest R&D investment. The is followed by China, whose R & D expenditure exceeds the sum of the following four countries, namely Japan, Germany, South Korea and France. The ten largest R&D-funding countries of 2018 accounted for $1.789 trillion in R&D expenditures, about 84.7% of the global total. In 2000, China accounted for nearly 5% of global R&D, joining the USA, Japan, South Korea and the countries of Western Europe as the largest funders of R&D. In 2009, China surpassed Japan to become the second largest funder of R&D. From 2000 to 2018, while China's share of global R&D rose from 4.9 to 26.3%, the US share fell from 39.8 to 27.6% and Japan's share fell from 14.6 to 8.1% (Progressive research service 2020).

On the other hand, according to the data of China's Ministry of science and technology (He et al. 2020), China's R&D investment expenditure has maintained rapid growth, ranking second in the world for the first time in 2013 and reaching 2.21 trillion yuan in 2019. Since 1995, the highest growth rate of R&D investment

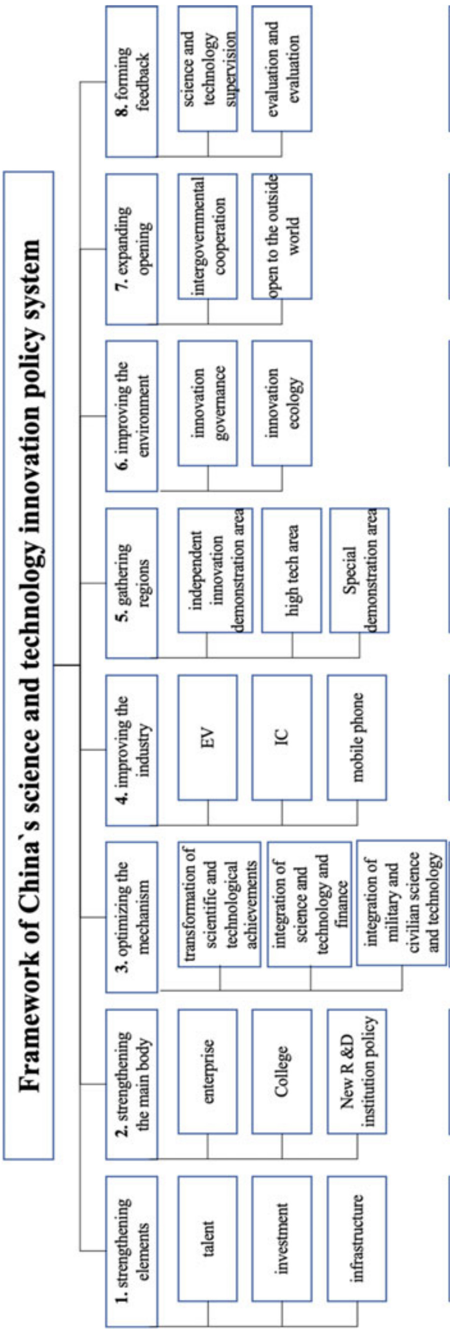

Fig. 2.3 Framework of China's science and technology innovation policy system. 2020 (*Source* Authors based on He et al. () and MOST (2016) Classifications)

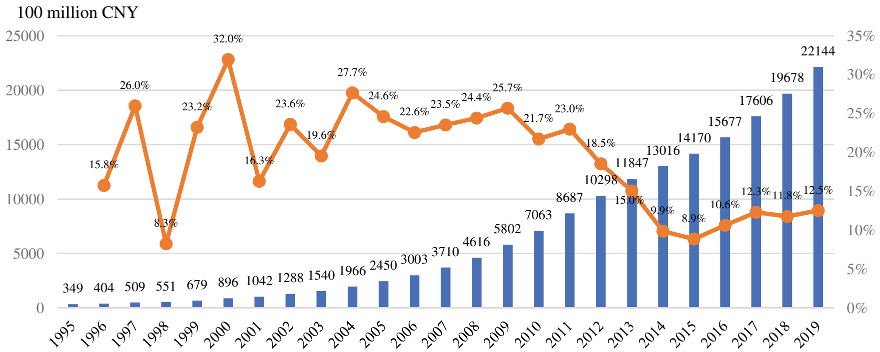

Fig. 2.4 Amount of investment in research and development and year-on-year growth rate in China (*Source* This figure is compiled by the authors using the original data from the Ministry of Science and Technology of China)

expenditure in China has reached 32%, showing a rapid increasing trend (see Fig. 2.4), which provides a strong financial guarantee for innovation-driven development.

According to the trend of R&D expenditure of Japan's Ministry of Education, Culture, Science and Technology on major countries and government-financed R&D expenditures (see Fig. 2.5a, b; MEXT 2019), China's R&D expenditure began to increase sharply after 2000. It can be seen from the government's independent R&D expenditure that the USA and China still rank first and second, while Germany ranks third.

2.3.5 The Guiding Role of Independent R&D Expenditure of Chinese Government

The investment of China's government financial R&D ventures has propelled the rapid growth of China's venture capital. Its impact on the rapid growth of China's new technology and start-up is multifaceted. This chapter makes a detailed arrangement on the investment fields and investment process of government-guided funds in China (see Fig. 2.6). According to a survey conducted by China Investment Research Institute in 2018, 73.3% of China's government-guided funds were invested in venture capital, and 83.3% of these funds eventually obtained more than three times of the raised funds, with the maximum amount of 10 times of the guiding funds. 93.3% of the guidance funds in the past three years have been invested in TMC (technology, media, communication) and health care. Among the media and communication industry, the majority of start-up enterprises have capital relations with BAT (Baidu, Alibaba, Tencent). BAT has also invested a huge amount of capital through the listing of shares. BAT funds are invested in two ways. One is the investment fund under BAT, and another is the direct investment of BAT entrepreneur group.

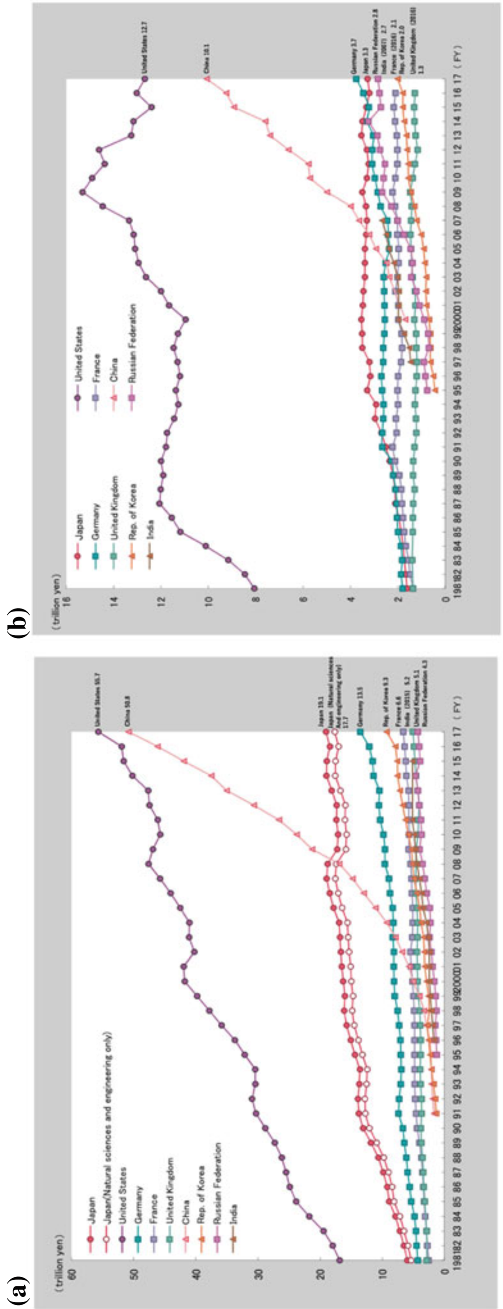

Fig. 2.5 **a** Trends in R&D expenditures in selected countries (OECD purchasing power parity conversion). **b** Trends in government-financed R&D expenditures in selected countries (OECD purchasing power parity conversion) (*Source* This figure was quoted from: MEXT(2019))

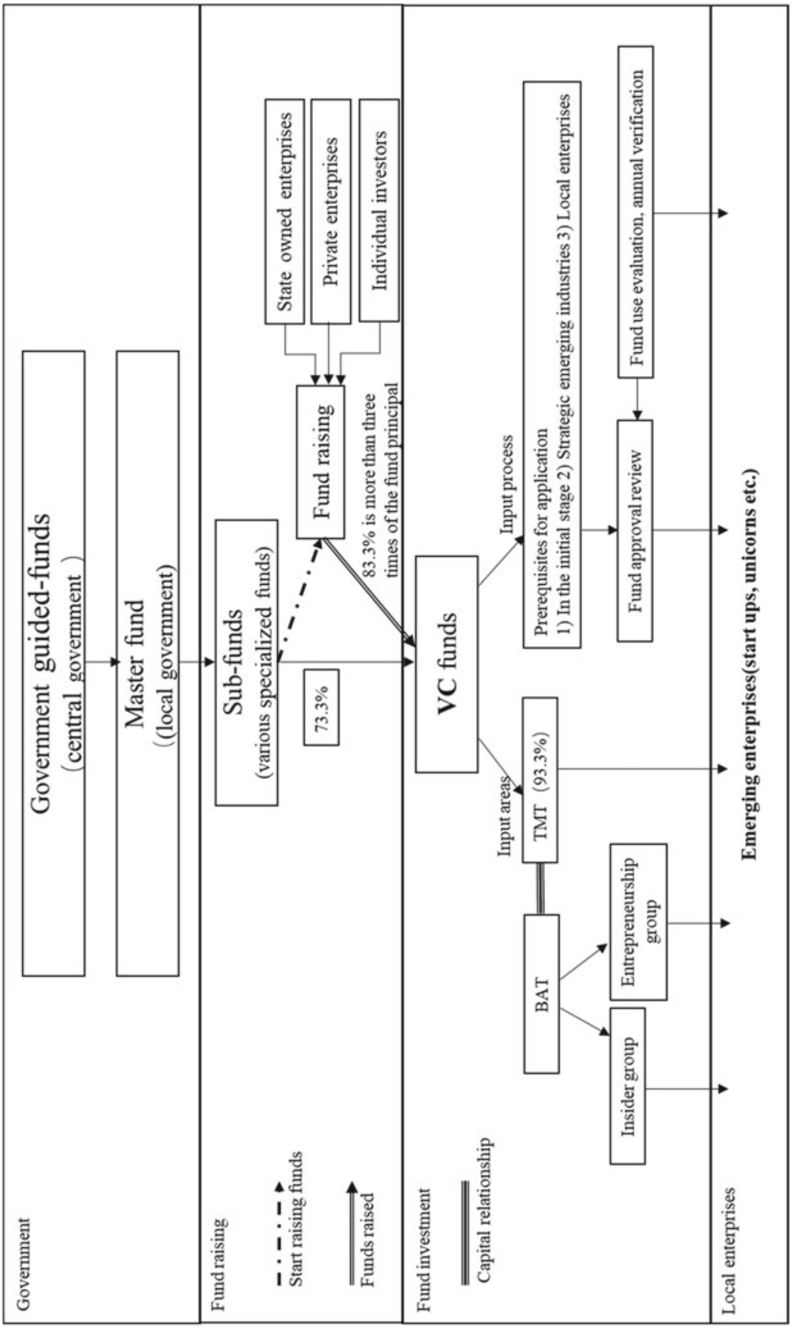

Fig. 2.6 Process of Investment and Use Of China's Government-Guided Funds (*Source* This figure was prepared by the authors using original data from: Ke (2019), MOST (2016), Kimura (2019) and Chinaventure (2019, 2020))

On the other hand, when enterprises apply for funds, there are a series of regulations, which can be roughly divided into three aspects according to different places: (1) in the initial stage, (2) strategic emerging industries and (3) local enterprises. For example, in Shenzhen, more than 70% of the special funds raised by government-guided funds should be invested in the early start-up enterprises, and the amount of the special funds equivalent to twice the principal of government-guided funds should be invested in the local enterprises in Shenzhen (Koichiro 2019).

Why can the government-guided funds cause such a large social capital effect? Ding (2019) made a detailed analysis and drew three conclusions. First, after 2020, Chinese investor groups will return to China and invest in China. The second is the Chinese version of NASDAQ, which was established in Shenzhen in 2009. The establishment of the Chinese version of NASDAQ makes it more convenient for local investors to recover their investment. The third is the rapid growth of China's Monetary Fund in 2016. This is directly related to the mass entrepreneurship and innovation policy proposed by the Chinese government in 2015. Premier Li Keqiang stressed in the "government work report" that mass entrepreneurship and innovation policy are the "double engines" that drive China's sustainable economic development. After that, the State Council issued "the opinion of mass entrepreneurship and mass innovation." In the opinion, it was mentioned that "supporting the venture capital." Reward the venture capital fund enterprises that participate in the establishment of state-owned enterprises and foreign enterprises. More importantly, the opinions put forward the creation of "government guidance fund" for governments at all levels. Due to the mass entrepreneurship and innovation policy, local governments at all levels to guide the creation of funds work rapidly.

According to the Research Report of China Investment Research Institute (2020), the government-guided funds began to grow rapidly in 2015, peaked in 2016 and then gradually decreased (see Fig. 2.7). The investment of the fund has promoted a rapid development of emerging enterprises in China's technology, media and communication fields, and has played a decisive role in promoting today's technology ecosystem in China. However, there are also some problems. These include giving priority to local enterprises in the use of funds and the geographical accumulation of technological innovation in China. By the first half of 2020, the establishment of the government-guided funds concentrated in six hot areas of Zhejiang, Beijing, Shanghai, Shenzhen, Jiangsu and Guangdong. The total size of the government-guided funds in the six hot areas is about 952.736 billion yuan, accounting for 44.41% of the total size. In terms of the number of government-guided funds, Jiangsu Province, Zhejiang Province and Guangdong Province (excluding Shenzhen) ranked first to third, respectively. From the perspective of the size of guidance funds, although the number of government guidance funds in Shenzhen is small, the average size of each guidance fund is about 3.9 billion, ranking first. The second is Beijing. The size of guidance fund is about 274.324 billion yuan, and the average size of each guidance fund is about 3.5 billion yuan. The direction of investment is also concentrated in the field of import substitution, lack of investment in the field of basic research (see Fig. 2.8).

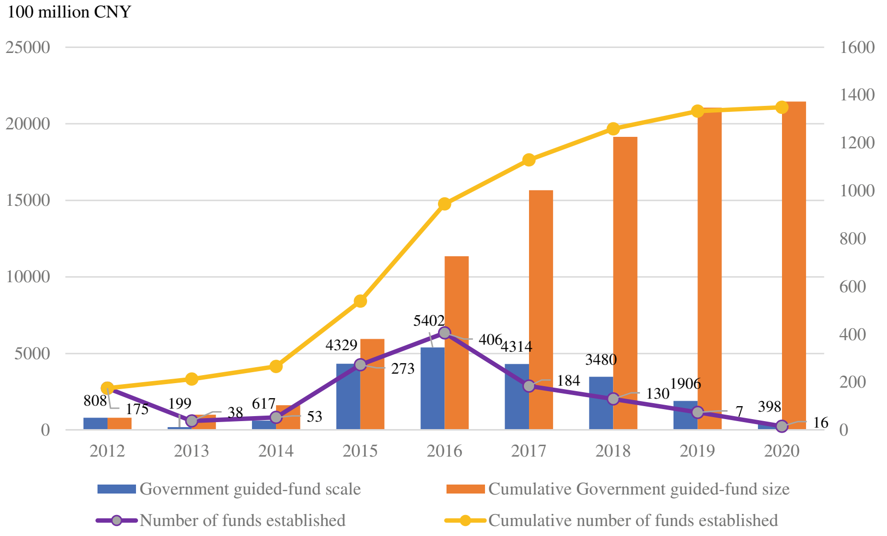

Fig. 2.7 Number and scale of government-guided funds established in China (*Source* This figure is compiled by the authors using the original data from the Special research report on government-guided fund in 2020 (Chinaventure (2020))

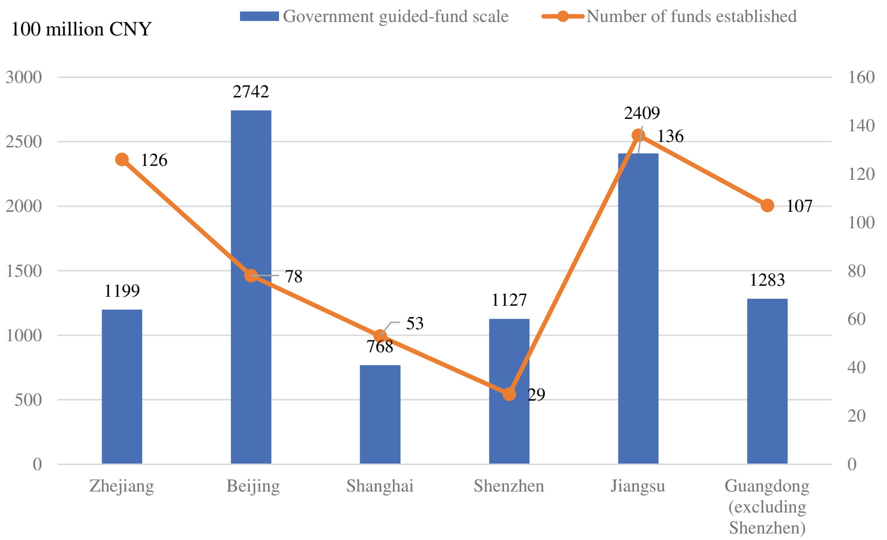

Fig. 2.8 Scale and quantity of government-guided fund in six hot areas in China (*Source* This figure is compiled by the authors using the original data from the Special research report on government-guided fund in 2020 (Chinaventure (2020))

2.4 Experiences and Lessons of Innovation and Technology Ecosystem in China

In the last 70 years since the founding of new China, China's science and technology innovation strategy has gone through five stages, and a series of decisive strategic matrix policies have been issued. Through countless practice and continuous learning, China's science and technology innovation policy system framework has been summarized, and huge scientific investment has been invested, which has formed today's booming science and technology innovation ecosystem. Among them, the government's various policy guidance and strong government-guided funds cannot be ignored. In terms of the use of government-guided funds, BAT has played a positive role in the development of emerging enterprises and local enterprises.

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Chapter 3
Drones Activity in Epidemic Prevention and Prospects in the Post-COVID-19

Jingnan Deng, Jinling Hua, Bismark Adu Gyamfi, and Rajib Shaw

Abstract Drone, also known as unmanned aerial vehicle (UAV), is an unmanned aircraft operated by radio remote control equipment and self-carrying program control device. At present, drones have been widely used. By adding payloads, drones play an important role in agriculture and forestry operations, power line patrol, meteorological monitoring, aerial photography, and other fields. In terms of material supply, drones have improved supply efficiency. The combination of these facts has revealed its importance in the management of COVID-19 pandemic. Since the COVID-19 epidemic, drones have frequently appeared in the work of fight against COVID-19. In the detection stage COVID-19, drone provided strong technical support for temperature measurement, whereas in the prevention and control stage, it has effectively guaranteed the safety of front-line medical workers and other member of the society. It is expected that drones will usher in a rapid development stage in the industry in the future. This chapter studies the impact of drones on the prevention and control of the COVID-19 epidemic, analyzes the specific operations of drones during the epidemic prevention period, and proposes ideas for the future development of drones in the post-COVID-19.

Keywords Drones · COVID-19 · Unmanned aerial vehicles · Epidemic prevention · Non-contact service

3.1 Introduction

Since the beginning of aviation technology, the military of various countries begun to develop aircraft that did not require pilots. Such development time has been more than 100 years (Yong 2017). The initial role of unmanned aerial vehicles was military unmanned drones meant for shooting training. With the advancement of technology, the functions of military drones have expanded to other applications such as reconnaissance and surveillance, intelligence gathering, and airstrikes. With the spillover

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J. Hua et al. (eds.), *Considerations for a Post-COVID-19 Technology and Innovation Ecosystem in China*, Disaster Risk Reduction,
https://doi.org/10.1007/978-981-16-6959-0_3

of military drone technology to the civilian field, driven by Moore's Law, and with the popularization of integrated manufacturing, the production of basic drone components begun to develop in the direction of miniaturization, low cost, and low energy consumption. In recent years, manufacturing costs continue to decrease, and with the gradual improvement and application of new technologies such as artificial intelligence and 5G communications, the drone industry has ushered in new development opportunities, and the scale of the industry has continued to expand (UNCTAD 2018).

Drone is an unmanned aircraft control by an internal program control system and radio remote control equipment, which specifically involve communication technology, data information processing technology, intelligent control technology, and aviation technology. At the same time, the main value of drones lies in the ability to form a working platform in the air and replace manpower through the application of various internal components to better complete aerial operations (Kang and Liu 2020).

According to their main uses, China's current drones can be divided into two main types: civilian drones and military drones. Among them, civilian drones can be refined into consumer drones and industrial drones. These three completely different drone equipment have great differences in specific uses and customer groups (see Table 3.1). Military drones are various specialized military equipment built for different purposes, such as radars, missiles, and material transportation. They are mainly used for reconnaissance, communications, and attacks. Most of their user groups are police and various armies. Consumer drones are usually equipped with cameras and other photographic equipment, whose main purpose is to meet the daily entertainment needs of the people while industrial drones are generally equipped with specialized detection equipment, such as lidar and atmospheric detection devices, infrared cameras. They usually play a role in the daily production work in various social fields, mostly customized production (Wang and An 2020).

3.2 The Development Status of Drones in China

In recent years, with the rapid economic development and the progress of science and technology, China attaches great importance to the research and development of drones. The drone industry has therefore exploded at an unprecedented rate of development. From the data of the overall scale of China's drones (see Fig. 3.1) in the last five years (2015–2019), it can be observed that in 2015, the overall market size of China's drone industry was only 6.6 billion yuan. However, in 2019, the market size exceeded 20 billion yuan, increasing to 27.8 billion yuan, with an average year-on-year growth rate of 43.8%.

The fastest growing sector is the civilian drone market. According to data on the scale of China's civil drone market from 2015 to 2019 (see Fig. 3.2), China's civil drone market has grown very rapidly in the past five years, with an average annual growth rate of 73.1%. In particular, 2018 ushered in explosive growth. The market size of China's civil drones reached 11.2 billion yuan, an increase of nearly 100%

Table 3.1 Classification of drones

Class		Equipped equipment	Customer	Use
Military drone		Equipped with a variety of professional military equipment according to different purposes, such as photoelectric, radar and other sensors; missiles, materials, etc.	Police and army	Reconnaissance, attack, communication relay or as a target aircraft
Civilian drone	Consumer drone	Most of the equipment is cameras and other shooting equipment, according to the need will be equipped with a platform and picture transmission equipment	Ordinary consumers or aerial photography enthusiasts	Meet the entertainment needs of consumers
	Industrial drone	According to the needs of the industry, it is equipped with various professional detection equipment, such as thermal infrared camera, lidar, atmospheric detector, etc.	Optimize customized production for industry users, emphasizing the practicality of solutions	Serving all walks of life, e.g., agriculture, land-use planning

(*Source* Authors)

year-on-year, and the market size of civil drones surpassed the market size of military drones for the first time. In 2019, the market size of China's civilian drones reached 21 billion yuan, reaching close to 76% of China's overall drone market. From the above data, it can be seen that China's civilian drone market is in a period of rapid growth. From only 36% of the market in 2015 to 76% in 2019, it has become the main growth part of China's drone market.

As one of the most important industrial bases for civilian drones in the world, China has maintained rapid growth in the drone industry since 2019. More than 7000 drone companies have obtained civil unmanned aircraft operating licenses, and

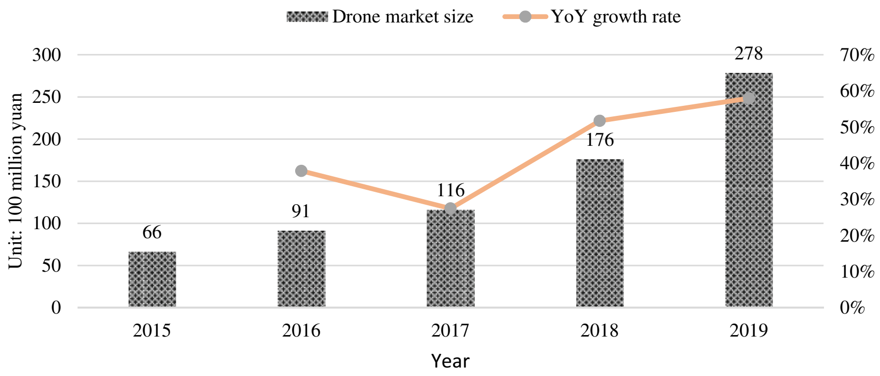

Fig. 3.1 Drone market in China (*Source* This figure was prepared the authors based on data from Qianzhan Industry Research Institute)

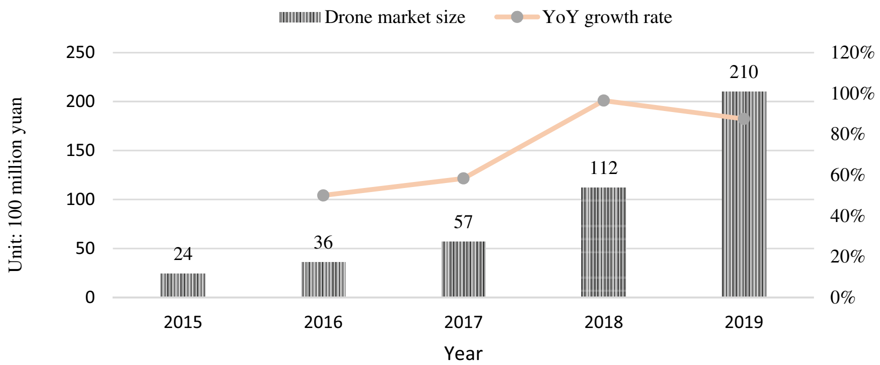

Fig. 3.2 China's civilian drone market (*Source* This figure was prepared by authors based on data from Qianzhan Industry Research Institute)

the transaction scale exceeded 50 billion yuan. According to the "Guiding Opinions of the Ministry of Industry and Information Technology on Promoting and Regulating the Development of Civil Drone Manufacturing" issued by the Ministry of Industry and Information Technology of China, China's civilian drone industry continues to develop rapidly, with an output value of up to 60 billion yuan by 2020. The average growth rate is more than 40% (MIIT 2020). Due to the impact of the COVID-19 epidemic, the drone market has further increased significantly. The Ministry of Industry and Information Technology of China pointed out that civilian drones was to increase by 181.1% in the third quarter of 2020 (MIIT 2020). It is also expected to exceed the development target of 60 billion yuan of output directed by the Ministry of Industry and Information Technology by 2020. This shows that society pays more attention to the development of drones and drone systems.

3.3 The Role of Chinese Drones During the COVID-19 Pandemic

Compared with consumer drones, industrial drones have a wide range of applications and huge development potential. As an efficient and convenient auxiliary method, industrial-grade drones replace the original tools to serve all walks of life. It has the advantages of low cost, high cost-effectiveness, good maneuverability, and convenient use, which reduce the risk of manual operation. These improve the security and maneuverability of their task executions (Kang and Liu 2020). In 2020, the outbreak of COVID-19 was characterized by strong contagion and high pathogenicity. Strict prevention of "human-to-human transmission" was the key to epidemic prevention. As a representative of intelligent unmanned work, drones have become an effective tool for isolating, preventing, and controlling the new coronavirus, even treating patients and eliminating the virus by virtue of its unique advantages. It has the characteristics of efficient and non-stop working ability and zero contact. In this context, many drone manufacturers or companies in the drone-related fields have gradually explored the application practice of drones, unearthed the potential market for drones, and created many new application scenarios and applications mode. These have played important roles in security inspections, sterilization operations, logistics and distribution, publicity and communication, and temperature measurement (Fig. 3.3).

3.3.1 Drone as Unmanned Rapid Epidemic Prevention and Control

i. *Drone as an Efficient Infection Prevention*

As an efficient epidemic prevention publicity, anti-epidemic personnel use drones to perform aerial patrol tasks, with capabilities to control and play warning sounds through its built-in programs. Furthermore, there is the capability of a high-altitude megaphones and dedicated handheld smart controllers to accurately convey information. For example, in the Standard Industrial Park of Nansha District, the Walkera V1100 aerial propaganda drone broadcasts the park's epidemic prevention regulations with the phrase "put on masks" while patrolling various areas of the park. Through its high-definition images, the park's epidemic prevention personnel were able to promptly issue an advisory instruction to the other parties if someone is found without mask.

ii. *Drone as Virus Containment Tool*

Drone also assists in quick virus containment. That is the disinfection system of an unmanned aerial vehicle device uses the internal spray system to quickly spray the disinfection gas to improve the coverage and uniformity of the disinfection. This process is able to contain the new coronavirus, pathogenic bacteria, and other sources

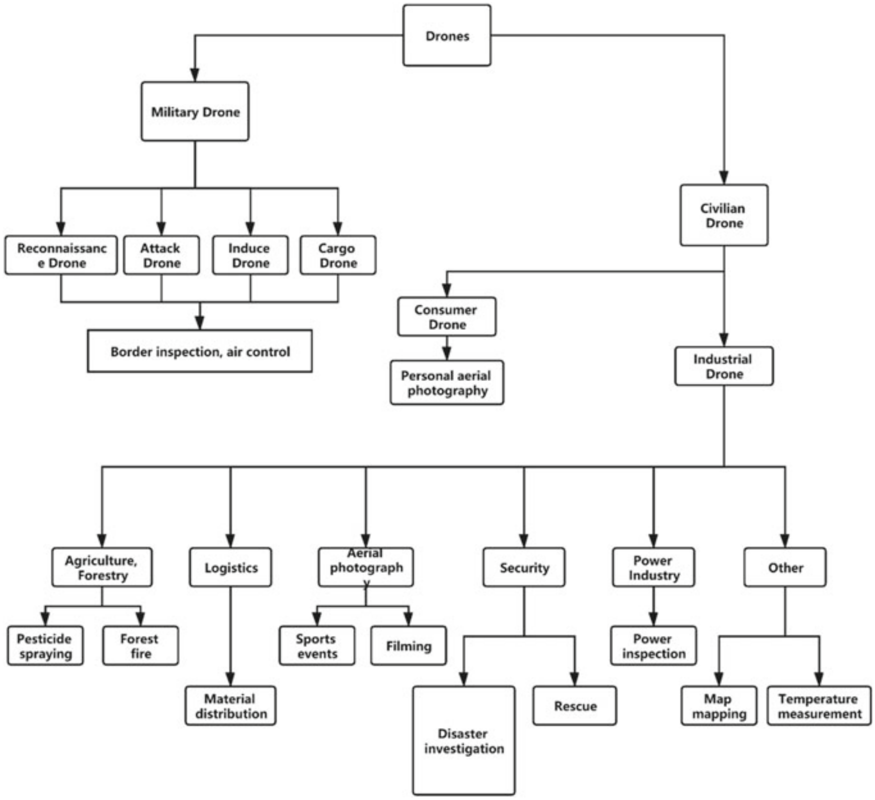

Fig. 3.3 Drone classification and application scenarios (divided by field) (*Source* Authors)

of infection in the air, and effectively reduce the risk of cross-infection that operators may have in the course of their work. Guangzhou Jifei Technology utilizes the full advantages of agricultural drones and launched the "Spring Thunder Operation." It invested 5 million yuan and set up a special fund for epidemic prevention and disinfection. It also provided support for voluntary epidemic prevention and disinfection operations for Jifei users across the country. As of February 12, 2020, 285 teams and more than 2000 agricultural drones had participated in the disinfection operation, and a total of about 677 million square meters of epidemic prevention services have been completed in 14,903 villages, towns, and communities in 20 provinces across the country.

iii. *Remote Body Temperature Measurement*

Drone can be equipped with an infrared thermal imaging lens, which can measure the body temperature of residents remotely and avoid infection caused by contact. For example, many communities in the downtown area of Yichun, Jiangxi, uses thermal imaging drones to remotely measure the temperature of key personnel in the community and carry out daily temperature measurement work for epidemic prevention and control. Some residents are resistant to the staff's door-to-door temperature measurement, resulting in slow progress in temperature measurement work. Infrared thermal imaging drones enhance efficiency while effectively dispelling residents' concerns.

3.3.2 Drone as Rapid Transportation of Medical Supplies

In the process of material supply, reducing human-to-human contact is the key to preventing further spread of COVID-19. This makes the delivery of materials more difficult and challenging especially the transportation of medical supplies and test samples. The use of drones to transport medicines, disinfectants, masks and other medical supplies to reduce human-to-human contact, shorten the delivery time, and even provide services to remote areas with accessibility challenges. These tasks as performed by drones are extremely important for medical care. China's Antwork Robotics Company, for instance, has completed several tasks of delivering test samples and medicines with drones to places at several kilometers away. For delivery tasks that require 20 min using ground vehicles, air delivery only needs 6 min. It greatly reduces the transportation time and also minimizes the risk of contact infection during transportation.

3.4 Potential Challenges of Drone Development in the Post-COVID-19 Era

With the advancement and development of unmanned vehicles and related technologies, drones have rapidly expanded from the military field to the civilian field in recent years, especially their role in the COVID-19 management. This has increased its popularity and has resulted in exponential market surge. In the future, the market share of civilian drones will account for the main development part of the entire drone market share, and drones will play an increasingly important role in the post-COVID-19 era. At present, a drone can now be bought in China for a few thousand yuan, and later maintenance and repair costs are not high. Since there will be no pilots, passengers, or a relatively small payload capacity, the consequences of the accident as compared to a civil aviation aircraft will be much smaller. In addition, the operation and control of done are almost free from the constraints of the operator's physical conditions. Compared with the high requirements and sophisticated training level of ordinary aircraft pilots, the operation of drones is simple and easy to learn, with low requirements for personnel. This gives rise to a broader spectrum of personnel operation, irrespective of some disabilities. However, compared with ordinary civil aviation aircraft, drones also have some disadvantages. Since the flight of the drone is all commanded by the personnel on the ground, the maneuverability of the aircraft is bound to be poor and its response capacity is insufficient. In the event of in-flight difficulties, it is very dependent on the operator's judgment on the scene and the aircraft. Although its size and lightweight bring some advantages during flights, it is more susceptible to extreme weather such as strong wind and heavy rain, and during those times, drones are usually blown away or damaged.

These notwithstanding, the emergence of consumer drones has made the application of civilian drones more and more widespread. Perhaps in the near future, drones will become a product that every household can use like a car. With the increasing number of drones and the continuous expansion of drone application fields, the standardized management of drones becomes more and more important, and challenges such as the production, circulation, and legal supervision of drones have gradually become prominent.

3.4.1 Challenges of Drone Production and Sales

At present, in terms of drone manufacturing, China's relevant regulations are not perfect, and the entry barriers and production standards for the drone manufacturing industry have yet to be established. As a major producer of drones, China has not made specific regulations on the quality standards and industry access standards for drone production. In the long run, this is not conducive to the development of the industry. In the production and sales of drones, the current laws and regulations cannot fully meet the needs in manufacturing. The main problem is the lack of industry access thresholds and the lack of production standards. The Ministry of Industry and Information Technology of China has publicly solicited opinions on the "Administrative Measures for the Production and Manufacturing of Civil Drones (Draft for Comment)" to study the above issues (MIIT 2020), aiming to standardize the production and guide the development of drones in the production field standardize management. Control should be strengthened in the production process to ensure that the manufacturer's name, performance introduction of the drone and other information can be found on each drone fuselage, so that the relevant responsible companies and persons can be quickly found in case of accidents in the future.

In the sales and circulation of drones, only certain drones are regulated in terms of export. According to the Ministry of Commerce of the People's Republic of China pointed out in a document issued on 31st 2015, the Ministry of Commerce, customs and other departments will jointly exercise export control on drones that meet certain requirements for range and loading capacity. This is a plan to prevent drones with sophisticated technology from being used by illegal organizations, as well as protect the technology of Chinese drones. However, there is law governing domestic sale of drones and their circulation in China. In order to regulate the management of drones, the sales and circulation of drones should be registered under the real-name system, just like the purchase of cars and other products requiring the real-name system (Huang and Xiong 2015).

3.4.2 Challenges of Drone Management Regulations

The civil drone is not only a special aviation vehicle, but it also has another attribute, which is as a commodity. Especially the recent emergence of consumer-grade drones makes the attributes of drones more complicated (Zhang 2015). Existing laws and regulations have many confusions and ambiguities in the management of drones. The management and control of drones lack standardization, systematization, and operability. The following highlights some of these issues.

i. *Incomplete Drone Registration System.*

Regarding the registration and management of drones, China currently has no special regulations for drones. There is the registration and management methods for general aviation aircraft, which obviously cannot meet the needs of managing drones. Registration management is very important to the standardized management of any industry, and the same is true in the field of drones. Regarding the real-name registration of drones, the functional department of the Civil Aviation Administration has made regulations to implement real-name registration for drones with a take-off weight that meets certain requirements. Such as the registration number containing the information of the manufacturer and user of the drone is sprayed on the part of the drone that is not easily damaged, but the actual practicability is not high, especially on consumer-grade microdrones (Su and Lu 2010). In order to improve the airworthiness management system of drones, a real-name registration system for drones should be established. In China, buying a car requires binding the personal ID card number to the license plate on the car, so each car can easily find the owner of the car. It is possible to imitate the motor vehicle management system, register the serial number and personal ID number on each drone, and establish a unified drone database across the country so that agencies across the country can manage it online. As a preliminary step in the management of drones, registration is also conducive to the implementation of follow-up monitoring measures and is a guarantee for follow-up management measures.

ii. *Unclear Drone Regulatory Agencies*

In terms of institutional arrangements, the regulatory agencies for drones are relatively complicated. Currently, agencies in China that have the authority to manage drones include the Civil Aviation Administration, local flight management agencies, the General Administration of Sports, Public Security Agencies, and the military. Although the functional structure of the supervision department is in place, the specific content of the work of each department is not complete. Because there is no special department or organization to manage drones. Instead, multiple existing departments manage drones in a fragmented manner. As a result, there have been situations in which departments shirk each other or scrambled for management rights (Jin et al. 2016). Therefore, it is important to clarify or set up a special drone supervision agency. Therefore, regulations can be made on the management system, and clear requirements for the standardization of the corresponding procedures of supervision can be made, and the supervision department can be given a certain degree of autonomous decision-making power, so that it cannot be unable to manage due to management authority when a critical situation occurs.

iii. *Insufficient Legal Liability Standards for Illegal Use of Drones*

At present, the penalties for drone violations in China are not very strong. Most of the time, drones cause accidents and damage but operators usually receive fines which are relatively small, and sometimes it does not even have a disciplinary effect on the operators of the drones. In China, is still a lack of legal regulations for drone operations. Crimes caused by the operation of drones (such as photographing private information, causing damage to other people's property or health) are considered civil liability due to the lack of legal basis for judgment. When they are involved in accident insurance, commercial contract compensation, etc., there is no special adjustment to the provisions. They can only be adjusted in accordance with the ordinary provisions of the contract law, tort law, and civil procedure law. The Law of the People's Republic of China on Public Security Administration Penalties (Revised Draft for Public Comment) issued in 2018 further stipulates that, low-altitude flying drones, powered parachutes, delta wings and other aircraft and aviation sports equipment that violate national regulations, will be detained for not less than 5 days and not more than 10 days. However, if the circumstances are serious, they shall be detained for not less than 10 days and not more than 15 days. This is an improvement, but compared with the consequences of "black flight" such as disorder at the airport and delays in passenger time, the penalty is still insufficient.

In addition, China does not have specific provisions for drones in terms of privacy protection. This needs to be improved as soon as possible to formulate corresponding provisions specifically for drones. Privacy is an important personal right, but much attention is not placed on it in China. In fact, it is not uncommon for drones to infringe on privacy rights. For example, drones with photography functions pose threat to the privacy of those its cameras capture unawares. Privacy, as one of the personal rights of citizens, should be strictly protected. As a device that can be launched at any time and may have audio and video functions, there is the possibility to cause hidden dangers to the privacy of Chinese citizens, as well as threat to national security. At present, China's privacy protection and penalties for infringement of citizens' privacy rights are much lower than those in other countries. Cases of drone infringement of privacy rights are even rare in China. The imperfections have caused the public to have a relatively weak concept of privacy protection and lack the awareness of privacy protection. Therefore, legal channels should be improved to allow citizens to maintain their privacy rights, increase protection of citizens' privacy rights, and increase penalties for using drones to violate privacy rights.

In view of the above being organized and implemented, the future of the drone industry after COVID-19 pandemic would improve with more cutting-edge improvement in its technology and increased application in more complex situations.

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Chapter 4
Social Media Development and Application During Pandemic and Post-pandemic from the Perspectives of Recovery and Preparedness

Yongxi Jang, Jinling Hua, Bismark Adu Gyamfi, and Rajib Shaw

Abstract Social media use has highlighted its role in the spread of information during the COVID-19. To be able to understand the impacts of social media in China during the COVID-19, this chapter firstly introduces the development and progress of social media since 2000 and to understand its role in the spread of the incident. Then using literature reviews technique introduces the performance and analyzes the impact of social media in the epidemic in China. However, it is revealed that there are some problems of social media exposed in this epidemic. Therefore, if measures can put in place in these exposed problems, could serve as directions for handling crisis events in post-COVID-19 society.

Keywords COVID-19 · Social media · Infodemic · Pandemic recovery · Preparedness

4.1 Introduction

The concept of social media originated from Anthony Mayfield's e-book "What is Social Media" in 2007 and defines social media as a new type of online media that gives users great space for participation (Mayfield 2017). The more widely accepted definition is proposed by Keplen and Henlein, as series of web applications based on the technology and ideology of Web 2.0, which allow users to create content by themselves and communicate with each other (Kaplan and Haenlein 2010). Nowadays, even though many scholars have their own understanding of what social media is, the common point in the current definition of social media emphasizes user-generated content or interactive digital technology. Hence, people could produce, share, filter, and disseminate information through social media. To understand the concept of social media, we could understand from the following three perspectives.

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J. Hua et al. (eds.), *Considerations for a Post-COVID-19 Technology and Innovation Ecosystem in China*, Disaster Risk Reduction,
https://doi.org/10.1007/978-981-16-6959-0_4

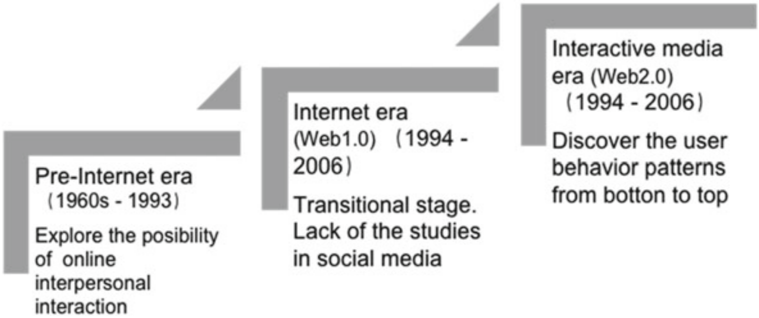

Fig. 4.1 Stages of social media research (*Source* Authors)

4.1.1 Web 2.0-Era

Web 2.0 is a new era relative to Web 1.0. It refers to a web-based platform and a user-led content Internet model. The term Web 2.0 was invented by Darcy DiNucci in 1999 and later popularized by Tim O'Reilly and Dale Dougherty at the O'Reilly Media Web 2.0 Conference in late 2004 (O'Reilly 2005). In the Web 1.0 era, the generation and delivery of information followed a traditional model, that is, only few people or companies publish their own generated content on web pages for people to browse. Thereby forming a single pattern in which one speaks and spreads an information while the audience listen and read. At that time, it could be said that the Internet was still a powerful tool for a small number of elites to control resources, with limited public participation. Figure 4.1 shows the main difference of Internet era. With the vigorous development of network technology, especially the emergence of the World Wide Web, it has been sought after by a large number of netizens for its openness and interactivity.

4.1.2 User-Generated Content

From the conceptual understanding of social media and the brief introduction to Web 2.0 technology, it is not difficult to find that user-generated content is the core feature of social media, and it is also an important difference between Web 2.0 and Web 1.0. There are a series of social media software established in the Web 2.0 era. That is, people make their own choices to establish connections and interactions based on their likes and dislikes of content. These characteristics promote the flourishing of social media. Everyone is not only a receiver of information, but also a publisher and disseminator. It leads to a trend of "democratization" in information dissemination, that is, the control of information dissemination has changed from the past mass media to individuals in each social media platform.

4.1.3 The Network Community

A community is a group of people with common hobbies and needs, with content, interaction in multiple forms. With the development of the Internet, human social relationships have developed into "virtual relationships" from blood, geographic, and industrial relationships. Nowadays, social media has become an important means for individuals to build network relationships. The network community is a new relationship group based on social networks. The concept of "community" emphasizes the people in the community, as well as the sense of belonging and group consciousness of the group. Thus, this community is maintained by a strong relationship. The emergence of social media fully proves that the medium is the relationship, and the new medium is the new relationship. A key promoter of this community is Facebook which took more than ten years to develop from a campus network to a global social network with more than 2.45 billion users. The reason is largely derived from its core value: "Community," "Caring," "Power."

4.2 Development of Social Media Worldwide

Social media is a tool and platform that people use to share opinions, insights, experiences with each other. The rapid and widespread adoption of the technology is changing the way we communicate and access information. The latest "2020 Global Digital Report" released by *We Are Social and Hootsuite* shows that social media, digital technology and mobile are things that everyone in the world cannot live without (Mayfield 2017). Today, nearly 60% people in the world has already connected to the Internet (4.54 billion users), an increase of 7% (298 million new users), compared to January 2019. Over 5.19 billion people now own cellphones and the number of users has increased by 124 million in the past year. Furthermore, there are more than 3.8 billion of social media users in the world and this number has increased by more than 9% since the same period in 2018 (321 million new users). For social media, MySpace platform can be said to be the first social media and its monthly active users achieved one million in 2004. Nowadays, the mainstream social media platforms include Facebook, YouTube, WhatsApp, Instagram, etc., and they are introducing new functionalities while updating their existing user interfaces to compete for users and the social media market. These have enabled various transitions over the years. The following gives few examples.

4.2.1 Facebook

Founded in 2004 by Mark Zuckerberg, Facebook (FB for short) is a social network service and social media web site originating from the USA, California. At the beginning of its establishment, it was originally called “the facebook” and the name was inspired by the nickname “face book” provided to students in the address book (or roster) that contains photos and contact information for students in American high schools (Eldon 2008). In addition to text messages, Facebook users can also send pictures, videos, documents, stickers, and audio media messages to other users and share the user’s location through the integrated map function. Users must register to use Facebook. After registration, they can create personal files, add other users as friends, send messages and get automatic notifications when other users update their personal files. In addition, users can also join groups with the same interests. These groups are classified according to work location, school, or other characteristics. Users can also add friends to different lists for management, such as “colleagues” or “best friends.” After 16 years development, now Facebook has become the largest social media platform in the world and had more than 2.6 billion active users in the first quarter of 2020. According to Statistics, 350 million pictures are uploaded every day on Facebook.

4.2.2 Twitter

Founded in 2006, Twitter has experienced very rapid development. In 2007, an average of 400,000 messages were generated every quarter. By 2008, this number had grown to 100 million. In February 2010, Twitter users sent an average of 50 million messages per day. As of March 2010, Twitter officially recorded more than 70,000 third-party applications (NewStatesmen 2010). According to the information provided by Twitter, an average of 65 million messages were generated per day, or 750 messages per second as of June 2010. Per the account given by Compete.com web site, Twitter has rose from the 22nd social network site to third as early as January 2009 (Kazeniac 2009).

Twitter’s information volume often suddenly soars when important events occur. For example, in the 2010 World Cup, the number of messages sent by users per second was 2940 during the 30 s that the Japanese team competed with the Cameroonian team and scored. This record was broken when the Los Angeles Lakers won the 2010 NBA Finals on June 17th. This record was 3085 messages per second. Further again, this record was again broken during a World Cup match between a Japanese team and a Danish team. This time 3283 messages were generated per second. Another example of an event-initiated record-breaking phenomenon was when the American singer Michael Jackson died on June 25, 2009. During that period, Twitter users posted more than 100,000 messages containing Michael Jackson’s name every hour, causing Twitter’s server to crash.

Since the rapid development of Facebook and Twitter, offline relationship began to gradually expand to the online. Hence, these platforms amass huge users in billions at a time. Figure 4.2 shows user volume of some social media platforms. Some social media platforms such YouTube have 1.68 billion, while WhatsApp has more than 68 billion users.

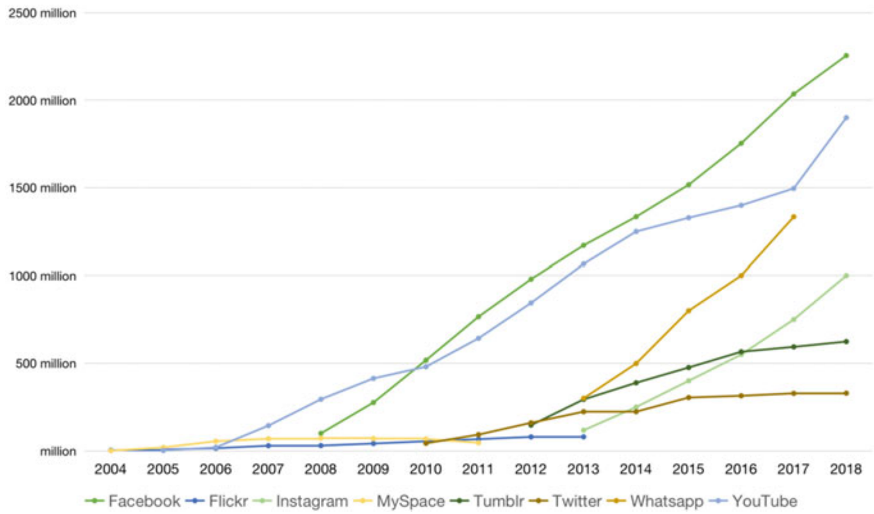

Fig. 4.2 Number of people using social media platforms, 2004–2018 (*Source* This figure was prepared by the authors with data from Statista)

4.3 Social Media Development in China

The establishment of the Shuguang BBS Forum in 1994 marks the beginning of Chinese social media, and its development is experienced various forms such as forum, blogs, online videos site, microblogging, group buying site and other multi-purpose messaging mobile phone applications. More and more social applications have been integrated into people's lives, and people's awareness of social media is gradually deepening. The current mainstream social media in China include Sina Weibo, WeChat, and TikTok.

4.3.1 Sina Weibo

The development of microblog in China started in 2007, and it has experienced three stages. They include the introduction period, silent period, and the growth period. 2007 is the introduction period of Weibo, with the popular of Web 2.0 products in the global Internet, Weibo emerged as a kind of "mini blog." However, Weibo was not promoted in the early days of its birth. During 2007 to July 2009, Weibo is at an initial and slow development stage, and it is difficult to explore. In terms of services and functions, they are mainly imitating foreign microblog products. At that time, Weibo are not yet mature, relatively few users, relatively low attention, and its value has not yet been fully reflected. The full growth period in August 2009 marked the launch of Sina Weibo microblogging platform and has since seen as rapid growth to become one of China's most influential social media platforms which is usually referred simply as Weibo. At the beginning, the 140-character limit of Weibo made its content short, easy to operate and its spread platform also made it to be quickly adopted by the public. Nowadays, Weibo has no limit on the number of words, and it has changed the traditional way of communication through its unique communication characteristics. First of such is that the release of Weibo information is very fast and content sharing is also very convenient such that its information release speed exceeds that of traditional paper media and other online media.

Secondly, Weibo information acquisition is more open and interactive. On the Weibo platform, there is an option to choose whether to follow a user according to their interests or by the type and quality of the published content. What's more, users can comment on the content of the follower and reply to comments at any time. This kind of synchronous interaction has completely replaced books, printing, broadcast, and television.

The third is that the content disseminated on Weibo is not only a simple content, but a dissemination based on the "endorsement" of a trust relationship and its efficiency; therefore, its influence and dissemination power are quite huge.

Nowadays, Weibo plays important roles in social and public events, shows strong participation in political exchanges and communication, which indirectly or directly influences government decisions. Weibo has a powerful network information amplification ability and a centralized release ability of public opinion in public events. Therefore, to some extent, Weibo has become a new medium for political participation. It is an extremely important variable to promote the process of political civilization in China.

4.3.2 WeChat

Established in 2011, WeChat begins to lead the trend of social media and gradually formed a "hypermedia" ecosystem. Figure 4.3 shows that, among China's 1.4 billion population, the number of monthly active users of WeChat exceeds 1.2 billion in 2020. Now WeChat is the social media platform with the largest number of users in China.

WeChat spreads mainly in two ways. The first occurs in a form of chat and conversational spread. This communication between individuals and groups is almost unimpeded in a single chat dialog. After user selectively subscribes to an official account (being it government or other agencies), he/she is able receive messages sent by these official accounts regularly. This "private customization" message reception is also carried out in the form of dialogue. The second of WeChat's information sharing is the social communication in *Moments*, which is a very private SNS-like mechanism embedded in WeChat. Moments not only satisfying users' demands for communication functions but also meets users' social needs. The information posted in *Moments* is abundant due to access to the internet.

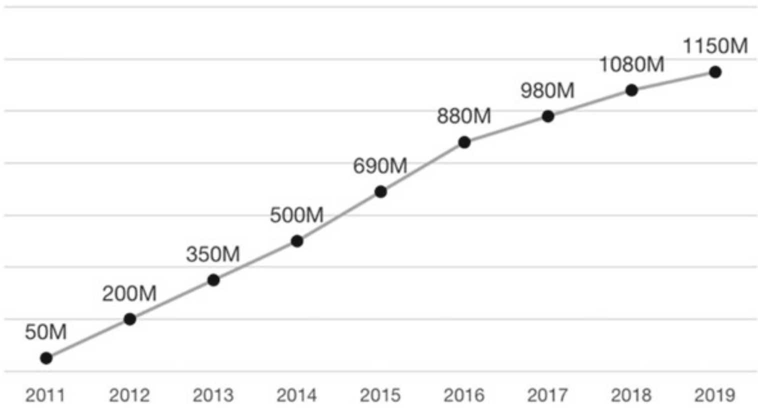

Fig. 4.3 WeChat monthly active user 2011–2019 (*Source* This figure was prepared by the Authors with data from Statista)

The use of WeChat by state agencies began in 2014 and has now become an important social media platform for government information disclosure. WeChat platform provides the opportunity for state agencies and citizen to cordially communicate in more efficient and swift manner. For example, in 2013, there was an earthquake in Yaan, Sichuan. The local government immediately sent relevant information to more than 100,000 followers through the Government WeChat "Weicheng," which played an important role in relaxing people's anxiety and maintaining normal social order. The timely and accurate post of important information by the government's WeChat account are incomparable by other social media platform.

4.3.3 TikTok

Launched in September 2016, TikTok, known in China as Douyin, is a Chinese short video sharing social application, operated by a Chinese owned company ByteDance. The social media platform is used to produce short films in various forms, such as dance, lifestyles, and others, with a clip duration ranging from 3 s to 1 min (Zhiwu 2019). TikTok has 800 million monthly active users and over 60% of the total, more than 70% these active users live in China. Regardless of country or regional differences, TikTok ranked sixth in the global mobile application ranking among monthly active users in 2019. In addition, the latest data from App Annie (a global mobile data source company) shows that users in China accounted for 80% of the total time using TikTok in 2019, which shows that users in China spend about 9 Euros every 10 min when using TikTok. The platform has unique characteristic that different from other social media platforms. This characteristic is "de-specialization" in information production. The interaction in TikTok is very simple. Users only need a smart phone to complete a short video shooting, editing, and soundtrack. TikTok also provides "one-click" filters and special effects, breaking the traditional complex operation of relying on professional machine shooting and computer editing, greatly reducing the threshold of video production, realizing the shift of users from information recipients to disseminators. At the same time, to cultivate users' habits and interests, TikTok collaborates with celebrities to launch video templates of songs and dances. Users can get the sound or special effects of the video with one click, which greatly stimulates the enthusiasm of them to participate. Many governments also create official account in TikTok to better manage public affairs.

4.4 Overview of Social Media Used in China During COVID-19

Since the first reported cased of COVID-19 infection in December 2019 in China, it has gone on to spread rapidly to become a global pandemic. Evidence suggests that information on COVID-19 spread rapidly through social media, enabling people across the country to take corrective actions in time. During the epidemic, social media does not only provide useful data sources for epidemic information monitoring and prediction but also plays an important role in public information acquisition on medical and health services at various stages of the management of COVID-19.

At present, in the life cycle theory of emergency crisis events, researchers propose a classic four-stage division method of public opinion dissemination in social media: early stage, outbreak stage, spreading stage, and retreat stage (Fink 2014). Based on this theory, Yin (Yin et al. 2020) analyzed 1,851,142 pieces of news, Weibo and WeChat articles related to COVID-19 from December 30, 2019 to March 15, found out that the public's attention to relevant information in the early stages of the epidemic has also increased. Li (2020) found that between December 23, 2019 and January 30, 2020, the number of daily epidemic-related Sina Weibo in and outside Hubei Province was positively correlated with the number of confirmed cases of COVID-19 ($P < 0.001$). The increasing trend of the percentage of cases also has predictive value ($P < 0.001$). The popularity of the public's discussion of the epidemic is closely related to the occurrence and development of the epidemic, and the potential development trend of the epidemic can be predicted to a certain extent.

4.4.1 Early Stage of Information Dissemination

On December 1, 2019, the first confirmed case of pneumonia of unknown cause occurred in Wuhan, Hubei, China, but this did not cause anyone's attention. On December 26, 2019, two more cases of pneumonia of unknown cause were found. The gradual increase in infection numbers begun to cause panic among the masses. Dr. Li Wenliang, an ophthalmologist at Wuhan Central Hospital, was one of the medical personnel to spread the news to the outside world at the very beginning of the COVID-19 and was later called the "epidemic whistleblower."

On December 30, 2019, Dr. Li Wenliang firstly spread the news "7 cases of SARS have been diagnosed in the South China Seafood Market" to WeChat group, reminding fellow health officials to "let family members and relatives take precautions to the infectious diseases." Although the news at that time was still a bit inaccurate, this was the first time that COVID-19 as a potential person-to-person infectious disease appeared in public. In order to prove that what he said was true, Dr. Li also sent out a clinical pathogen screening result and chest CT of the patient with the statement "detection of high-confidence positive index SARS coronavirus positive" in the WeChat group. An hour later, he added in the group, "the latest news is that the coronavirus infection has been confirmed and virus typing is in progress." That night, people began to discuss on WeChat platform groups and Weibo. At 10 am on December 31, 2019, "pneumonia of unknown cause in Wuhan" became the most searched phrase on Weibo. After that, mainstream media such as China Business News, Beijing News, CCTV News, and the People's Daily paid attention and followed up with reports.

However, on January 3, 2020, Dr. Li Wenliang was warned and admonished by the local police station for "publishing false statements on the internet." Although the Wuhan police decided to withdraw the letter of admonition against Dr. Li and apologized to his family on the evening of March 19, 2020, this can be said too late for the justice. Dr. Li Wenliang was diagnosed with COVID-19 on January 31st and died of it on the morning on February 7 at the age of 34 (Li 2020).

Wuhan is a city with well-developed transportation and extensive connections. During the early period of COVID-19, from December 2019 to January 2020, because no protective measures have been taken and there was some kind of neglect of the warning from social media, within two months, the number of cross-infected people increased exponentially until COVID-19 broke out as pandemic.

A model based on the contents discussed by Sina Weibo users suggests that the public's attention to relevant information in the early stages of COVID-19 increased. From December 23, 2019 to January 30, 2020, the number of daily epidemic-related contents on Sina Weibo was positively correlated with the number of confirmed COVID-19 cases ($P < 0.001$) and it also has predictive value for the percentage of cases trend ($P < 0.001$). The public's discussion of COVID-19 in social media is closely related to the development of the epidemic. Hence, the potential development trend of COVID-19 can be predicted by social media in a certain extent. However, in the 20-odd days from early December to the end of December, after COVID-19 came to public view for the first time as an infectious disease through social media, it did not attract enough attention. Although the National Health Commission sent experts to Wuhan for investigation and analysis, it was only judged as a viral pneumonia and patients' isolation was not carried out in time, which greatly increased the probability of human-to-human transmission. It was not until January 20, 2020, that Academician Zhong Nanshan clearly stated that there was human-to-human transmission happened through CCTV.

4.4.2 *Outbreak and Spreading Stage of Information Dissemination*

After the early period, COVID-19 broke out quickly and the number of new cases rapidly increased and set a panic among the public. As the initial outbreak city of COVID-19, Wuhan was placed under lockdown, with schools and companies closed. People were confined to their homes and were asked to wear masks whenever they went out. The question to the possibility to finding all suspected cases as soon as possible and effectively cutting off the source of infection, increasingly became the focus of Wuhan's epidemic prevention and control and these questions keep testing decision-makers at that time.

In early January, Zhang Xiaochun, a doctor in Wuhan, felt depressed. Her patient had a fever that lasted for more than a week and a CT scan showed symptoms of pneumonia, a sign of the COVID-19 that swept Wuhan city. However, the test to confirm the diagnosis requires few days. For Zhang Xiaochun, this means that the life-saving treatment and the isolation of patients will be postponed.

On February 3, at the most severe time in Wuhan, a large number of patients with suspected COVID-19 could not be admitted to the hospital. Relying on Dr. Zhang's rich medical imaging experience, she bravely started a social media campaign to appeal for use of CT images as a diagnosis of COVID-19. On her social media platforms, she wrote a statement, "don't be superstitious about nucleic acid testing anymore. CT imaging is strongly recommended as the main basis for diagnosing COVID-19. It is strongly recommended that the government requisition hotels, guesthouses or student dormitories, admit suspects and most medical observers and compulsorily isolate them for treatment." This statement was the first to push the reliability of nucleic acid testing to the public. At that time, nucleic acid testing was the only basis for diagnosing COVID-19, but due to the high "false negative rate" of it, a large number of suspected patients could not be admitted in time.

The statement, which lasted only 10 min for fearing being punished by state officials, was rapidly reposted in WeChat. Later someone posted the screenshots on Weibo, her voice quickly spread and attracted widespread attention from the society. At the peak of the epidemic, in the "darkest" moment of tension in all aspects, her voice is extremely shocking.

Zhang Xiaochun's statement spread rapidly on the Internet. Some university professors, NPC (Chinese National People's Congress) deputies and CPPCC (Chinese People's Political Consultative Conference) members took the initiative to contact her and asked her to compile a more detailed and systematic proposal and plan, which they would forward to the National Health Commission and the Prevention and Control Command and other related departments. On February 5, the National Health Commission announced to the public the "Diagnosis and Treatment Plan for COVID-19 (Trial Fifth Edition)". It was only 2 days later after Zhang Chunxiao posted her statement. The fifth edition points out that clinically diagnosed cases refer to suspected cases with imaging features of coronavirus. In terms of case discovery, reporting and treatment, the plan pointed out that for suspected cases and clinically diagnosed cases should be "immediate isolation and treatment" and "single-room isolation." What's more, "samples should be collected as soon as possible for pathogenic testing."

From the criteria for the classification of "clinically diagnosed cases" to the admission methods of single-room isolation, all of them are highly consistent with Zhang Xiaochun's suggestions. After few days of preparation, Hubei Province announced the number of confirmed cases on February 12 as 13,332, becoming a "super peak" far above the average. The changes in number were due to the admission of Zhang Chunxiao's "clinically diagnosed cases" suggestion in the statistics.

Since then, with the advancement of "hospitalized all patients" and community investigations, the number of new cases has been declining day by day and the epidemic has ushered in an inflection point. In mid-February, daily new data and feedback from front-line medical staff all showed that the epidemic has been effectively controlled and nucleic acid testing resources are no longer strained.

From January 3 to mid-January, Zhang Xiaochun started a social media campaign to simplify screening for the COVID-19. As China struggles to deal with one of the deadliest epidemics in its recent history, this is a rare public effort that quickly gained support from public health experts and the government. It is obvious that social media played a vital role during that time.

Zheng Wen analyzed 690 posts on Sina Weibo from February 4 to 22, 2020, and found that the information for help is closely related to the severity of COVID-19, medical resources, and population density in the region. Han found that users who posted Weibo during the epidemic were mainly concentrated in areas with severe epidemics such as Wuhan, Beijing-Tianjin-Hebei, Yangtze River Delta, Pearl River Delta, Sichuan, and Chongqing. These research suggest that social media sensitively reflect the front-line information of COVID-19. In summary, when the main ways to obtain information about COVID-19 were limited or lagged, social media still had a certain sensitivity and accuracy in the feedback of individual case characteristics and became the primary source of information about COVID-19, which played a vital role in the spread of COVID-19. During the outbreak stage of COVID-19, Chinese official media, and self-media had intensively reported on the epidemic. They updated the daily number of infections through social media in real time and reported on the progress of vaccine research. The shocking numbers attracted the attention of the public and made the public most intuitively aware of the horror of COVID-19.

4.4.3 Retreat Stage of Information Dissemination

By March 2020, COVID-19 had been relatively and effectively suppressed with the active cooperation of the people across the whole country. The number of suspects or confirmed diagnoses was gradually decreasing. Some cities in China had seen zero COVID 19 infection growth for several days. The role of social media in this stage is mainly in twofold. One is to release information about the epidemic and receive feedback from the public. The other is the government and self-media's use of social

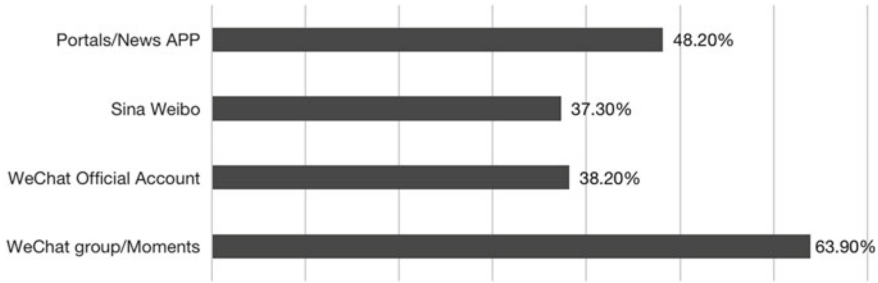

Fig. 4.4 Main channel to obtain COVID-19 information in China (*Source* Authors)

media to post health knowledge, guide public participation and stabilize the public. With the rapid development of science and technology in China, mobile phones and the Internet are rapidly popularized. Nowadays, social media has become a main medium for receiving information. The role of social media in disaster events is fully reflected, especially in COVID-19.

According to Fig. 4.4, WeChat group/Moments is the "first channel" for the public to know about COVID-19, accounting for 63.9%; portals/News APP is 48.2%, nearly 40% of the public obtain information on WeChat official accounts (38.2%) and Weibo (37.2%); videos/short videos account for 15. 1%.

4.5 "Infodemic" in Social Media During COVID-19

"Infodemic" is a combination of "information" and "epidemic." Sylvie Briand, the director of the Global Infectious Hazard Prevention Department of the World Health Organization (WHO), gave an authoritative interpretation of this concept earlier. She pointed out that the outbreak of COVID-19 is also an outbreak of a virus-related "infodemic" (Richtel 2020). "Infodemic" refers to the fact that too much information (some correct, some wrong) makes it difficult for people to find trustworthy sources of information and guidance that they can rely on. "Infodemic" has three main characteristics as following (Hua and Shaw 2020).

4.5.1 Rapid Spread

COVID-19 has become a major public health emergency with the fastest spread, the widest range of infections and the most difficult prevention and control since the founding of the People's Republic of China. The cumulative increase in the number of people infected with the concurrent "infodemic" may always increase exponentially. There is a risk of rapid expansion of infected "infodemic" people in an instant and some unclear rumors accelerated the spread. This rapid spread has become one of the most important characteristics of the "infodemic". As the Director-General of the World Health Organization Dr. Tedros Adhanom Ghebreyesus said at the 56th Munich Security Conference on February 15, 2020 that, "while fighting the pandemic, the international community also needs to fight false information and rumors. Fake news spreads faster than viruses and is very dangerous" (Picture 5) (UN News 2020). As COVID-19 is globally spreading, it has become a public health emergency of common concern to the people of all countries in the world, making global attention form a focal point in this specific time, thereby greatly promoting the spread of information dissemination. In China, there have been hundreds of rumor refutation in the past month which is a clear proof to that.

4.5.2 Indistinctness of Authenticity

The quality of information about COVID-19 in social media is not optimistic. Kouzy et al. (2020) investigated 673 pieces of COVID-19-related information on Twitter and found that 24.8% of the content contained false information and 17.4% of the content contained unconfirmed information. For example, various conspiracy theories surrounding the source of COVID-19 have become one of the focuses of people's attention and discussion in the "infodemic." Regarding this very professional problem, most people are in a state of a layman. The conclusions made by professional and non-professional voices from all parties lack sufficient facts and data to prove it, making it difficult for hundreds of millions of bystanders to distinguish the authenticity. Not only that, in mid-February 2020, some readers said that the book "Empirical Basic Theory and Application of Traditional Chinese Medicine" predicted the outbreak of COVID-19 ten years ago. The Shanghai Library's reference librarian used professional search capabilities to conduct a detailed search. Finally, they proved that this book does not exist, but rather a paper with similar content. However, it does not involve any content related to COVID-19 prediction. Thus, the prediction of COVID-19 as attributed to the book was fake news. On February 20, 2020, Dr. Tedros Adhanom Ghebreyesus said at a press conference that, "don't speculate or spread rumors about COVID-19. Everything should be based on facts. There are many false news and conspiracy theories. We must be very careful. Don't believe the news that has not been scientifically confirmed (BBC News 2020)."

4.5.3 Harmful Effect

"Infodemic" may even harm people's mental health. Bastani et al. (2020) investigated the content of discussions on Telegram and WhatsApp mobile phone application messages issued by Iranian medical organizations and found that false news cause psychosocial effects such as stress, fear, etc., but also may lead to the prevention of treatment errors and even affect an individual's health and other issues. Li (2020) conducted a study on 17,865 active domestic Weibo users and found that these users showed more anxiety, anger, and depression emotions after the declaration of COVID-19 ($P < 0.01$), while life satisfaction was significantly reduced ($P < 0.01$). This conclusion is supported by the BIS theory, that is, people do have more negative emotions for self-protection (Mortensen et al. 2010). In addition, after the announcement of COVID-19, low life satisfaction, and higher social risk judgments were detected. This is also supported by the BIS theory, which explains that when the social uncertainty become more, such as unknown causes and unclear transmission routes, people will tend to show negative risk judgment like higher risk perception or risk assessments. In this way, they can detect unclear cause of infection in time and keep themselves away from being infected (Wiedemann and Schütz 1997). Furthermore, insufficient controllability caused by coronavirus and the scare of uncertain risks led to higher risk assessments, which consistent with perceived risk theory (Slovic 1987). What's more, after the outbreak of COVID-19, Chinese government issued a series of policies and regulations that restricted people's travel and had to self-quarantine. These restrictions made the quality of people's life deteriorated and showed low-grade life satisfaction.

4.6 Directions of Social Media for Pandemic Control

As a real-time and open network information sharing medium, social media does not only provide useful data source for epidemic information monitoring and prediction during the epidemic, but also provides an important way for public information acquisition, medical and health services, and public opinion monitoring. In the context of globalization, making full use of the timely, forward-looking, and sensitive monitoring advantages of social media can provide useful ideas and methods for the prevention and control of COVID-19 and even new infectious diseases in the future.

4.6.1 Pay Attention to the Early Warning of Social Media

The information dissemination of COVID-19 fully demonstrates the characteristics of public health crisis communication. It is different from other forms of crisis or emergencies neither in content nor intensity, but combines emergencies, natural disasters, emergency rescue, highly infectious threats, uncertain medical research findings and multiple factors, which have created a different uncertain risk and unstable dissemination environment from the past. In this dissemination environment, the previously stratified "all-knowing and all-powerful" traditional dissemination system is difficult to play a role, especially in the early warning stage. "What we need to reflect is that in this pandemic, China actually missed early warning stage." Under this trend, we need to pay attention to the "early warning" function of social media. We need to quickly blow the "whistle" in the early stages of unpredictable disease outbreaks and treat sudden public crisis warnings in a tolerant way. Li Wenliang and other "whistleblowers" have provided good examples.

4.6.2 Build up a New Network Gatekeeping Mechanism

Social media gives ordinary people the ability to disseminate information and organize mobilization, break the traditional hierarchical structure and form "mass amateurishness". This new characteristic brings about the deconstruction of the dissemination mechanism: with the help of social media, ordinary people can bypass the traditional "gatekeeping mechanism" and obtain independent information release and dissemination channels. On the other hand, because social media dissemination announcers are sometimes amateurs, the authenticity of the information is not strictly controlled, and it is easy to spread a large number of rumors. If the rumors are not dismissed in time, it will affect social harmony and stability. Under this situation, to build up a new network gatekeeping mechanism is an important part in the future. Social media in China shows the value that cannot be ignored in the control of COVID-19 as following, which could provide reference for further application:

i. Wechat: Prominent Influence of New Media in The Vertical Field

During COVID-19, many people used WeChat to obtain medical consultations in China. By February 20, 2020, the "COVID-19 Real-time Dynamics Channel" produced by the Internet medicine new media account "Dingxiangyuan" had reached 2.32 billion views, which then became an important source of information for the public. This channel mainly provides two types of contents. One is information-based content, such as real-time data of the epidemic, real-time broadcast of key information and science popularization of COVID-19 knowledge. The other is service-based content, such as national fever clinic search, patient sharing data search and online free consultation. The new media in the vertical field has satisfied people's needs for COVID-19 information more quickly and accurately and played a unique role in helping public correctly understand the development of COVID-19.

On February 2, 2020, the popular science team "paperclip" released a video "Everything About COVID-19" on WeChat and TikTok, which attracted widespread public attention. The number of its WeChat articles reading exceeded 100,000 in 2 h. The video uses 3D modeling animation to show the virus transmission and the principles behind it. At the same time, professional data was used to calculate the fatality rate and the fatality rate is used to infer the number of confirmed cases. It further explained the basic reasons for the people to wash their hands and wear masks. This video has a strong educational meaning in such an unprecedented period.

ii. Weibo: New Cooperation of Mainstream Media and Self-Media

In the fight against COVID-19, self-media's rapid dissemination, extensive mobilization and profound influence have played a very important role. For example, on February 4, Sina Weibo cooperated with government departments and mainstream media, created a new channel "help COVID-19 patients," setting up publishing help, free consultations, treatment services and fever clinics sections. At the same time, each help messages were checked and vitrificated by staff. The number of reading in the channel exceeded 2 billion by February 20 and more than 1300 messages had been verified through Weibo. On February 5, "People's Daily Online" official account subsequently opened the "COVID-19 Help Channel". It used Sina Weibo platform to solicit help seekers' information, which attracted widespread attention. Mainstream media actively use the internet to open information solicitation channels. This kind of real-time cooperation was rarely seen in the past and has opened a new social media cooperation era, that is the authority of official media make up for the information uncertainty brought by social media such as Weibo, while social media platforms assisted in the rapid spread of official information among the public.

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Chapter 5
Toward a Digital China Through Digital Economy

Jinling Hua and Rajib Shaw

Abstract In the era of digital economy, whoever seizes the digital economy will seize the first opportunity. This chapter summarizes the development process of China's digital economy and the overall digital scale of the information industry so far. It examines both the universal features and unique aspects of China's digitalization process. The concept of digital economy has four meanings: digital industrialization, industry digitization, digital governance and data value. Digital economy has become the key driving force of global economic growth. In 2019, the scale of digital economy in 47 countries around the world reached US $31.8 trillion, accounting for 41.5% of GDP, and the average nominal growth rate was 5.4%. Under the situation of increasing downward pressure on the global economy, the sustained, stable and rapid development of digital economy has become an important driving force for stable economic growth. In the future, with the continuous innovation of digital technology, accelerating the integration of traditional industries, the role of digital economy in promoting economic growth will become increasingly prominent. Big data, artificial intelligence, cloud computing and other new-generation information technologies are fully integrated into various fields of consumption at a faster speed. With the continuous acceleration of digitization, networking and intelligence, many new formats have been cultivated to accelerate the release of information consumption demand.

Keywords Digital economy · Smart technology · COVID-19 · Smart city · Digital management

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J. Hua et al. (eds.), *Considerations for a Post-COVID-19 Technology and Innovation Ecosystem in China*, Disaster Risk Reduction,
https://doi.org/10.1007/978-981-16-6959-0_5

5.1 Introduction

In recent years, a new generation of information technology, represented by big data, AI and 5G, has developed rapidly. Digital economy has become an important engine to lead the global economic and social change and promote high-quality development of China's economy. Agricultural economy and industrial economy take land, labor force and capital as key production factors, while digital economy takes data as key production factor. At the Fourth Plenary Session of the 19th CPC Central Committee in October 2019, data was listed as a factor of production for the first time. The 14th Five-Year Plan adopted on October 29, 2020 emphasizes "accelerating the development of digital economy, promoting digital industrialization and industrial digitization, promoting the deep integration of digital economy and real economy, and building a digital industrial cluster with international competitiveness" (State Council 2020).

The China Central Economic Work Conference held in December 2020 further pointed out that "we should vigorously develop the digital economy and increase investment in new infrastructure. We should expand investment in equipment renewal and technological transformation in the manufacturing industry. It is necessary to carry out urban renewal action, promote the transformation of old residential areas in cities and towns, and build a modern logistics system. We should strengthen unified planning and macro guidance, make overall plans for industrial layout, and avoid duplicate construction of emerging industries". On March 5, 2021, the fourth session of the 13th National People's Congress was held. Premier Li Keqiang said in the government work report that the term "digital economy" has been written into the government work report four times since it was first written into the government work report in 2017. This also shows that China's digital economy is entering a mature period in the past year.

5.2 The Scale of Digital Economy

"Digital economy" has become a hot word in economic activities and social life. In the process of development, it has burst out a great energy of leading the times. In the process of fighting against COVID-19, it has highlighted its importance. Data shows that the scale of China's digital economy reached 35.8 trillion yuan in 2019, accounting for 36.2% of GDP, and its contribution rate to GDP growth reached 67.7%. In 2020, the added value of China's digital economy exceeded 41.36 trillion yuan (Zhongshang Institute 2020), accounting for nearly 40% of GDP and contributing nearly 70% to GDP. It is expected that it will further increase to 4.756 billion yuan in 2021 (MIIT 2021). From 2020 to 2026, the average annual growth rate of China's digital economy will remain at about 15%. By 2026, the scale of digital economy is expected to exceed 95 trillion yuan (Qianzhan Institute 2020) (Fig. 5.1).

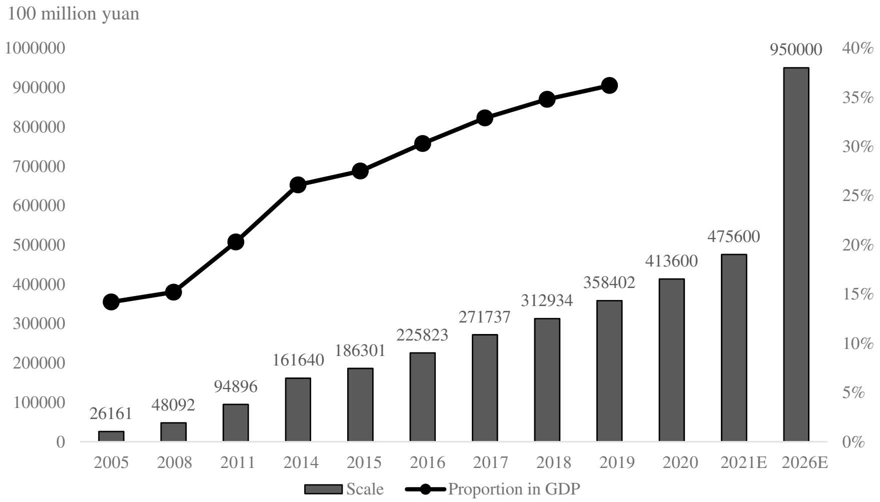


Fig. 5.1 Scale of digital economy in China (*Source* This figure was prepared by the authors using original data from MIIT, Zhongshang, Qianzhan Institute). *Note: 2021E, 2026E = estimates

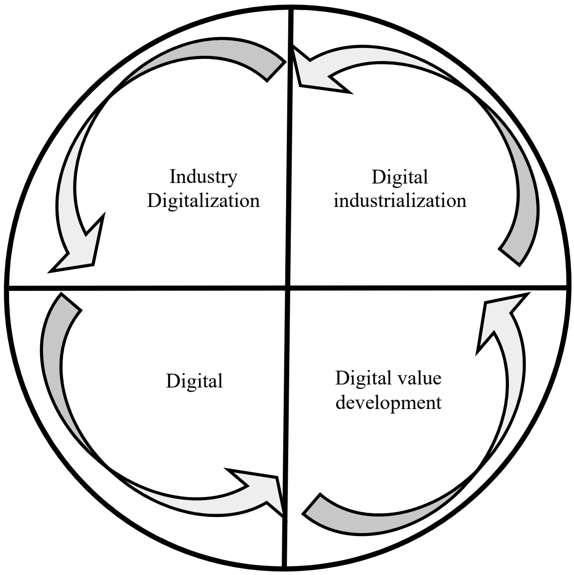
5.3 Digital China

5.3.1 The Framework and Meaning of Digital China

The government work report in 2021 focuses on accelerating digital development, striving to create new advantages of digital economy, accelerating the pace of digital society construction, improving the construction level, creating a good digital ecology and building a digital China. The definition of digital economy in white paper 2020 of China Academy of information and communications technology (CAICT) is as follows. Digital economy is a new economic form which takes digital knowledge and information as the key production factors, digital technology as the core driving force, modern information network as the important carrier, through the deep integration of digital technology and substantial economy, continuously improves the level of digitization, networking and intelligence and speeds up the reconstruction of economic development and governance mode (CAICT 2020a).

CAICT divides "digital economy" into four orientations: digital industrialization, industry digitization, digital governance and digital value development. Digital industrialization and industrial digitization are the core of the development of digital economy. Digital governance leads the profound change of production relations and is the guarantee of the development of digital economy. Data value reconstruction of production factor system is the basis of digital economy development (CAICT 2020a).

Fig. 5.2 Four orientations of digital economy in China (*Source* This figure was prepared by the authors using original data from CAICT (2020a))



i. *Digital Industrialization*

CAICT (2020a) defines digital industrialization as follows: *Digital industrialization, namely information and communication industry, is the leading industry of digital economy development, providing technology, products, services and solutions for the development of digital economy. Specifically, it includes electronic information manufacturing industry, telecommunications industry, software and information technology service industry, Internet industry,* etc. *Digital industrialization includes but is not limited to 5G, integrated circuit, software, artificial intelligence, big data, cloud computing, blockchain and other technologies, products and services* (Source: CAICT 2020a) (Fig. 5.2).

ii. *Industry Digitization*

On the contrary, CAICT (2020a) also argues on industry digitization as follows: *Industry digitization is the main position of the development of digital economy, which provides broad space for the development of digital economy. Industry digitization refers to the improvement of production quantity and efficiency brought by the application of digital technology in traditional industries. Its new output constitutes an important part of digital economy. Digital economy is not a digital based economy only, but an integrated economy. The real economy is the foothold, and high-quality development is the general requirement. Industry digitization includes but is not limited to the new industry, new mode and new format of industrial Internet, integration of industrialization and industrialization, manufacturing, IOV, platform economy and other new industries* (Source: CAICT 2020a).

iii. *Digital Governance*

CAICT (2002a) defines digital governance as *the guarantee for the rapid and healthy development of digital economic innovation. Digital governance is an important part of promoting the modernization of national governance system and governance capacity. It is a new government governance model that uses digital technology to establish and improve the system of administrative management, innovate the way of service supervision, and realize the optimization of administrative decision-making, administrative execution, administrative organization, administrative supervision and other systems. Digital governance includes governance model innovation, the use of digital technology to improve the governance system and enhance the comprehensive governance capacity. Digital governance includes but is not limited to multi governance characterized by multi-agent participation, technology management combination characterized by "digital technology + governance", and digital public services* (Source: CAICT 2020a).

iv. *Digital Value Development*

CAICT (2020a) also defines digital value *as the key factor of production in the development of digital economy. Accelerating the process of data value is the essential requirement of the development of digital economy. General secretary Xi Jinping stressed the importance of building a digital economy based on data. The Fourth Plenary Session of the 19th CPC Central Committee made it clear for the first time that, data can be used as production factors to participate in distribution according to contribution. On April 2020, the State Council of China clearly proposed to "accelerate the cultivation of data factor market" (the State Council's opinion on building a more perfect market-oriented allocation system and mechanism of factors). Data can be stored and reused, showing the characteristics of explosive growth and massive agglomeration. It is the basic strategic resource for the digital, networked and intelligent development of the real economy. Data value includes but is not limited to data collection, data standard, data confirmation, data labeling, data pricing, data transaction, data flow, data protection* (Source: CAICT 2020a, b).

5.3.2 The Development Characteristics of Digital Economy in China

The research of China National Industrial Information Security Development Research Center found that there are several new characteristics of China's digital economy development that deserve attention (CIC 2021). These are:

- China's 5G construction continues to lead the world.
- Giving full attention to the value of data has become the core to urban development, such as smart city.
- The digitalization of manufacturing industry has been further deepened.
- China's e-government ranking has reached a new record.

In particular, in 2021, the epidemic prevention and control work continued, the epidemic data gathered, and the importance and value of data governance was re-emphasized. This year's two sessions of the National People's Congress are still carried out in the way of live + online video. Nowadays, digital scenes supported by 5G, 4 K ultra-high definition, AI virtual assistant, VR and other technologies, such as cloud conference and cloud hall, have gradually matured, and the government and enterprises are forming a joint force to further promote the development of digital economy. By the end of January 2021, 23 provincial and 31 key cities in China as well as local governments had defined the government data overall management institutions. More than 70% of the provincial governments, 80% of the vice provincial governments and 50% of the prefecture-level municipal governments had established government data open platform relying on the government portal website to realize the rapid development of data aggregation.

CAICT et al.'s "Blue Book of China's urban digital economy index (2021)" estimates the scale of urban digital economy. The results show that the pulling effect of digital economy is more obvious in the city dimension. The average scale of digital economy in the leading first tier cities is 1.4 trillion yuan, accounting for 52% of GDP. The average scale of digital economy in the new first tier cities is 371.8 billion yuan, accounting for 46%. For first-tier cities and new first-tier cities, the contribution of digital economy to GDP growth is more than 70%. However, the proportion of digital economy in GDP between the third- and fourth-tier cities is not big, and there is still a large space for the development of digital economy.

5.4 Current Situation of China's Digital Economy

Digital industrialization is the leading industry of digital economy development, and industry digitization is the main position of digital economy development. From the perspective of the scale of digital industrialization and industry digitization, China's digital economy, products and services are accelerating the integration and penetration of all walks of life, and industry digitization has become the main engine of digital economic growth (Fig. 5.3).

5.4.1 Digital Industrialization Development

i. *Internet-Related Industries*

By the end of 2020, the number of Internet users in China reached 989 million, and the Internet penetration rate was 70.4% (MIIT 2020). As of November 2020, Internet and related service enterprises above a certain scale achieved business income of 1146.6 billion yuan, a year-on-year increase of 12.7%. In 2020, the total market value of the top 30 listed large Internet enterprises increased by 63.8%. The market value growth

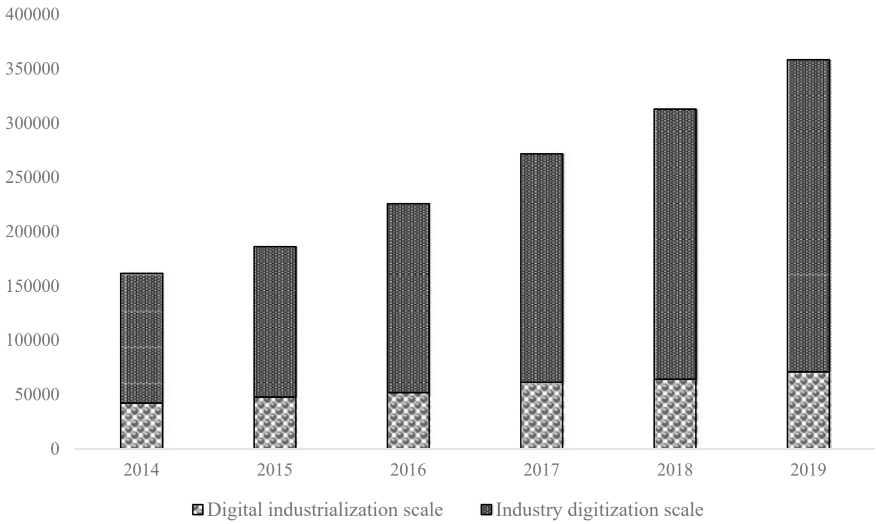


Fig. 5.3 Scale of digital industrialization and industry digitization (100 million) (*Source* This figure was prepared by the authors using original data from CAICT (2019))

rate of enterprises engaged in the integration of Internet and traditional services is as high as 102.7% (CIC 2021). In the face of the sudden epidemic, the Internet has shown great power and played a key role in the prevention and control of COVID-19 (Fig. 5.4).

ii. *Telecommunication-Related Industries*

According to the statistical bulletin of MIIT at the end of 2020, the total revenue of telecom business in 2020 was 1.36 trillion yuan, an increase of 3.6% over the previous year, and the growth rate will be 2.9 percentage points higher than the same period last year. According to the price of 2019, the total amount of telecom business was 1.5 trillion yuan, up 20.6% year on year. Among them, the fixed communication business grew rapidly, and the driving effect of emerging business was obvious. The revenue of fixed communication business reached 467.3 billion yuan, an increase of 12% over the previous year, accounting for 34.5% of the revenue of telecommunication business. This is an increase of 2.8 percentage points over the previous year, and the proportion increased for three consecutive years. By applying new technologies such as cloud computing, big data, Internet of Things and artificial intelligence, China will vigorously expand new businesses and make the revenue of fixed value-added and other businesses the first engine of growth. In 2020, the revenue of fixed data and Internet services reached 237.6 billion yuan, an increase of 9.2% over the previous year; accounting for 17.5% of the total revenue of telecom services from 16.6% of the previous year. This drives the revenue growth of telecom services by 1.53 percentage points, thus contributing 42.9% to the revenue growth of telecom services in the whole industry. The revenue of fixed value-added services will reach 174.3 billion yuan;

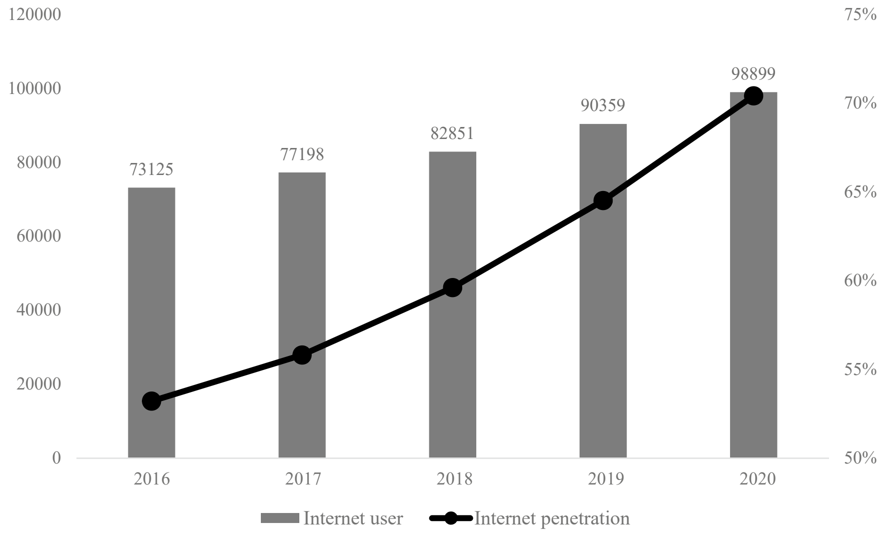


Fig. 5.4 Internet user scale and Internet penetration in China (ten thousand) (*Source* This figure was prepared by the authors using original data from MIIT (2020))

representing an increase of 26.9% over the previous year and accounting for 42.9% of the total revenue of telecom services. It increased from 10.5% to 12.9% over the previous year, driving the revenue growth of telecom business by 2.82 percentage points and contributing 79.1% to the revenue growth. Among them, the revenue of data center business, cloud computing, big data and Internet of Things business increased by 22.2%, 85.8%, 35.2% and 17.7%, respectively, over the previous year, and the revenue of IPTV business was 33.5 billion yuan, an increase of 13.6% over the previous year.

On the other hand, the revenue of mobile communication business reached 889.1 billion yuan, a decrease of 0.4% over the previous year, and its proportion in the revenue of telecommunication business dropped to 65.5%, 6.4 percentage points lower than the peak in 2017. Among them, mobile data and Internet business achieved a revenue of 620.4 billion yuan, an increase of 1.7% over the previous year, accounting for 45.7% of the telecom business revenue from 46.6% in the previous year, driving the telecom business revenue growth by 0.79 percentage points, and contributing 22.3% to the revenue growth (MIIT 2020).

iii. *COVID-19 Epidemic Prevention and Control-Related Industries*

During the epidemic period, the national integrated government service platform launched the "Health Code," with a total of 900 million people applying for use and more than 40 billion times of use. It supported most areas of the country to achieve "one-yard access." Big data plays an important role in epidemic prevention and control and resumption of production. Major online education platforms have launched various kinds of free live courses for students, and the scale of users has grown rapidly. Affected by the epidemic, Internet users' demand for online medical services is also growing, which further promotion of the digital transformation of China's medical industry. As of December 2020, China's online education and online medical users were 342 million and 215 million, respectively, accounting for 34.6 and 21.7% of the total Internet users (CNNIC 2021).

iv. *Online Consumption and Online Payment-Related Industries*

Since 2013, China has become the world's largest online retail market for eight consecutive years, with online retail sales reaching 1.176 billion yuan in 2020, an increase of 10.9% over 2019. The number of online shopping users was 782 million, accounting for 79.1% of Internet users. In the epidemic, reducing too much contact has been concerned. Webcast also became the mainstream of consumption in 2020, which is a digital economy mode of "Online + real consumption." Live e-commerce has become a popular shopping method, with 66.2% of Internet users having purchased live products (CNNIC 2021).

With the rapid growth of online consumption, online payment industry is also growing rapidly. In December 2020, China's online payment users reached 854 million, accounting for 86.4% of the total Internet users (CNNIC 2021). Through the supply chain service, online payment can assist merchants to push information accurately and promote the digital transformation of China's small and medium-sized enterprises to promote the development of digital economy. In 2020, China's central digital currency carried out digital RMB test in Shenzhen, Suzhou and other pilot cities. In the future, digital currency will further optimize its functions and cover more consumption scenarios.

v. *Data-Flow-Related Industries*

Supporting data traffic transmission-related industries are also booming. By the end of 2020, the relevant AI market reached 36.3 billion yuan. The scale of cloud market has reached 173.7 billion yuan, including 95 billion yuan for public cloud and 78.7 billion yuan for private cloud. It is estimated that the overall scale of cloud market will reach 290.2 billion yuan in 2022 (Fig. 5.5).

According to CAICT statistics, there are 3242 active big data enterprises in China. Big data enterprises grew rapidly in 2013 and 2015. After reaching the peak in 2015, the market became more and more mature, and the number of new enterprises began to stabilize. In August 2015, the State Council promulgated the "action plan for promoting big data development," which promoted big data as a national development strategy. At the same time, the new generation of information technology, smart city, digital China and other development strategies gradually promote the social and economic digital transformation, the industrial support of big data has been strengthened, the application scope has continued to expand, and the industrial national model has achieved corresponding rapid growth. At present, more than 70% of 3242 enterprises in China's big data field are small enterprises with 10–100 people scale. In the industrial development stage, SMEs play an important role in innovation and entrepreneurship. With the new infrastructure becoming a new driving force to promote the domestic economic development, the external market environment and

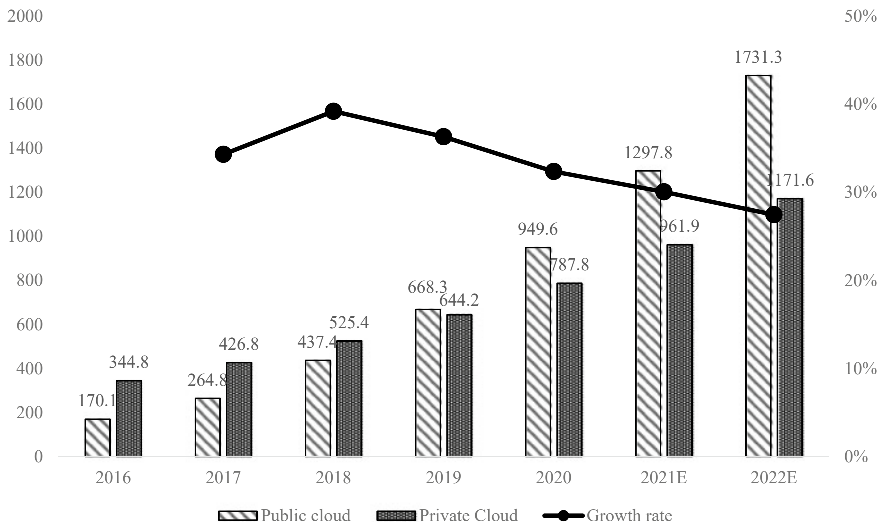


Fig. 5.5 Cloud market size in China (100 million) (*Source* This figure was prepared by the authors using original data from CAICT (2020a)). **Note* 2021E, 2022E = estimates

infrastructure that big data SMEs face have also changed greatly, which affects the distribution of enterprises' scale (Figs. 5.6 and 5.7).

CAICT (2020b) sorted out 1404 enterprises involved in big data application in the industry according to the proportion of the industry and found that finance, medical health and government affairs are the most important types of big data industry applications. In addition, the Internet, education, transportation, e-commerce, supply

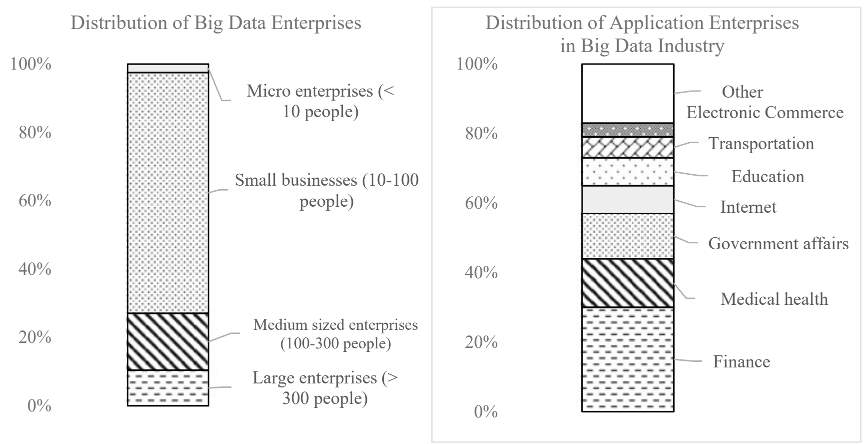


Fig. 5.6 Big data enterprise scale and related industries in China (*Source* This figure was prepared by the authors using original data from CAICT (2020b))

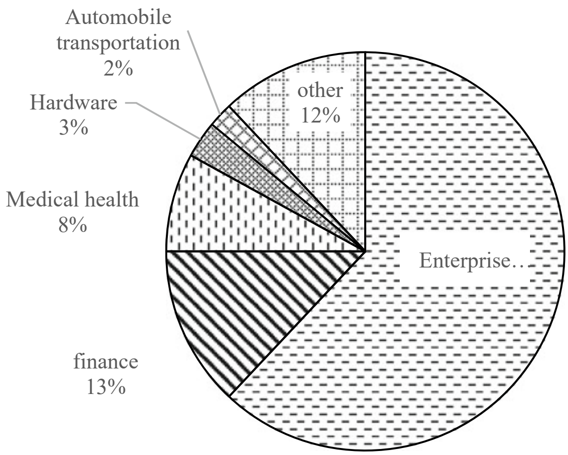


Fig. 5.7 Classification of enterprises receiving financing in China (*Source* This figure was prepared by the authors using original data from CAICT (2020b))

chain and logistics, agriculture, industry and manufacturing, sports culture, environmental meteorology and energy industry were the first time. CAICT also sorted out the financing and acquisition of big data enterprises. By 2019, enterprises providing services for big data enterprises had the highest proportion of investment, accounting for 62%, followed by 13% in the financial industry and 8% in health care. With the further popularization and penetration of the Internet and mobile Internet, the enterprise service market will continue to expand.

5.4.2 Industry Digitalization Development

Industry digitization is the main position of digital economy development. Industry digitization refers to the improvement of production quantity and efficiency brought by the application of digital technology in traditional industries. Its new output constitutes an important part of digital economy. In recent years, digital economy has been infiltrating into China's three industries (Fig. 5.8).

i. *Digitalization Process of Chinese Enterprises*

There are many contradictions in the process of digitalization of Chinese enterprises. iResearch roughly divides the process into three parts (iResearch 2021). That is:

- Investment: This includes IT consulting and purchasing software, hardware and services. This part is the foundation and preparation for the digital transformation of enterprises.
- Internalization: It includes the internal configuration and learning of the purchased software, hardware and services, so that they can be integrated into the original working system and process of the enterprise. This part is the core and key of enterprise digitalization.

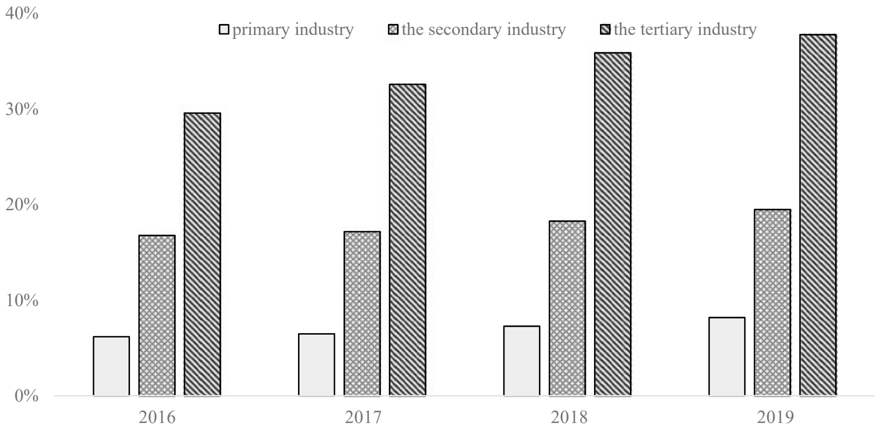


Fig. 5.8 Penetration of digital economy in the three industries in China (*Source* This figure was prepared by the authors using original data from CAICT (2019))

- Output: Including the actual use of IT software system after transformation and upgrading in the development and production of enterprises, and promotion and application in the upstream and downstream and partner ecology. This part is the output and result of enterprise digitalization, which is also of great significance for the digital penetration of the whole industry (Fig. 5.9).

ii. *The Market Scale of Digitalization of Chinese Enterprises*

In 2019, the market scale of China's digital new procurement exceeded 10 billion yuan, with a growth rate of more than 20%. The market scale is expected to exceed 20 billion yuan in 2022. In the context of the slowdown in the growth of ERP industry, the scale growth of the procurement industry mainly comes from the application of ERP-based procurement module and SaaS (Software as a Service) tools and services, and the comprehensive manufacturers with e-commerce background have gradually become an important force. At present, the market is still dominated by traditional ERP software manufacturers. However, with the continuous improvement of technical ability and the gradual increase of scenario precipitation, manufacturers

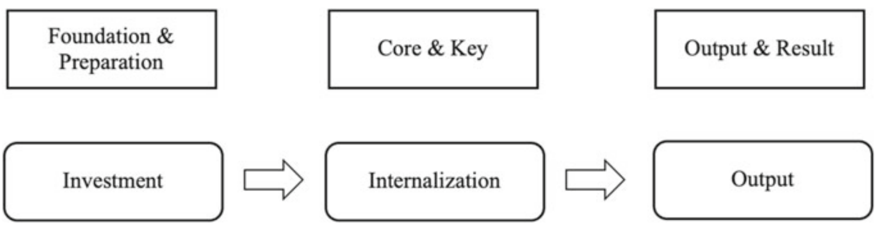


Fig. 5.9 Digitalization process of Chinese enterprises (*Source* This figure was prepared by the authors using original data from iResearch (2021)]

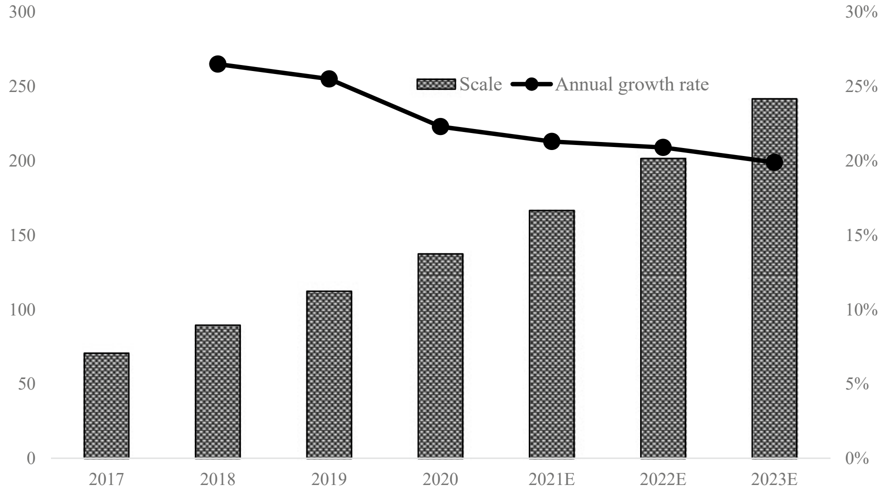


Fig. 5.10 Digitalization process of Chinese enterprises (100 million) (*Source* This figure was prepared by the authors using original data from iResearch (2020)). **Note* 2021E, 2022E, 2023E = estimates

committed to making enterprise procurement tools will become an important driving force for market growth (iResearch 2020) (Fig. 5.10).

iii. *Economic Contribution of Chinese Enterprises' Digitalization*

CIC has conducted a detailed follow-up survey on 7102 enterprises since 2017, of which 65.02% are in the secondary industry, 32.91% are in the tertiary industry and 2.07% are in primary industry. According to the survey results, the contribution share of Chinese enterprises' digital transformation to the added value of enterprises was 11.08% in 2018, 12.51% in 2019 and 13.31% in 2020, which plays an increasingly prominent role in boosting economic output. It is estimated that in the next 10 years, the GDP increment brought by enterprise digital transformation will reach 1.388 billion yuan. From the perspective of development level and balance, the contribution of digital transformation to enterprise added value of the three industries is greater in the tertiary industry, than in the secondary industry, and greater in industry than in primary industry. The contribution share in 2020 is 15.47%, 12.89% and 4.69%, respectively. The gap between service industry, industry and agriculture is gradually widening. From the perspective of development growth rate, the contribution share of agriculture has accelerated. Taking the growth rate in 2020 as compared with that in 2019 as an example, the growth rate of agriculture reached 59.5%, which is 3.6 times that of service industry and 4.5 times that of industry (Fig. 5.11).

The contribution share of digitalization of industrial enterprises is in a ladder shape. Among the industries, the contribution share gap of digitalization is relatively large, and the contribution share gap between electronic and mining enterprises is the largest, reaching 4.63%. The contribution share of electronics and transportation equipment industries is significantly higher than the national average, becoming

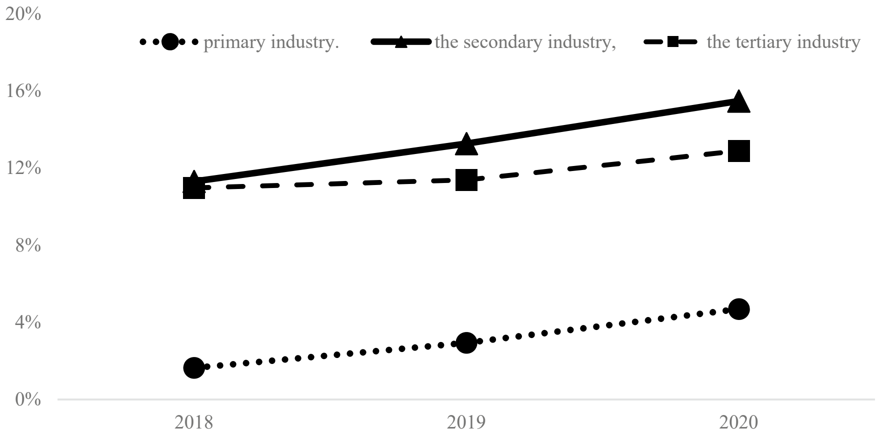


Fig. 5.11 Contribution share of digitalization of three industrial enterprises in China (*Source* This figure was prepared by the authors using original data from CIC (2020))

the leading industries in digitalization. The petrifaction, medicine, light industry, mechanics and food industries are at the same level as the national average. Spin, metallurgy and mining industries are 1 percentage point lower than the national average (CIC 2020) (Fig. 5.12).

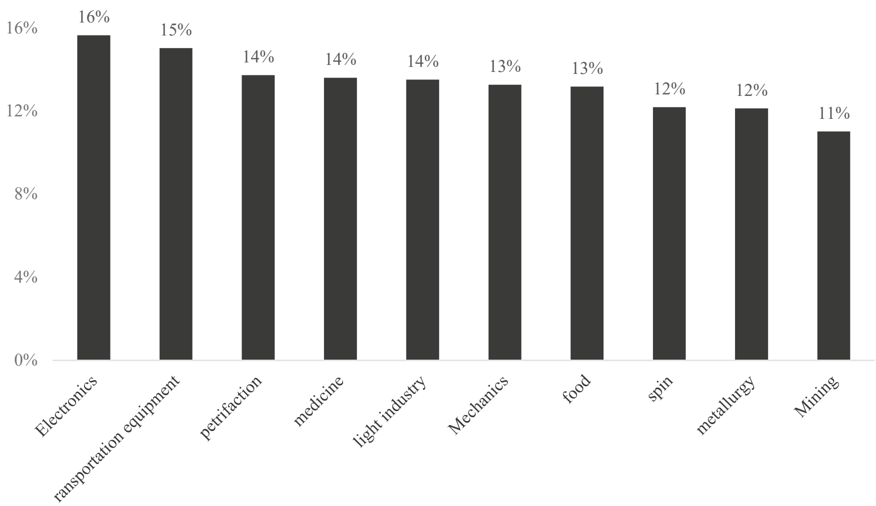


Fig. 5.12 Contribution share of digitalization of industrial enterprises in China (*Source* This figure was prepared by the authors using original data from CIC (2020))

vi. Digitalization of Chinese Manufacturing Enterprises

There are two characteristics in the digitalization of manufacturing enterprises. The first is the key points of high-level leadership and strategic planning. The second is the promotion of equipment transformation, procurement and sales online. In CIC's in-depth research on manufacturing enterprises, it is found that leading enterprises attach great importance to the role of senior leaders in enterprise digitalization. 46.21% of the leading enterprises said that their digitalization was driven by senior managers, while only 44.46% of other manufacturing enterprises did so. The top-level design of digitalization is particularly important. 46.45% of leading enterprises put digitalization at the core of enterprise strategy and war planning, which is 4.73% higher than other manufacturing enterprises.

Digitization can start from the links that are easy to achieve results, which can enhance enterprise confidence and encourage enterprises to increase digital investment, for example, digital transformation of instruments and equipment, increasing the use of robots. Digital marketing can quickly show the digital results in a short time and become the priority of most enterprises. Online purchasing and sales can not only save time and cost, but also help enterprises turn from single manufacturer purchasing to multi-channel purchasing, reducing the risk of supply chain rupture (Figs. 5.13 and 5.14).

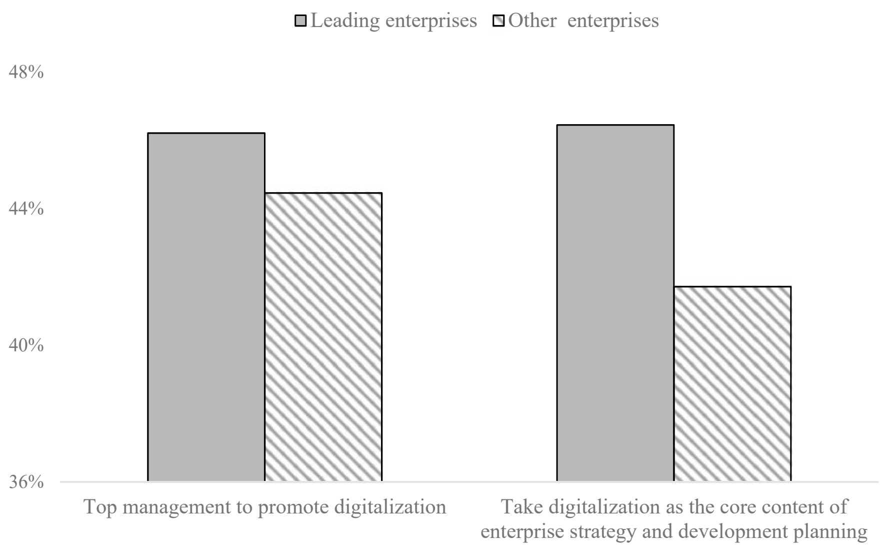


Fig. 5.13 Organization and planning of Chinese manufacturing enterprises (*Source* This figure was prepared by the authors using original data from CIC (2020))

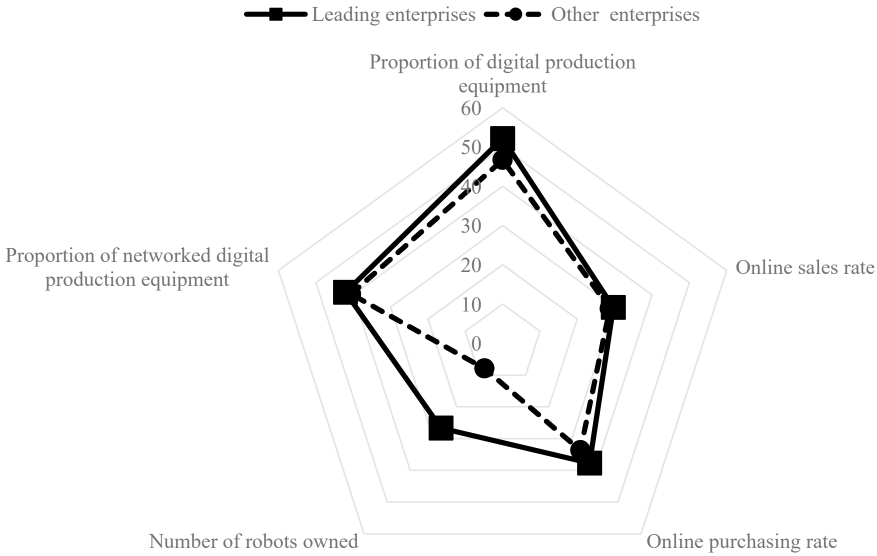


Fig. 5.14 Equipment transformation and online in manufacturing enterprises in China (*Source* This figure was prepared by the authors using original data from CIC (2020))

v. Digitalization of Chinese Small- and Medium-Sized Enterprises

Small- and medium-sized enterprises (SMEs) play an important role which is an important pillar of national economy, an important carrier to solve people's livelihood employment and an important part of China's economy. The Fourth National Economic Census Series Report issued by the National Bureau of Statistics shows that in 2017, there were about 28 million SMEs legal entities, an increase of 115% over the end of 2013, accounting for 99.8% of the legal entities of all enterprises; If it is included in individual industrial and commercial households and family workshops, the number of SMEs in China reaches 93.794 million, accounting for 95.6% of the main body of various industrial and commercial markets in the country.

iResearch survey shows that in 2019, the number of SMEs and individual business households in China reached 121,319,000, accounting for 96.4% of all kinds of business entities in China. SMEs enterprises are the main force to solve the employment of people's livelihood in China. Hence, at the end of 2018, SMEs in China absorbed 233.04 million employees, an increase of 5.5% over the end of 2013. This accounts for 79.4% of all employment personnel, and the total assets of the enterprises reached 402.6 trillion yuan, accounting for 77.1% of the total assets of all enterprises. SMEs has made outstanding contribution to China's economy. The value of SMEs' final products and services accounts for more than 60% of gdp60%, and the tax payment accounts for more than 50%. In addition, about 70% of the patent rights and more than 80% of the new product development in China are from SMEs (Fig. 5.15).

Since 2015, China's SMEs digital service industry as a whole has maintained rapid development. In 2015, the market scale of the industry was only 17.94 billion

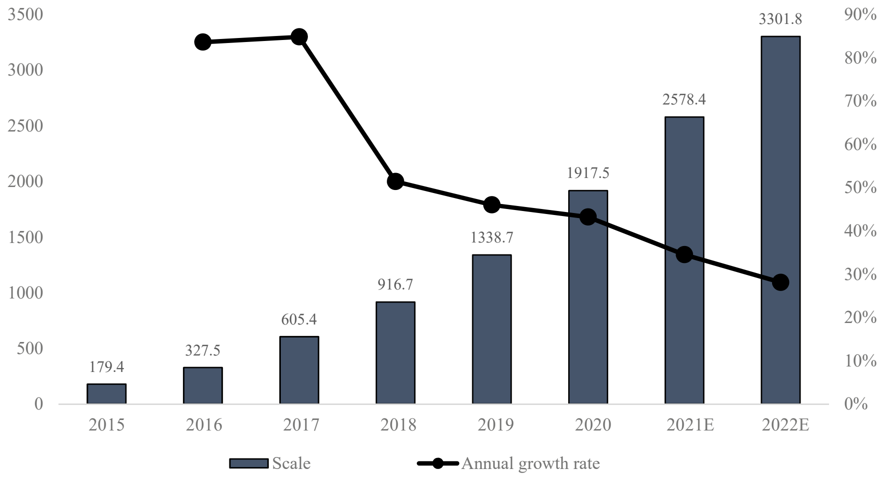


Fig. 5.15 Scale of China SME digital service industry (100 million) (*Source* This figure was prepared by the Authors using original data from iResearch Institute (2020)). **Note* 2021E, 2022E = estimates

yuan, and by 2019, it has exceeded 100 billion yuan. At the beginning of this year, the epidemic spread across the country, and all kinds of SMEs suffered a huge impact, but at the same time, the epidemic also greatly stimulated the demand of SMEs for digitization. Whether it is the single business model, the lack of online operation ability, or the backward internal management and marketing mode, as well as the blocked financing channels, the shortcomings of SMEs exposed in the epidemic situation are also the driving force of digital service providers. iResearch predicts that in the future, the scale of digital service market of SMEs will maintain a high growth rate, and the industry as a whole will produce more innovative service modes and gradually become mature, enabling SMEs for a long time (iResearch 2020).

The epidemic has also pressed the acceleration button for the digitalization of SMEs. The reason is that the offline customer acquisition channels are blocked by the epidemic, while accelerating the digitization of SMEs. Affected by the epidemic, consumers stay at home for a long time and consume through online channels, and many offline customer acquisition channels of SMEs are blocked. However, only a small proportion of SMEs had completed the online + offline layout before the epidemic, so a large number of digital upgrades of SMEs were generated during the epidemic period to build online "cloud stores." According to iResearch analysis, the epidemic situation has objectively accelerated the digital upgrading process of SMEs, and the enterprises that provide digital services such as smart payment, online financing, digital marketing and digital management of SMEs will usher in a period of rapid development (iResearch 2020).

5.4.3 Digital Governance Development

Digital governance is the guarantee for the rapid and healthy development of digital economic innovation, and an important part of promoting the modernization of national governance system and governance capacity. CAICT believes that data governance is divided into broad sense and narrow sense. In a narrow sense, data governance mainly refers to the technology and activities of data governance, which is the process of standardizing the disposal and application of data within the organization. Data governance in a broad sense is a set of behavior system to activate and release the value of data elements through diversified governance means, which is the key to the development of digital economy. Data governance is a set of behavior system for enterprises, government, society, market and other multi-participants to achieve the goals of improving data quality and application value, promoting data resource integration and circulation sharing, and ensuring data security through technology, system, personnel, law and other means. In the process of data governance, the data management within the organization, the data flow between organizations and the security guarantee covering the whole life cycle of data are three key issues (CAICT 2020b).

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i. *Digital Management of Enterprises*

In the process of digital transformation of enterprises and governments, data is the basic and strategic resource. Only by consolidating the foundation of data management can we improve the quality of data resources, support the data flow and application at the upper level and give full play to the value of resources (CAICT 2020b). China released the data management capability maturity assessment model in 2018, but it shows a diversified trend in the practice of all walks of life. In the financial industry, it is "management system first," and Internet enterprises usually "practice and exploration first," There is a significant gap in data asset management ability between different industries. Sixty-seven percent of the institutions in the financial industry have established an organization level data governance framework and defined the responsibilities of the relevant management. Eighty-five percent of the institutions said that they have incorporated data governance into the annual strategic plan (CCUA 2019). In the telecommunications industry, China Unicom started the comprehensive capacity building of data asset management at the organizational level in 2014 and achieved the consistency of index data and detailed data of 31 provincial companies. It has established an organizational structure including information management committee, data governance office, business data management unit and data production unit and started the construction of enterprise level data center in 2019 to realize data logistics centralized logic centralization (China Unicom official website).

In the Internet industry, DiDi established data governance department, data architecture department, data platform department and data science department in 2017 to control the whole life cycle of data by using big data platform. By dispersing data scientists to various business departments, DiDi deepen the combination of data requirements and business requirements (DiDi official website). In addition, the China Internet Association has also set up a Data Governance Working Committee in July 2020 to promote the improvement of the data governance capability of the Internet industry (ISC official website) by building a public platform and formulating common standards. Looking at the industries with insufficient data asset management capability, the main reasons include weak information foundation, insufficient data management input personnel and professional level, limited driving force of data asset management, etc. For example, industry is still in the management software stage of ERP, CRM and SCM in terms of informatization foundation, which makes the cost of enterprise-level data collection, storage and analysis remain high. At present, 41% of industrial enterprises still use manual document method for data management (CCUA 2019). In terms of data management input personnel and professional level, nearly 50% of industrial enterprises invest less than 5 people in data management, and no professional data management team has been established. In the aspect of data asset management drive, data is mostly used to monitor production operation and equipment failure, and there are too few data application scenarios, lacking the driving force of data asset driving business development.

ii. *Digital Governance of Government*

Compared with enterprises, the scale of government data resources is larger. Data covers all aspects of people's life, and the potential value of data is huge. The opening of government data will provide great energy for promoting the high-quality development of digital economy. From 2010 to December 2020, in addition to Heilongjiang Province, a total of 56 policy documents on government data opening have been issued in 30 provinces (CAICT 2020b) (Figs. 5.16, 5.17, 5.18, 5.19 and 5.20).

According to the CNNIC report, as of December 2020, there were 14,444 government websites in China, mainly including government portals and departmental websites. Among them is 1 Chinese government website, 894 government websites

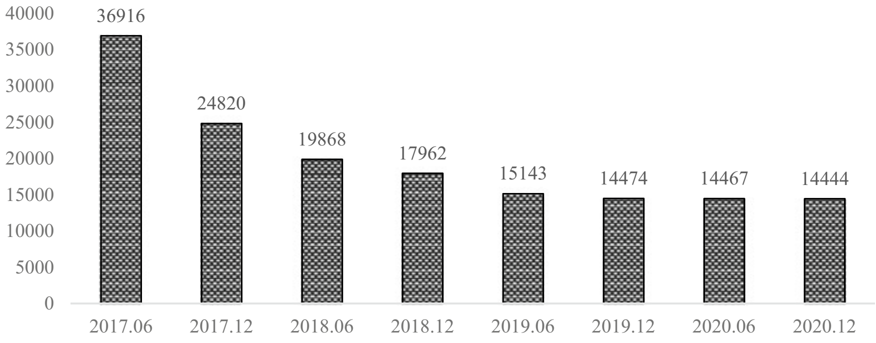

Fig. 5.16 Number of Chinese government websites in China (*Source* This figure was prepared by the authors using original data from CNNIC (2021)]

Fig. 5.17 Number of government websites at all levels in China (*Source* This figure was prepared by the authors using original data from CNNIC (2021))

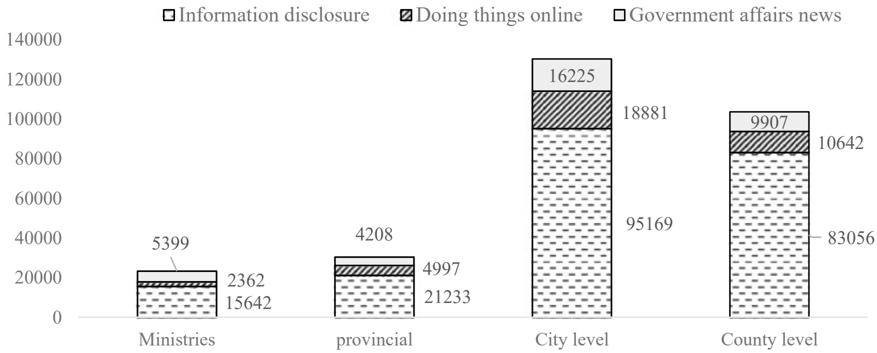

Fig. 5.18 Number of columns in government websites at different administrative levels (*Source* This figure was prepared by the authors using original data from CNNIC (2021))

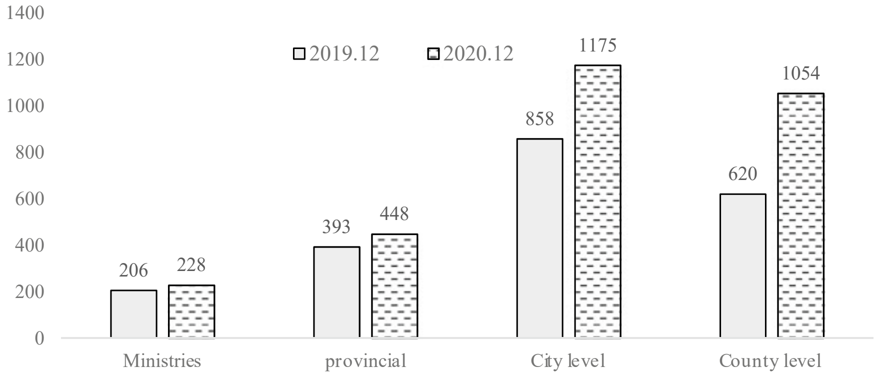

Fig. 5.19 Number of articles on homepage of government websites (ten thousand) (*Source* This figure was prepared by the authors using original data from CNNIC (2021))

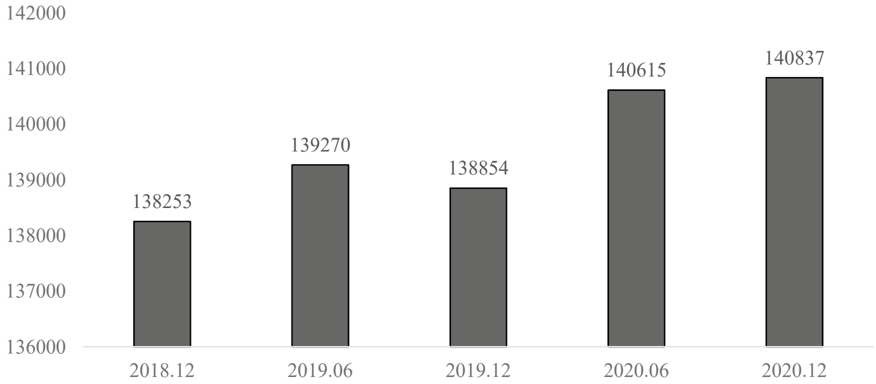

Fig. 5.20 Number of Weibo of government in China (*Source* This figure was prepared by the authors using original data from CNNIC (2021))

of State Council departments and their internal and vertical management agencies, accounting for 6.2% of the total government websites, and 13,549 government websites of administrative units at or below the provincial level. There are 11,862 government websites in administrative units below the municipal level, accounting for 82.1%.

Furthermore, there are 298,000 public columns on the websites of governments at different administrative levels, mainly including information disclosure, online affairs and government affairs. The municipal website has the most columns, reaching 137,000, accounting for 45.8%. Among the government website columns, the largest number of information disclosure columns is 215,000, accounting for 72.1%. The second was the online service column, accounting for 1, 2.4%. The number of government affairs dynamic columns accounted for 12%.

In 2020, there was an increase in the number of articles on the home page of government websites, with a total number of 29.06 million, an increase of 39.9% over the previous year. County-level government website home page article updates the highest growth rate, up to 70%. In addition to the government website, the number of microblogs of government agencies certified by Sina platform is 140,837, and the number of government headlines (today's headlines and government public information release platform) has reached 82,958.

China's government data open sharing system has been gradually improved, and its characteristics are mainly reflected in three aspects.

- Data sharing open content: All localities solicit opinions and suggestions from industry associations, relevant enterprises, the public and industry authorities, open the list of itinerary data and adjust it in time.
- Open range of data sharing: There are public data resources involved in the expansion of government data to 70-page units, and the total number of national open data sets has increased dramatically. It has increased six times from 2017 to 2019 (CAICT 2020b) and will continue to increase in the future.
- The forms and types of data sharing are also diversified. It provides open forms of data sharing, including service application, data visualization, research results and innovative solutions (CAICT 2020b).

The implementation of data opening and sharing has also been further accelerated. Taking Shenzhen municipal government data open platform as an example, since it was launched in November 2016, as of July 2020, the number of visits to the platform was nearly 24.78 million, and the total amount of data is nearly 270 million, covering 14 fields such as education, science and technology, transportation and so on (Fudan University 2020).

5.4.4 Digital Value Development

China's data trading industry started in 2014. The next year, big data was promoted to the national strategic level, and 2015 is considered to be the first year of the development of China's data industry. Data trading also started with the support of national policies. From 2014 to 2016, China's big data trading flourished everywhere. In less than three years, 13 big data exchanges, centers and platforms were established (CAICT 2020b). After the end of 2019, the pace of data trading industry layout continues to accelerate, but most of its operations are not smooth, the data trading volume is far lower than expected, and even many of them have fallen into outage, and the data trading industry is still in the small-scale exploratory stage. There are some problems in data legalization, digital right confirmation and digital transaction.

CAICT believes that the reason lies in the positioning and operation mode of the data exchange and the incomplete supporting laws for data trading. On the one hand, it is difficult to cultivate the platform dependence of data suppliers and demanders on the exchange due to the confusion of trading rules such as similar positioning and service mode during the construction of data exchange. Furthermore, the definition of data ownership is still in a gray area, and the relevant legislation is not yet perfect. In the practice of the industry, there is no consensus or reference ownership rules. Therefore, the risks of property rights disputes and failure to supervise make both the supply and demand parties flinch. In addition, the spelling of data security and personal privacy leakage incidents also lead to the distrust of the society on data transactions, which is in the protection of national security, personal information and trade secrets. Therefore, the initiative and enthusiasm of the theme to participate in data transactions are reduced. This is also a big obstacle to the development of data exchange (CAICT 2020b).

Therefore, on July 1, 2019, the Ministry of industry and information technology issued the "special action plan for improving the network data security protection ability of the telecommunications and Internet industry", carried out a one-year special activity, focused on data security compliance assessment, special governance and supervision and inspection, established a network data security guarantee system for the industry and the Internet, and promoted the construction of the industry data security governance system. On May 14, 2020, the "key points of network data security compliance assessment for Telecom and Internet enterprises in 2020" was released, which defined the key systems and norms of industry data classification and classification, security assessment, security certification, early warning disposal and many others.

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Website

ChinaUnicon official website http://www.chinaunicom.com.cn
DiDi official website https://www.didiglobal.com
ISC official website https://www.isc.org.cn

Chapter 6
Big Data and Its Implication in China

Zuquan He, Jinling Hua, Bismark Adu Gyamfi, and Rajib Shaw

Abstract The big data is a new conception in Informational Technology (IT) field. However, the application of big data has changed the Internet industry with its unique value. The government of China realized the value of big data in early phase then supported the development of big data with several measures. Hence, the big data industry has seen rapid development for the past years and played an important role during the COVID-19. Based on the prevention system led by the central government of China, big data from different parts were combined in one platform to track the infection source, epidemical research and economic recovery in China. The applications during the COVID-19 will be great fertilizer for the development of big data in China in forming a model for application of big data. However, the constitution of model of big data will be the most important challenges in the opportunities brought by big data.

Keywords Big data · Economic recovery · COVID-19 · Healthcare · China

6.1 Introduction—Relationship Between Big Data and Covid-19 in China

When we refer to the official reports of Chinese government related to Covid-19, the application of big data will always be founded in several sections. As one of the early adopters of big data for research and control of this pandemic, analysis on relationship between big data and Covid-19 in China could be an inspiration for other countries struggling in coronavirus and looking for economic recovery.

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J. Hua et al. (eds.), *Considerations for a Post-COVID-19 Technology and Innovation Ecosystem in China*, Disaster Risk Reduction,
https://doi.org/10.1007/978-981-16-6959-0_6

6.1.1 Definition of Big Data

As an Information Technology (IT) term, big data means datasets that are too large or complex to be dealt with by traditional data-processing application software. In the view of the pioneer of big data, it means we directly manage and analyze all the data without sampling survey (Mayer-Schönberger and Cukier 2013). Compared with data which we collected by sampling survey in the past, big data have five characteristics:

- Volume: Big data should be "big" in volume. Generally, the size of big data should be over terabytes and petabytes (Sagiroglu 2013). Besides, the value and potential insight of big data are also determined by the volume. As a result, the capturing data, data storage, data analysis become an essential challenge for application of big data. Nowadays, the cloud database computing is required for big data management.
- Velocity: The high speed of the generation of big data to meet the demands, and the high speed of the feedback or digestion of the big data (Marr 2015). More and more big data are collected by different organizations in high speed and handled by different organizations in high speed.
- Variety: This characteristic come naturally with volume and velocity (Jain 2016). The data generated with high speed and huge size mean the variety of the date could be astonishing. As a result, we have enormous types of data we could use.
- Veracity: The messiness or trustworthiness of the data (Marr 2015). We could get different data from different sources, and most of them are not really structured data, which means that we need special analytic technology to ensure the accuracy of bug data.
- Value: The reason why we need big data and why we pursue research on big data. With the ability to turn big data into value, the big data could be an essential tool for decision (Marr 2015), marketing, etc. Based on the demand, big data could offer different value with different view.

We could get a conclusion from these five characteristics that big data could come from every organization that has the ability to collect and store huge amount of data. To make good use of them, we should handle the conception of big data and practice with new special analytic technology.

As a new concept, big data have enormous potential in economic field. The traditional economics was based on traditional statistics. However, big data give a new chance to economics, such that its huge dataset allow specialists to conduct more accurate research. Besides, the big data industry itself has a high economic potential, according to the prediction of World Economic Forum, big data could create 4.4 million IT posts in the world and one IT post could create 3 posts. The number of economic gains from big data application is enormous, that is why many countries are promoting the application of big data, especially in China.

6.1.2 Big Data in China

As one of the populous countries, data collected by government or other organizations could easily be considered as big data in China. Internet as a new pillar of Chinese economy appeared with large Internet corporations such as Alibaba and NetEase. The management of data collected by such organizations support their decision and the management of such huge data itself became a business service. On the other hand, the Chinese government is also active user of big data. Thus, from local to central government, making decisions based on analysis of big data is becoming a common phenomenon. The rapid development of big data in just 10 years in China might owe to the support system established by Chinese central government. To manage the governmental information, the cooperation between local government and cloud service company has a history over 10 years in some regions. On September 2015, the Prime Minister Li Keqiang signed the Action Outline for Promoting the Development of Big Data, clarifying the support system and the direction for big data in China (State Council of PRC 2015). In this outline, the government underlined its data share of government and the support for related industries, which meant that big data could be supported both in public and private domains.

The outline from the State Council has been well executed after 2015. To give a direction of big data development, the State Council of China published the document of Application and Development of Big Data in Heath Care Industry in June 2016 and big data began to be considered officially as a new tool in medical service. The Outline of Strategic Development of Informatization in China was published by the State Council of China in July 2016. In this outline, the application and development of big data was considered as an important part of the development of informatization in China, and the integration of big data with other information technology was underlined by the State Council. Such includes the combination with cloud storage and cloud computing, AI and other new technologies. On July 2016, in the most important guidance document for future development which is the "Outline of the 13th Five-Year Plan for the National Economic and Social Development of the People's Republic of China", the central government stressed the fully support for the development of the big data (Xinhua Net 2016).

Based on the new Five-Year Plan, the awareness of integration began to be accepted by different ministries. As a beginning, the Ministry of Land and Resources of China published "The Opinions on Development and Application of Land and Resources Big Data" to promote the internal integration in the system of Land and Resources Administration. Subsequently, the Ministry of Transport of China published "The Opinion on Open of Big Data Resources in Transportation Industry" to promote the open of big data collected by public transport service suppliers such as the railway and airlines. These official documents played an important role in the application of big data during Covid-19. In December 2016, the Ministry of Industry and Information Technology of China, the policy maker of the information industry in China, published the "Development Plan of Big Data Industry." This plan was more detailed than the Five-Year Plan; it supported the development of big data in private domain and gave the private corporations and official departments the instruction of how to apply and develop big data. As a result, the development of big data has become a part of the national development strategy. Hence, the government began the cooperation with private enterprise and state-owned enterprise (SOE) in different areas.

The development of big data in Guizhou Province is one of the best examples for the development model of big data in China. For other new industries, the central–local government support system and a development center is the usual model in China. As for the big data, the Guian New Area established in 2014 was the big data industry center build with central-local government support. In 2015, Guian New Area was assigned as the Big Data New Area with the publishment of "The Three-Year Plan of Promotion of Big Data in Guian New Area." The local government published the promotion regulations in Guizhou Province to attract private corporations and SOE to establish their data center in Guian New Area. As the follower of policy, the SOE in China was the leader that offered the direction of new the policy. As a result, the China Telecom was the first to establish their data center in Guian New Area, then private corporations followed the SOE to enter this new area. Before Covid-19, there were already over 30 data centers of private corporations and SOE in Guian New Area. The development of big data in Guizhou Province was in the way of large-scale model.

Basically, we could make a conclusion of the characteristics of the big data development in China as follows:

- High speed of development: Big data became an industry and began to take shape in several years, there were high-level support systems from the Chinese government. The central government published several important documents to support and direct the development of the industry and also established special new areas. Leadership of the government, as the big data centers in China in the first stage were mainly established by SOE such as mobile operators and they were the practitioner of the direction shown by the outline published by the central government.
- Dominated by large companies: It is partly directed by the characteristics of big data since only large companies have access to collect big data and to manage them. For instance, besides the large-scale SOE, other large companies include Huawei, Tencent, Alibaba, etc. These famous corporations were the main dominator of this new industry in China.
- Low resource sharing rate of big data: It is not only the sharing of big data between the government and the private corporations, but also inside the government itself. As the bureau in the same level could not initially get access to the database of other departments (e.g., the police bureau of a city could not get access to the data of electricity supply bureau in the same city), it was even more difficult to share the date with private corporations. The cooperation between the government and the private part stayed just on the paper. However, in the following section we could see how Covid-19 has changed the big data industry in China.

Based on the support system established by the central government, in some developed areas in China, the local government began the cooperation with private companies in management of governmental information. On the other hand, more and more private corporations entered this field and considered big data as a potential force for development by establishing their own database and analytical technology. When the outbreak of Covid-19 became a national emergency after the lockdown of Wuhan, big data came in sight of central government and soon played an important role in tracking and minimizing its spread and containment, as well as in economic recovery in later time (Haleem et al. 2020).

Several kinds of big data from different organizations were applied to support the decision of government. As the research of China Center for Information Industry Development (CCID) showed, three kinds of big data were adopted usually in different phase of epidemic control (Hui 2020). We could conclude those big data as below:

- The data from mobile operators like China Unicom, China Mobile, showing location information. Through analysis, the government could locate users who got access to high-risk area and their movement in subsequent days.
- The data from travel service suppliers, such as the data from the operator of railway, the data from traveling site, etc. The government could tract the infected people and give an alert to those who had contact during his movement.
- The data form government agencies. For example, the data from the National Health Commission and Local Health Commission. Their data could show the amount of infected people in different area and the tendency of the pandemic.

However, we should point out that these three kinds of big data were not used separately in different phase, all data from different sources were integrated by one temporary commission composed by representative of government and specialists. They made analysis based on different request by government agencies and then gave further suggestions.

6.2 The Applications of Big Data in China During Covid-19

Big data did show their value during the past a few months in China, however as we mentioned in Sect. 6.1, as per the five characteristics of big data, turning big data to value needs some sort of ability. In this section, the case of the first wave from Wuhan and the second wave in Beijing will be taken as example for explaining the mechanism that the Chinese government established to minimize the infection.

6.2.1 Big Data in the First Wave from Wuhan

After the lockdown of Wuhan, the Mayor of this city announced in a news conference on January 26, 2020, that over 5 million people had left Wuhan before the lockdown. What was the destination and how did they leave Wuhan? It became the worry of not only the public but also the government. To minimize the spread of the coronavirus, the central government had a quest to track the movement of the population and to get prepared for a control. In the same day of this conference, the central government established a temporary leading commission to integrate governmental resources and social resources for epidemic control. The central government named the commission as the Central Leading Group for Novel Coronavirus Prevention and Control and the Prime Minister Li Keqiang was the leader of the team. Under the instruction of this team, local governments found local leading groups to pull resources together. This leadership system was important for the application of big data, since on the one hand they have the authority to get all kinds of data from different parts and the specialist team could make the analysis in real time to support the decision at the central government level. On the other hand, the local leading team could also act efficiently with support from the central leading group and supply local data to central team as reference.

For example, just after the leading team sent a medical specialist team to Wuhan on February 6, the leading team got the result of the two problems raised by the public and the medical specialists based on traveling service data, especially the data from public transportation operators (the real-name system for railway and airplane). The data came from Baidu Map (since most of the Chinese use Baidu Map for navigation while driving and the map application have access to location information).

As shown in Fig. 6.1, the first destination for people who left Wuhan was cities in the same province. The medical specialists team form the leading group announced the special alert to other prefecture-level cities in Hubei and predicted the outburst of COVID-19 in those destination cities such as Huangshi and Ezhou after verified the data. On the other hand, the leading group instructed other provinces to track and locate those people from Wuhan based on the data from public transportation that they shared to local government. As a result, most of the potential carriers from Wuhan were tracked in a short time, and the follow-up screening came to verify those who had contact with these people from Wuhan. As a conclusion, the big data played important role in the first wave of COVID-19.

After the first phase, the effect of big data was emphasized by the leading group, more and more organizations began to share their big data with local government and took active actions with support of big data. During the check of local communities in Wuhan, the SOE State Grid Corporation in Wuhan offered their electricity usage data to Wuhan leading team and made the analysis of habitants in important communities such as the Baibuting Community. The team of this SOE classified all families in the community to reduce the time for check. This case was highly valued by the leading team, and they encouraged other governmental organizations to share their data with local leading team.

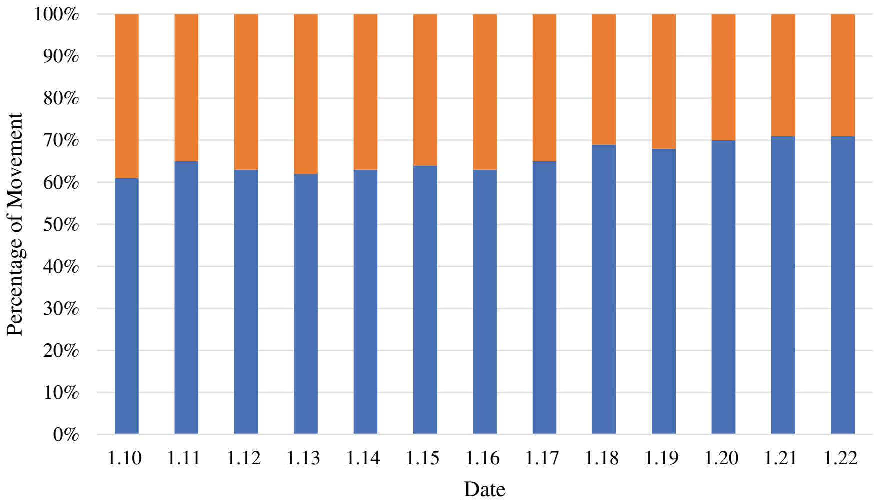

Fig. 6.1 Movement from Wuhan to other places during spring festival travel rush (January 10th–January 22nd) (*Source* This figure was prepared by authors using the data from Baidu Map). **Note* the orange part is the proportion of people from Wuhan whose destination was out of Hubei Province, the blue part is the proportion of people from Wuhan whose destination was other cities in Hubei Province

As a complement of this system, the government integrated the data from several governmental organizations and uploaded an App named Detector of Close Contact. The interface of App constituted by three parts. There is a search window of Close Contact, where users could input their personal information such as ID number in this window. Below the search window, there is introduction of the status, if the result of search is red, it means that the user was close contact of Covid-19, on the contrary, if the result is green, it means that the user was not close contact of Covid-19. In the bottom of the interface of app, there is explanation of the definition of Close Contact. In this app, the close contact was defined as people who directly lived with confirmed cases and includes colleagues in the same office, classmates and teachers in the same classroom, passengers of the same vehicle, etc. Since this app was based on big data from transport service suppliers, this app was aimed to find close contacts who were passengers of the same airplane, train, bus with the confirmed case or suspected case (inside the range of the same row, the 3 rows in front and 3 rows in back) (CETC 2020). Users could confirm whether they were close contacts or not with several types of personal information (Cellan-Jones 2020). The app would compare the personal information of users with traveling information and confirmed case information in the shared database, in just few seconds the result could be displayed. The access to big data for public improved the efficiency of epidemic control by realizing the self-confirmation of close contact. According to the official media, this app has served for 150 million times of inquiry, over 90 thousand cases of close contact were confirmed by users themselves (State Administration of Science Technology and Industry for National Defence of PRC 2020).

In the first wave of Covid-19 from Wuhan, the system of leading group integrated all kinds of big data to make the decision for preventing Covid-19. The big data were applied in different levels of government, and even the public could get access to it as the complement of the system of prevent and control. Generally, we could conclude that the big data were important in the early phase of Covid-19, and the application of big data in China showed how to turn big data to value by establishing the system leaded by powerful commission to integrate big data for different objectives.

6.2.2 Big Data in the Second Wave

In June, the first wave of Covid-19 from Wuhan was basically controlled based on the tendency of new cases. The National Heath Commission announced the transition from treatment and prevention to prevention and control. In this phase, tracking and locating the source of infection was essential for the prevention of second wave. The case of Xinfadi Market in Beijing gives an example for how to use big data in tracking source of infection.

The first confirmed case in June in Beijing broke the 0 confirmed case record for 56 days. However, if the medical specialist could not track and locate the source, there will be another outburst in few weeks. Polymerase chain reaction (PCR) test was conducted for all residents in Beijing. Furthermore, all the movement data collected by mobile operators, payment data collected by mobile payment corporations of the confirmed cases were followed to track the source of infection. Based on the analysis of big data, the medical specialist located the source of infection in Xinfadi Market, a market of seafood in Fengtai city of Beijing. All communities near to this market were quarantined, and this second wave was controlled in a short time.

The specialists did not stop here. To prevent new case like Xinfadi Market, they tried to verify the source of infection in about 4000 stores existed in this market. Based on principals of epidemiological investigation, they analyzed the samples of the 3000 people who had gone to Xinfadi Market during May 20–May 30. By analyzing the movement data offered by mobile operators, the medical specialists located the source of this wave to the 14th booth: S14 (Pang et al. 2020). After the confirmation of the source, the specialists did a new turn of epidemiological investigation and verified the staff of S14 have not had contact with confirmed cases before. The joint team from Tsinghua University, Peking university and other medical institutions made a research based on previous data and confirmed the source of infection might be the seafood imported from outbound. This research prompted the Chinese government to enforce the control of imported cases, which lead to the enforcement of restrictions on in-bound activities.

6.3 Application of Big Data in Economic Recovery

The economic activities could not stop all the time under the pressure from Covid-19. However, the government had to run the risk of the second wave in all the big cities if all activities get back to normal the same time. How much labor could get back to factories? How many enterprises could resume their production? The analysis based on big data gave the suggestion to local government. On 10th February 2020, the joint team constituted by members from Faculty of Medicine and Faculty of Information Engineering publish a research named "Time–Space Research on Prevention and Control of Covid-19". In this report, the specialists from Faculty of Medicine employed the traditional Model of SIR/SEIR (susceptible, infectious, removed/recovered, E = exposed). The big data from Shenzhen government such as mobile operator data, local demographic parameters and the analysis model made by Faculty of Information Engineering to pursue their research (Shenzhen University 2020).

The specialists made simulation with the SIR/SEIR model, and the results showed that if the flow of people could be restricted to 50% of normal level, the peak of new contamination will be later than normal condition and the amount of new contamination will also get controlled compared to normal flow. Nevertheless, the time when the government cancel the limit of flow will have no effect on peak amount in the condition at that moment. As a result, the restriction of flow was necessary, and the economic recovery should be conducted step by step. The transmissibility of the Covid-19 as one basic parameter was not confirmed by any paper. The team took the result calculated by Hong Kong University, the incubation period was set as 14 days, and the percentage of people with mask was set as 97%.

The SIR/SEIR model was a combined model of SIR model and SEIR model. The SIR model was a basic model to simulate the contamination; the incubation was not considered in SIR model so the research team combined it with SEIR model to consider the incubation factor. However, these two models have common base. Thus, they divided people into four categories: S type, susceptible to the infectious disease. E type, exposed to the disease, which means they have contacted with confirmed case but could not infect others. I type, infectious of the disease, they could infect the S type and turn them to E type. R type, recovered or dead. It refers to those who have been quarantined or recovered from the disease, if the immunity is not permanent, R type could transform to S type once again if the immunity is not of time.

The SIR model was based on the equation as follows:

$$\frac{\mathrm{d}S}{\mathrm{d}t} = -\beta IS, \frac{\mathrm{d}I}{\mathrm{d}t} = \beta IS - \gamma I, \frac{\mathrm{d}R}{\mathrm{d}t} = \gamma I.$$

The summit of I comes when $S = \gamma/\beta$ and decrease progressively (γ refers to the recovery rate and β means transmissibility of the virus). In this model, the E type (such as the carrier of Covid-19) was not considered, so the research team combined it with SEIR model to make the result be more accurate. The SEIR model was based on the equation as follows:

$$\begin{cases} \frac{dS}{dt} = -\beta IS, & \frac{dE}{dt} = \beta IS - (\alpha + \gamma_1)E, \\ \frac{dI}{dt} = \alpha E - \gamma_2 I, & \frac{dR}{dt} = \gamma_1 E + \gamma_2 I. \end{cases}$$

Here parameter γ was divided into γ_1 (recovery rate during incubation) and γ_2 (recovery rate during infection period) since it is usually not the same. The characteristic of this model is that the users consider that not all the contact case have ability to infect others. The further research of Shenzhen University showed their simulation of resumption of work. Based on big data analysis, they made a conclusion that when 60% companies resume their activities, the comprehensive benefit (from the view of epidemic control and economic recovery) was the highest.

Although the research was preliminary since it was completed in a short time, it offered an important reference to the local government to make the policy of economic recovery. To realize the economic recovery, the intercity and interprovincial movement of people should be considered. How to simplify the verification of quarantine for those who would get back to where they worked in? How to make sure they are safe for the destination cities? The Health code got into sight when the local government tried to find the solution. The Health code was an integrated app; with the green QR code, people could get access to municipal transportation or get into public facilities, those who with yellow QR code should be quarantined for 7 days, while red QR code means 14 days of quarantine. On the other hand, the Health code app worked as a collector and monitor for movement. These data could be collected by service suppliers and serve in the prevention system.

6.4 Outlook of Big Data in Post Covid-19

From the analysis above, we could conclude that the big data played an important role in different phases of Covid-19 in China. In this section, we are going to summarize the new development during the Covid-19. Besides, the development of big data in the future will also become a new task for China when the Covid-19 is well controlled.

6.4.1 Summary of Big Data During the Covid-19 in China

As we mentioned in Sect. 6.1, the big data industry in China before Covid-19 was led by official, large-scale companies, and the integration of big data between different departments. Another characteristic was the efficiency of cooperation between the government and private corporations. From the case of Wuhan in the first wave and the case of Xinfadi in the second wave, we could see some changes of these characteristics. The most important change is the sharing of big data. With the support of the leading team, several government departments began to share their database with others and the specialist could get access to them and make analysis based on the sharing big data, which improved the efficiency of the prevention and control

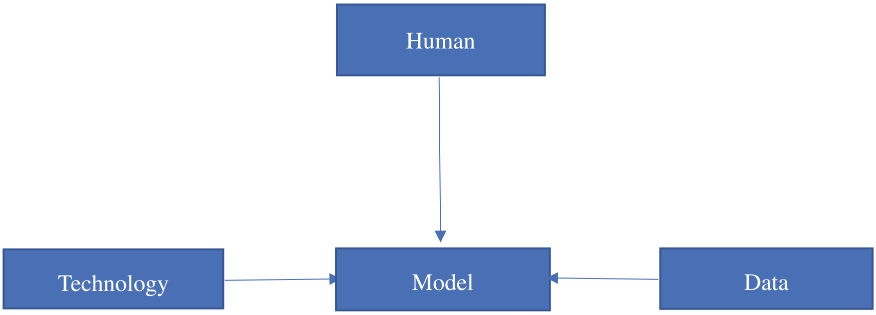

Fig. 6.2 Ideal model for application of big data (*Source* This figure was prepared by authors using original information from CCID)

of Covid-19. Another change was the cooperation between government and corporations. As we analyzed in the case of Wuhan, the data from the grid corporation helped the prevention and the control of Covid-19. With more high-quality big data, the value of big data could be bigger. Sharing and integration was the centric point for the new change of big data in China.

However, as the pioneer of application of big data, different kinds of problems were also found during the practice in China. To make good use of big data in various fields, keeping awareness of right model for the application of big data is indispensable for the development. This is presented in Fig. 6.2.

The application system should serve the people with appropriate analytical model with specific aim. The integrated data form the base of the system, information technology for management of big data and modeling supplied the formation of model, and interaction between the model and the users/objectives of the model turns big data to value. The awareness of users drives this system, but the model adaptation based on objectives decides the efficiency of the application.

Those problems founded during the application of big data in the period of Covid-19 were just in different parts of this system. As the research by CCID showed, for the base of the system, the integration level of big data from various sources was low in some regions and domains. The reliability of data was influenced; the analytical model could not run with best status. The technology of modeling is still in primary stage; hence, the analytical model of big data was restricted in several special conditions, and as a result, the ability of adaptation is limited. The awareness of the users was also important point. In fact, most of the local governments did not even consider the usage of big data. Government staff collected data and recorded the data by hand, investigated communities by themselves, etc. It was not only low efficiency, but also increased the infection risk. Therefore, what could we learn from those problems for the time post Covid-19?

- Improve the integration level. The organizations that want to use big data as resources should get enough data as the base, and they should have support from information technology suppliers to manage their data and create appropriate model to serve for them according to their needs (Xun and Xiaofeng 2020).

- Intensify the supervision of the application system. The risk of information leakage augments with more and more organizations are integrated in the application system. The main user (usually the government) should establish an independent supervising system to keep the safety of data (since they are from individuals), which means that the main user should be powerful in this system as the role that the Chinese central government played in Covid-19 (Chuanjun 2020).
- Improve the awareness toward big data. As the user, if the organizations could not realize the potential value of big data and still stuck in the traditional hand work, the efficiency will be low compared with those organizations that could make good use of big data. Keep the basic model of big data in mind; try to use big data from different sources to help your decision will be an important awareness if an organization want to improve or keep its efficiency.

6.4.2 Future Potential of Big Data in Economic Recovery

All industries in China were influenced by the Covid-19 in 2020. Returning to work means that the spread and potential damage of COVID 19 had slowed down. As an active factor in Covid-19, how to use big data in economic recovery post Covid-19 might be important for the owner of corporations and policy makers in central government in China. As for the private corporations, how to turn the value of big data to economic value will be a new task. As the pillar of the Internet Economic in China, the online shopping platform corporations in China have shown us an example how to turn big data to economic value, for example, the online shopping festival 6.18 on the platform Jingdong. During the promotion periods, Jingdong analyzes big data of shopping characteristics of every user and finds the new shopping trend such that most popular items are promoted to the home page of app. The app will then give a personal promotion according to the shopping record and the items which the users have seen in recent days. During the period of 6.18, the logistics becomes a problem. Recently, Jingdong analyzed the logistics data in previous years, and based on the condition of the orders, it coordinated the transportation of the commodities to improve their efficiency of logistics.

Another online shopping festival 11.11 conducted by Taobao was also a good example for the application of big data in economic recovery. In the past, online shopping was the priority of the youngers. However, because of the Covid-19, online shopping became a new choice for the middle-aged and elderly people. According to the report of official media in China, the online shopping searching from people over 60 years old was 10 times compared with previous year. To fulfill their needs, Taobao established a special page for elderly people based on big data analysis to promote commodities suitable for this group. The big data played an important role in the 498.2 billion RMB transaction volume, then stimulated indirectly, the economic recovery of China (People.cn 2020).

In the online shopping case, big data played a role in promotion, which means corporations could use big data to realize the precision marketing and promote commodities that consumers need. There are more potential economic values of big data, such as the application in manufacturing industries. As same with the promotion, big data analysis by manufacturing corporations could find what customers need and new production lines could be made in accordance with the needs of consumer. Besides, analysis based on manufacturing data allow the makers to improve their manufacturing process and to cut the cost. As the report of McKinsey showed, the big data analysis could reduce 10–15% cost of manufacturing process.

As for the government, how to accelerate the development and increase the economic value of big data will be the main task. The application of big data was concentrated in Internet economic field, so how to promote the application in many industries, especially the manufacturing sector will be a new growth point for Chinese economy. As for the industry big data, there are some problems existing in China. Manufacturing corporations could not collect big data or could not get access to big data from other source. This is still a common phenomenon since there is no sharing platform of industry big data in China. Large-scale companies that have ability to collect and manage big data tend to build a less interactive system to keep their advantage. From this point, to make big data a new growth point for industry, the promotion of sharing service will be an important point. Making big data more open, not only the big corporations could be profitable. Thus, if the middle- and small-sized companies could also get access to big data service, big data will be a new power to accelerate the economic development in China.

Another important problem is the weakness of the core technology. As the model in Fig. 6.2 shows, the hardware technology such as big data storage and management and software technology such as the algorithm model are important in development of big data. In the application of big data, China is the pioneer; however, in the technology base, China still lacks behind. How to promote the development of hardware technology and software technology and build an independent big data ecosystem will be an important task for the Chinese government. However, the sharing of big data will cause another problem as discussed on earlier sections. Hence, how do we protect data leakage when users get access to them? From the government level, there are two tasks waiting. One is the constitution of the law system. As published in Europe and other places, such as the General Data Protection Regulation and the CCPA in USA, a new law that could protect the personal information from leakage might be necessary for the healthy development of big data in China. That is, how to keep a balance of the efficiency of big data and personal information protection will be an important point when the central government try to enact this kind of data protection laws. Another is the establishment of supervision system. The big data service suppliers should not only establish their own internal supervision system, but also accept the supervision from the authority. How to build a system from central to local to keep the health of the big data ecosystem will be another task for the Chinese government.

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Chapter 7
Robotics and Its Advancement in Modern China

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Abstract The development of industries related to robotics in China was not vibrant compared to other parts of the world but have seen exponential enhancement in recent years. Before COVID-19 pandemic, the focus of robot industry in China was mainly related to industrial robots. However, the pandemic initiated new phenomenon by creating non-contact requirement that promoted the dependence of service robots for medical and delivery assistance. The quick development of service robot during COVID-19 in China was driven by external factor (the change of market requirement) and the internal factors (technological factors and market factors) that also boasted start-ups and other large-scale industries to design, develop and apply many kinds of robots. These became valuable in controlling the spread of COVID-19. This chapter chronicles some of these developments in the industry during the pandemic and future prospects.

Keywords Service robots · Market requirement · Start-up · Non-contact economy · China

7.1 Introduction—Robotics in China and Applications During COVID-19

Robotics as an interdisciplinary area has a history of over 60 years. As an industry integrated in computer science, engineering, and information technology, robotic technology has been applied in variables domains to improve production and efficiency (Nocks 2007). Exploring new potential in the field of robotics is always an important topic of scholars. Although it is evidenced that the COVID-19 pandemic has had a negative impact on many industries, the robotics sector showed a different

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J. Hua et al. (eds.), *Considerations for a Post-COVID-19 Technology and Innovation Ecosystem in China*, Disaster Risk Reduction,
https://doi.org/10.1007/978-981-16-6959-0_7

scenario in its application during the pandemic and is equally important in economic recovery of countries post-pandemic alongside other new technologies. This will be expatiated in the sections in this chapter.

7.1.1 Brief Introduction of Robotics in China

The concept of robotics is about how to comprehend, design, manufacture, and operate robots (Arreguin 2008). The definition of robot in China is based on the definition proposed by Masahiro Mori in the academic conference that a robot is an automatic machine with some kinds of intelligence to deal with different affairs. However, the classification of robot can be differentiated by two international standard classification: service robots and industrial robots. As Fig. 7.1, the Chinese Institute of Electronics classifies robot to include service robot (i.e., home service robot, public service robot, etc.), industrial robot (i.e., all kinds of robots used for industrial activities), and special robot (i.e., military robot, emergency rescue robot). Special robot in China was independent needed for governmental organizations (Guo and An 2016).

The introduction of robot technology in China has not been too long when compared with that of some developed countries, as the first industrial robot in China came into use in late 1970s while the first industrial robot in USA was applied in 1950s (LeadLeo Research Institute 2019). However, the development of robotics has witnessed tremendous supported from the Chinese government especially from 1980s (the period of the 7th Five-Year Plan). In 2015, the robotic sector became one of the top ten vital industries to realize the plan of "Made in China 2025." Traditional

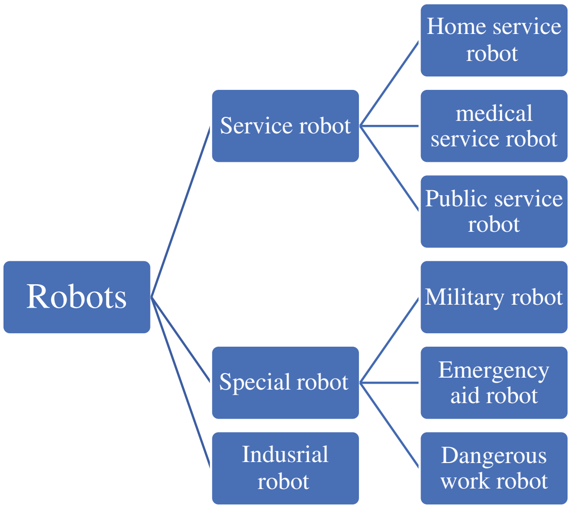

Fig. 7.1 Classification of robots defined by the Chinese Institute of Electronics. *Source* This figure was prepared by the Authors based on information from the Chinese Institute of Electronics

technology universities began their own research on robotics and state-owned enterprise (SOE) as well as private enterprises invested in robotics because they could get economic support from local government in many fields. More and more robots got in sight of the public and began to be a part of the normal life.

7.1.2 *Characteristics of the Robotic Industry in China Before COVID-19*

The development of industrial robot was one of the most important point underlined by China central government to promote the development of the robotic industry. Basically, the development of industrial robots in China can be divided into four phases. The first is the infancy phase (1970–1980), and this is where the first industrial robot came into practice. As a result, some manufacturing plants began to adopt primary robot in machine tool plants. The second is the exploitation phase (1980–1990). In this phase, industrial robots were listed in the 7th Five-Year Plan with the development of the industry after the reform and opening-up policy. As such, welding and load carrying robots were able to be made in China and practiced in heavy industry plants. Next phase is characterized as the practice phase (1990–2010). In this phase, more complicate industrial robots were developed in China, and one of the most important industrial robots in automatic assembly line, Selective Compliance Assembly Robot Arm (SCARA) assembly robot was developed and came into practice. With the development of industries in China, the need for industrial robots to improve production efficiency was more intensive in this phase and supported the "Made in China." From 2010, the industrial robot in China came into the new era when Tsinghua University and other research institute began to pursue research on robotics to support the development of industrial robots in China.

However, according to report of International Federation of Robotics (IFR) (as Fig. 7.2 shows), the density of industrial robots in China was 68/10,000 people. As an industrial country, it shows low efficiency of production in China, and at the same time, the future space of industrial robots in China is enormous if the Chinese government continue their Made in China 2025 plan. This is the reason the Chinese government is planning to invest more in this area and promote the cooperation between capital and research institutes to accelerate the development of industrial robots. Now, the characteristics of industrial robots in China could be concluded as three points:

- Leadership of the government in the market since industrial robots need much more investment than service robots and need high level research ability to support the development.
- Low-end product: as Chinese corporations have not controlled the core technology (retarder, controller, servo system), most of the products are low end and imitated.
- Wide development prospection: as there is high market potential (China has been the biggest market of industrial robots from 2013) and if China could develop

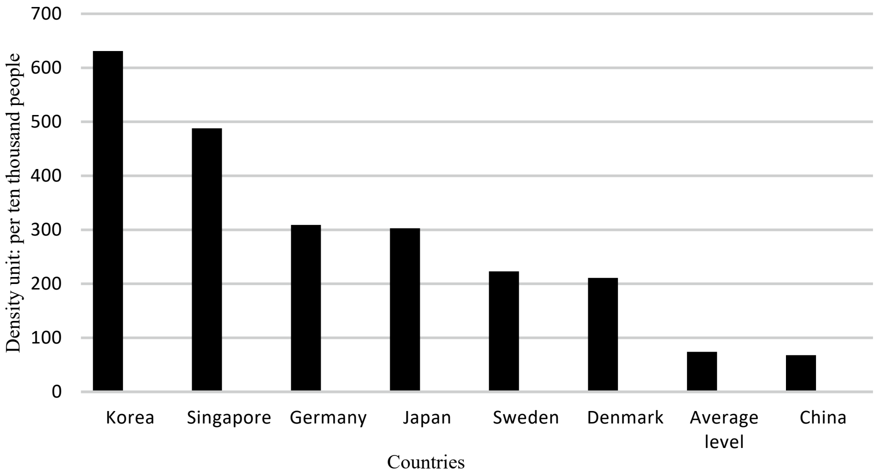

Fig. 7.2 Comparison of density of industrial robots in several countries in 2016. *Source* This figure was prepared by the Authors using data from IFR

their own core technology and break the monopoly of American and European companies in robotics market, the economic potential of industrial robot will be enormous. On the other hand, as industrial robots are applied in more and more domains such as automobile, medicine, electronics, metals, chemicals to improve the productivity, the domestic demands of industrial robots with the development of manufacturing industries in China are increasing. As a result, the central government of China has been trying to promote the development of industrial robots to realize Made in China 2025.

As for service robots, the condition seemed quite different in China before COVID-19. Firstly, the application and use of service robots in China is recent than industrial robots since the first home cleaning robot in 2006. As the technology for service robots is less sophisticated than industrial robots, there are more private corporations active in the market of service robots. According to the report of Chinese Institute of Electronics, the sales volume of service robots in 2019 was 33.1%; which is higher than 2018. Different from the industrial robots, service robot market in China was led by start-ups. As Fig. 7.3 shows, half of the service robot market is home service robot, while the rest are public service and medical service robot. For each kind of service robots, over 80% of the market share is private corporations, and most of these private corporations are start-ups.

As a result, service robot market is more active than industrial robot market which is led by SOE. The production of service robots is mainly in the domain of business to customer (B2C) which means that the makers should keep up with the change of demands of customers to expand their market share. The need of individual customers changes fast in different condition, so start-ups have higher ability to adjust their productions to fulfill these new needs. To conclude, the characteristics of service

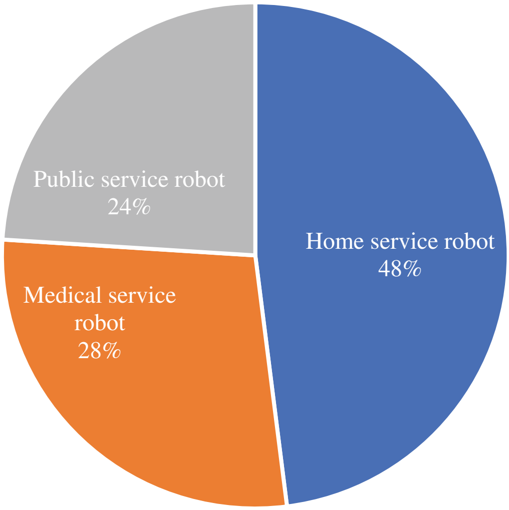

Fig. 7.3 Constitution of service robot market in China, 2019. *Source* This figure was prepared by the Authors using data from Chinese Institute of Electronics

robot industry in China before COVID-19 were a rapid growth, private capitals leadership, domination of home service robot. In the following sections, we could see the changes bought by COVID-19 in several aspects.

7.1.3 Robotics in COVID-19 in China

When the COVID-19 out broke in China, the lifestyle of people had to change to adapt to the new conditions. Change always means new requirements in society. Therefore, some pioneers in the robotics industry offered solutions to these new needs created by the pandemic. Why were robotics able to meet the new needs of people?

The route of transmission of COVID-19 was confirmed as droplet transmission, aerosol transmission, and contact transmission. As a result, to decrease the risk of contamination, people were to control their contact with others. However, almost all the socioeconomic activities were undertaken through contact with people in different ways. Hence, to fulfill these normal needs of people created as a result of social distancing, some steps were needed to adhere to the non-physical human contact measures. An example of one basic needs of human is presented in Fig. 7.4. In Fig. 7.4, after the lockdown of Wuhan on January 26, 2020, the non-contact request in take-out service became the majority. The percentage of people who chose to order food online also increased in a short time (Meituan Research Institute 2019). Just the same with the take-out food, the express delivery and other business filed were also challenged by non-contact request from customers.

With the help of service robot, non-contact activities could be fully initiated. In February 2020, the Ministry of Industry and Information Technology of China

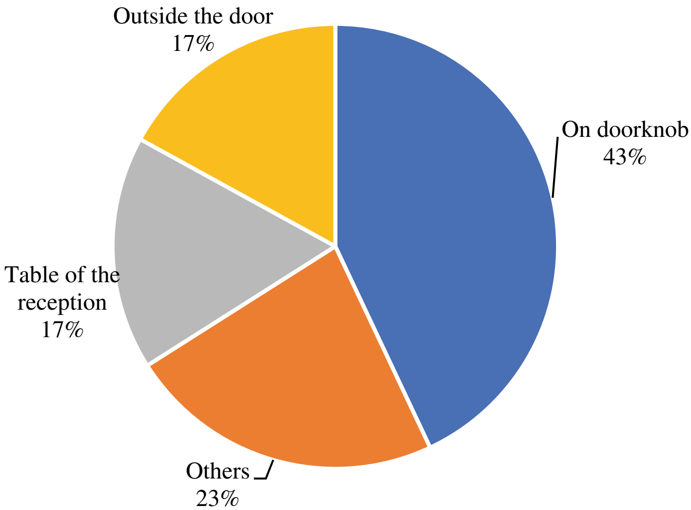

Fig. 7.4 Position of take-out food requested to be placed during the spring festival. *Source* This figure was prepared by prepared by Authors using data from Meituan

published an announcement to promote the application of information technology in prevention of COVID-19. More and more private and public organizations began to adopt robotics as one solution as result of the appearance of special service robots. Hence, in the peak of the pandemic, many kinds of special service robots were applied. If we follow the Chinese media, three kinds of special service robots were the most active robots in the prevention of coronavirus. They include medical assistant robot (robot that could undertake a part of responsibilities of medical staff), special public service robot (robot that serve in public place), merchandise delivery robot.

7.2 Applications of Robots in COVID-19

As me mentioned, three kinds of robots were widely used in COVID-19 in China. How were they applied in different conditions to fulfill people's non-contact needs?

7.2.1 Application of Medical Assistant Robot in COVID-19

As the WHO report: People's Republic of China Health System Review showed (Meng et al. 2015), the medical system of China was constituted of rural medical system and urban medical system. The rural medical system is formed by central county hospital and clinics in villages and towns. Severe cased and emergency cases would be sent to central county hospital because clinics in village and towns usually treat common and frequently encountered diseases. As for the urban medical system, the base of is its community health service organizations (private clinics or public health stations). The core of this system is constituted by city general hospital, provincial hospital, and key national hospital. The hospitals of different levels are responsible for severe and emergency cases and miscellaneous diseases from nearby area. At the same time, they are base of medical education and medical research center. The medical resources are mainly distributed to central hospitals in urban areas; as a result, there is remarkable deficiency in basic level medical system.

The most obvious effect of this system is the overload of medical staff in central hospital. As the research of Sichuan University and Sichuan University Huaxi Hospital verified, the average of work time for each doctor in urban hospital is over 50 h per week (Wen et al. 2015). Over 94% doctors and nurses feel very tired during their work time. As a result, 80% medical accidents are caused by exhaustion and lassitude (Chen et al. 2013). Hence, the many ways to relieve the burden on medical staff has been a topic for several years in China. During the COVID-19, the pressure on medical staff in China was doubled in hospital level since the basic level medical service could not deal with this kind of infectious disease. However, a reform of medical system could not be a short-term solution of this problem. Hence, hospitals and government needed emergency solution to relive the medical pressure. The medical assistant robots got into their sight and began to be adopted in deferent medical facilities.

What did the medical assistant robots do for COVID-19 in China? As the definition of Fig. 7.5, the medical robot applied was mainly assistant robot and medial service robot. The assistant robot refers to those robots which could take part in medical functions that are usually the responsibilities of professional medical staff. For instance, the robot could prepare medicament based on prescription and diagnosis and offer assistant in reference to doctors. The medical service robot on the other hand refers to robots that are able to accomplish non-medical tasks, such as disinfection robot, medicament delivery robot, and hospital guide robot. In COVID-19, these two categories of robots were adopted by some hospitals and they helped the medical staff to concentrate on treatment. For example, in the two special hospital constructed for patients of COVID-19, Huoshenshan hospital and Leishenshan hospital in Wuhan, the medical assistant robots were highly valued by medical staff and were praised by the media (People.cn 2020a, b).

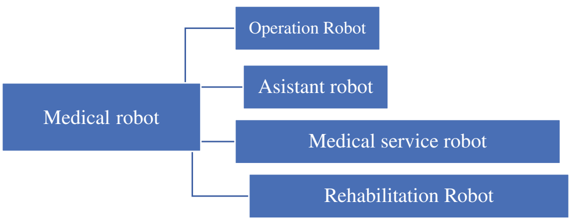

Fig. 7.5 Classification of medical robots. *Source* This figure was prepared by the Authors using data from IFR

According to a report, the medical service robot in Leishenshan hospital could accomplish two times disinfection in in-patient area and was capable to cover 120m^2 per minute with 7 nozzles. The efficiency of the robot was equal to four professional disinfection staff. When the robot finished disinfection, it could get back to preparation area and load medicine or medical device to deliver them to nurse stationed in different in-patient areas. All the actions of robot were automation. The administration team considered the robot as effective solution to minimize the risk of contamination of medical staff and increase the efficiency of medical materials saving such as protective clothing.

7.2.2 Application of Public Service Robot in COVID-19 in China

As mentioned in Sect. 7.1, the need for non-contact activities was one of the reasons for application of robots in different fields. Based on new needs as explained above, three kinds of public service robots were adopted in some cities by local organizations. The traditional temperature measuring robot initially applied in severe acute respiratory syndrome, caused by coronavirus in 2002 (SARS) were widely adopted at the gates and entrances of shopping malls, schools, etc. However, most of these temperature measuring robots could only take the temperature of one person and need some time to readjust and calibrate for another person. However, with the support of AI technology, new forms of robots were introduced and they became handy in the prevention of the spread of the virus. An example is the police robot Jianguo, which was a product of private company and the Ministry of Public Security of PRC. The robot was support by AI technology to accomplish patrolling task in key areas of the local highway instead of the police staff. Besides this, it was able to serve as a terminal police information system, work as guidance in railway stations by guiding the flow of passengers. The police robot Jianguo was able to assist by relieving the burden and workload of traffic police in rush hours (Legaldaily.cn 2020).

Another AI controlled robot commonly used the pandemic was the temperature measuring robot. Different from the traditional non-AI temperature measuring robots, this model could measure multiple targets in movement, recognize the faces as the pass by, and get temperature data even behind masks with infrared thermometer. When the temperature of an objective was over limit, the robot could send alert to administration staff. As an integrated model, the new robot could also store and upload data to cloud server and track data with cloud server support. This kind of robot was widely used in South China in COVID-19. Thus, in Kunming, over five middle schools adopted the intelligent temperature measuring robot to monitor the temperature of students (People.cn 2020a, b). As the population density in middle school is much more than other public facilities, the efficiency of temperature measuring was important factor. The intelligent robot was integrated in school broadcasting system and students could confirm the area data of temperature and mask with the big screen settled in campus. In the view of parents, the application of robotics in school guaranteed the safety of their children.

7.2.3 Application of Merchandise Delivery Robot

As we mentioned in Sect. 7.1, the needs of non-contact gave chance to the robotics in the traditional contact service, especially the delivery service. As a research from the Chinese take-out platform enterprise showed, 49.7% of the take-out orders were from residential districts in 2019 (Meituan Research Institute 2019). As Fig. 7.6, the amazing growth of remote work app users showed that more and more active population chose to work at home instead of their offices or place of work. This could however explain the results for the high increase in take-out orders. For those who were quarantined in hotels or other public facilities, they also had the same needs. Then the question arises that, how we deliver the food or other merchandises to customers in non-contact ways? Many then considered delivery robot as the ideal solution.

The most famous delivery robot in COVID19 was the intelligent delivery robot from online shopping platform enterprise, Jingdong. This private company adopted the new model in over 15 service regions. What the intelligent delivery robot could do was not only take the merchandise to its destination but also the integration with administration system of Jingdong. The command center could get detail functional data in real time and send message to customers when the robot is near to the destination. On the way, the delivery robot could recognize the traffic lights and observe other road traffic regulations. When the robot gets into position, customers could get their merchandise by message code or scanning (Tencent Cloud 2018). In quarantine hotels in Hangzhou, robot delivery service was welcomed by those who needed to be quarantined. The delivery robot was already equipped in some hotels before the

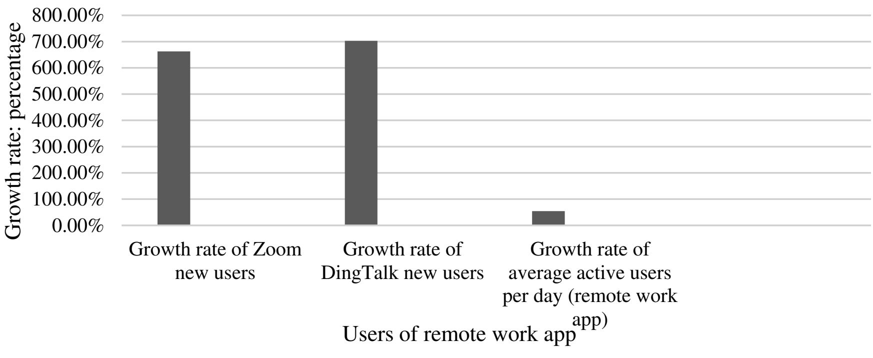

Fig. 7.6 Growth of remote work app in china during the spring festival, 2020. *Source* This figure was prepared by the Authors using data from Meituan

COVID-19, only 10% of them were functional (BJNEWS 2020). The delivery robot could deliver the reserved food to the door of the customers without contact.

7.3 Analysis Based on Application of Robotics in COVID-19

As we all know, the AI technology and robots have been widely used for industrial purpose. However, only a few had heard of them before the pandemic. There, its wide application during the pandemic poses the question as to why new robots could get into service in such a short time during the COVID-19 pandemic? The following describes it.

7.3.1 External Factors

The change of market needs represents the external factors as mentioned in Sect. 7.1. As a branch of information engineering, robotic have the same characteristic with other information industry that comprehends to changes and speed of market requirement and responds to speed and change. The medical service robots, public service robots, delivery robots and other robots were manufactured in just one month or less to fulfill new needs from government, public service organizations, and individuals. They are the responses from the makers of robots to the new needs born out of the COVID-19 pandemic. The needs from individuals to change their lifestyle and reduce contact with others, the needs from hospitals to decrease the risk of contamination and relive burden on medical staff, the needs from school, operator of the shopping malls to keep the normal function by monitoring the temperature, and other needs promoted the change of robotics in COVID-19 and created the new applications of robotics.

Another external factor is the high awareness toward robotics. As mentioned, robotics has been a key domain in national development plan since the period of the 7th Five-Year Plan (at that time the plan document underlined the industrial robot). In 2015, all fields related to robotics were listed in the plan of Made in China 2025, which meant that, the design, manufacturing, and operation of all kinds of robots are officially supported by central government. As a result, the development of technology related robotics could certainly make progress faster, even private companies related to robotics could cooperate with governmental organizations and official research institutes. The policy support accelerated all the complex procedures in cooperation. Furthermore, governmental organization was also willing to adopt these products. These notwithstanding, the new technology as supported by government drew more attention from media, since most of media in China have official background. Hence, push from official side finally become attraction to potential private users.

7.3.2 Internal Factors

All actions are conducted by the combination of internal and external factors. The same with the application of robotics in COVID-19. Even though there are new needs in the market, if the maker is not able to manufacture the appropriate product to fulfill these needs, there will be no supply in the market. Therefore, the existed technology of robotics before COVID-19 is important internal factors (see Fig. 7.7).

The most important internal factor is the technology supporting the production of robotics. The development of environment sensing technology, action control technology and man–machine interaction technology and AI in China was the foundation of the application of robotics during COVID-19. The environment sensing technology permits the robots to observe and treat information on environment around them, help them to identify the importance and different levels of information they receive from their sensors, and constitute a virtual map in their processor. The action control technology is composed by motor system, balance system, location system, and coordination system. With these four systems, the robots could be able to accomplish smooth movement. The most important technology is man–machine interaction system that allows people to input orders and information into the robot, or briefly, give them the task and get feedback from the robot. For example, as a disinfection robot, nurses are able to set up the disinfection course of the robot, monitor the function condition, get feedback when the robot finish its task through man–machine

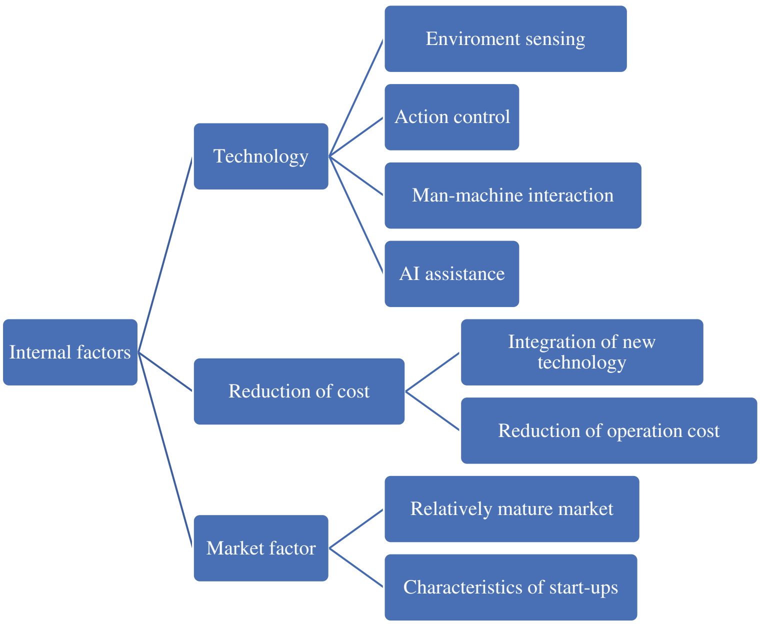

Fig. 7.7 Internal factors for application of robotics in COVID-19. *Source* Authors

interaction system. AI module can help recognize human face, locate the effective area for temperature measuring, and augment the accuracy of temperature measuring. All the technologies are mature technologies applied in previous models or robots made for other purposes in China. These intelligent products of robotics applied during the COVID-19 were just integrated mature technology modules suitable for needs in COVID-19.

In recent years, the integration of new technology into robotics has been a centric point. As we just mentioned, with the help of AI module, robots are able to accomplish more complex missions with lower cost than traditional technology. The reduction in cost stem from production procedure exhibiting the "experience effect." As more and more robots manufactured by makers, their experience over time increases efficiencies which drive down the cost of production. Again, the update of algorithms and stable Internet infrastructure such as the 5G service increased the work efficiency and reduced the operation cost of robots. All the factors had an influence on cost of robotics and finally caused the reduction of price, so that more organizations could afford robotics production.

Another factor is the relatively mature market. According to the data of Chinese Institute of Electronics, the sales of service robots in China were 2.2 billion dollars (Chinese Institute of Electronics 2019). The robot industry has already been a huge market with intense competition. Further contributing to the reduction in cost of robots is the characteristic of start-ups. The intelligent robots appeared in the case analysis were mainly from the production of start-ups. The characteristics of these start-ups are also important in the development of service robots during COVID-19. As start-ups are easier to change their ideas to follow the new needs and demand preferences, the innovation cycle in start-ups is shorter than large-scale corporations.

7.4 Future Potential of Robotics in China

7.4.1 Integration of Robotic Design with Other Technologies

To be able to meet the challenges as experience during COVID-19, we need to consider the future direction of robotics in China. The first is the recognition of robotics as a comprehensive and complex field of science that is in constant synchronization with new technologies in computer science and engineering. Thus, the recognition of marketing research on new needs, demands, and preferences that arise as a result of new conditions and scenarios should be an inspiration for investments in research and development. That will be able to generate new applications and upgrades that comprehend new designs, manufacturing and operation of improved robots integrated with other technologies such as AI, big data and 5G. The integration of intelligent robot with new technologies is a basic direction not only in China but also in the world.

7.4.2 Partnership and Collaborations

For large-scale corporations, investment in industrial robots poses high investment cost and other challenges but the discussions also show a huge potential. Therefore, to tackle the difficulties in improving the technology, there should be the need for cooperative support from research institute, universities, governments, and others as we analyzed. For middle and small-sized corporations, aiming social needs will be important. Even in post-COVID-19 period, medical service robots will be a big market due to the condition of medical system in China. As the aging population in China is increasing year by year (people over 65 years old in China was 12.6% of the population in 2019). Hence, robots toward these aging population such as rehabilitation robots could be a new growth point for these corporations.

As for the government, an industry cannot realize healthy development without common standard system. Now, the Chinese government has started the constitution of standard system; however, the system now is just embryo. The establishment of the standard system needs the combination of industry, official, and university; a mature standard system is the symbol of maturity of industry. As we analyzed, the robot industry could be an important point in economic recovery post-COVID-19. The industrial robot is not only important for the realization of Made in China 2025, the market of industrial robot itself is enormous. China could take advantage of this core technology in industrial robot, to create marvelous economic profit. However, besides the promotion of industry-institute-university cooperation, another important point to accelerate the development of industrial robot is to give more space to private capitals. Lack of innovation awareness is a common problem existed in most of SOE. As a new industry, providing more policy support to stimulate the private capitals will be a possible direction for Chinese government. For the service robot, there should be more direction such as the rehabilitation robot to create new market and reduce the internal friction of start-ups and new capitals. The activity of private capitals in service robot market is a good phenomenon for the future development.

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Chapter 8
Artificial Intelligence and Its Importance in Post-COVID-19 China

Yishuang Zhang, Jinling Hua, Bismark Adu Gyamfi, and Rajib Shaw

Abstract Artificial intelligence (AI) has been a powerful tool in the fourth industrial revolution as industries have been shifting to using technologies in data management, supply chain, and logistics. In this pandemic, when the economy and health sectors face enormous threats, AI creates a solution by filling in gaps of each industry. AI's computer vision and prominent data processing roles help provide convenience and accessibility to many datasets. Through AI algorithms, researchers and data scientists could process data and create swift and efficient models to generate outcomes highly impossible to human's abilities. In China, AI has developed early COVID-19 triage protocols, information dissemination, and health service logistics. The AI, coupled with big data, could create a solution for the quicker tracking of cases and modeling of statistics, promoting early diagnosis and treatment to the patients in need of medical attention. This chapter focuses on using AI during this time of the pandemic and some implications for current and future applications.

Keywords COVID-19 · Artificial intelligence · Biometric surveillance · Cloud computing · Logistics

8.1 Introduction

The emergence and existence of the threat of the COVID-19 through its causative agent, SARS-CoV-2, have significantly threatened people's lives, especially those who are most vulnerable to diseases. The vulnerability of children, the aged, pregnant women, immunocompromised, and frontline health workers of COVID-19 call for an immediate response to the detection and containment of infected individuals. Through the help of early diagnoses, those infected by the virus can be isolated

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J. Hua et al. (eds.), *Considerations for a Post-COVID-19 Technology and Innovation Ecosystem in China*, Disaster Risk Reduction,
https://doi.org/10.1007/978-981-16-6959-0_8

and cured. Therefore, along with the development of technology for early detection, proper governance is needed to end this pandemic. This pandemic has much challenged numerous aspects of society. These aspects include education, politics, economy, and mobility. According to the World Health Organization (2020), infected persons may not be easily traced because some do not show symptoms (asymptomatic). Hence, these asymptomatic people can easily roam around, unknowingly transmitting the virus to other people. Nonetheless, with practical and appropriate medication and treatment interventions, there is a high chance that the infected COVID-19 individuals can recover. Aside from the improvement of pharmaceutical strategies, such as the development of an antiviral drug or a vaccine, effective COVID-19 management lies on the proper implementation of safety protocols at the local and national level, which include the maintenance of social distancing, a series of lockdowns, and execution of quarantine protocols to help block the transmission of the virus. As a result, people's mobility is lessened, thus maintaining the flow of essentials, which can sustain people's lives.

With the leadership of Xi Jinping, the People's Republic of China has been focusing on the innovation and development of technologies since 2012 (Weinstein 2020). China's adoption of high-tech products and services is helpful for its military applications, manufacturing industry, education, healthcare, and environmental sustainability. In actuality, the Chinese government released policies in 2017, documenting its development plan using artificial intelligence (AI). One of the main goals of this development plan is to improve the country's healthcare system by incorporating intelligent strategies. With the emergence of the pandemic, the Chinese government's desire to use AI-related tools has intensified. In June 2020, the state council released a white paper that encourages AI not only in research and development (i.e., analysis, forecasting) and in real-time monitoring and surveillance of probable, suspected, and infected COVID-19 individuals. These AI-tools are also beneficial to properly decide on the resumption of the economy and the demographical stratification of the vulnerability of individuals from the virus.

8.2 Artificial Intelligence

The intelligence of technology nowadays is attributed to the incorporation of AI. This intelligence is often used in the production of autonomous vehicles (i.e., cars, drones), wherein the machine is shouldering the decision and resolution of the social dilemma rather than solely by the driver himself. In banks and finance, AI plays a significant role in computer vision and big data processing (Pham et al. 2020). John McCarthy coined the term "artificial intelligence" because it simulates human thinking in making critical decisions and carrying out actions. Therefore, machines and computers are given the ability to learn and think based on human intelligence, hence preventing human errors.

Chao (2020) said that AI is a valuable tool in the fourth industrial revolution because businesses and companies have already been exploring and incorporating

Table 8.1 Pros. and cons. of AI

Advantages	Disadvantages
1. Elimination of human error 2. Risk-taking 3. No rest periods 4. Constant productivity despite repetitive tasks 5. Digital assistance 6. Quick decision-making 7. Accessory for future inventions and innovations	1. Expensive creation costs 2. Enables laziness 3. Unemployment 4. Apathetic 5. No out-of-the-box thinking

Source Authors

AI for information flow and data management. Nonetheless, like any machine, AI possesses advantages and disadvantages (caused mainly by its limitations) (Kumar 2019). In Table 8.1, Kumar discussed the most relevant advantages and disadvantages of AI. Therefore, researchers and AI developers must consider the costs and benefits of using AI before its usage. Nonetheless, the ideology that AI can destroy humanity if placed into the wrong hands is not yet provable as AI applications have not yet been scaled up to more significant levels to manipulate and destroy human civilization. For now, the benefits outweigh its costs, making AI a solution for the fight against the COVID-19 pandemic.

The evolution of AI over the years makes its previous manifestations an intrinsic computer function, such as recognizing text and characters and the calculation of algebraic functions. This development implies the evolution in human thinking, which perpetuates the most complicated tasks requiring complex decision-making skills. Thus, the importance of algorithms, which frame human intelligence for the benefit of addressing problems. Based on Turing (1950), in the article entitled "Computing Machinery and Intelligence," he discussed the goals and envisaged AI. According to the paper, AI falls under the branch of computer science that personifies machines by injecting them the ability to (1) think humanly, (2) reason, (3) act humanly, and (4) act rationally. Therefore, the process of thinking and reasoning of machines are based on algorithms created by humans. These algorithms are a product of process flow diagrams consisting of decision trees and if-the statements. Hence, understanding AI also entails the comprehension of its two critical approaches: (1) machine learning and (2) deep learning (Pham et al. 2020). By definition, machine learning is the machine's ability to learn and extract relevant information from data's representative features. On the contrary, deep learning focuses on resolving complex problems by patterning them from simple representations.

The benefits of using AI to mitigate the effects of the COVID-19 pandemic are more significant than its costs (Bragazzi et al. 2020). Hence, Beck et al. (2020) studied drug repositioning to identify current commercial drugs and analyze their effects on the patients using the deep learning approach. This study aimed to use AI in predicting antiviral drugs that infected COVID-19 patients could use because vaccine development is currently underway, taking years to prove its efficacy. Similarly, Zhavoronkov et al. (2020) designed potential SARS-CoV-2's protease inhibitor models through generative deep learning methodology. This study is purposeful for discovering potential drugs that can disrupt the structure of the virus, rendering it useless and nonfunctional. Another relevant study by Zheng et al. (2020) focused on diagnosing COVID-19 infected individuals via their chest computed tomography (CT) scan results. Using deep learning, coupled with image processing, an accuracy of 91% was achieved for the prediction and identification of a COVID-19 patient. Thus, a helpful study can save time and call for immediate treatment and quarantine protocols. Nevertheless, even though these technologies still need clinical trials and approval, these studies pave the way to creating reliable models that predict the fate of the virus from the existing big data.

8.3 China's AI-Related Health Strategies

Being the first epicenter of the COVID-19, China focuses on its digital health strategy, which has inspired different nations to support AI and information and communication technologies (ICT) to cater for their citizen's healthcare needs. Indeed, computer engineers play a vital role in the fight against this disease. According to ITU News (2020), the advancement of technologies can create "magical combinations," providing innovative solutions to healthcare concerns. The AI, coupled with big data, can create a solution for the quicker tracking of cases and modeling of statistics, promoting early diagnosis and treatment to the patients in need of medical attention. Some of the AI-related activities being implemented in China include early COVID-19 triages, vaccine research and development, mass testing, and individual risk evaluation. An interview with Shan Xu, a computer engineer from Information and Communications Technology department in China, revealed that they are working with big companies in the country (i.e., Alibaba) to provide a large cloud and server for the storage of big data, which are useful for AI computation and analysis. As of May 2021, there had been 90,872 confirmed COVID-19 cases in China. Among which, the country had 4,636 deaths, which accounted for 5% of the total number of cases. On the other hand, the country has been constantly experiencing a 95% recovery rate. Figure 8.1 shows the country's total cases, in logarithmic scale, with the assumption that it has already flattened the curve by May 2021.

McGregor (2020) reported how China's possession of big data gives the country an edge in AI. Access to big data is the primary requirement of a successful AI implementation. The incorporation of AI in CT scans helps triages patients with probable COVID-19 infection. Using AI algorithm, China developed a highly accurate model that detects radiological changes and compare them with a standard. The author added that the sensitivity of the AI-coupled machine was 92.3%, which could be considered highly sensitive. Based on a journal article of Arora et al. (2020), the use of AI-coupled CT scan to examine a patient's chest is a promising solution for the high false-negative possibility of RT-PCR assay. However, CT scan must solely not be used, since it can produce misleading results (i.e., pneumonia). Nevertheless,

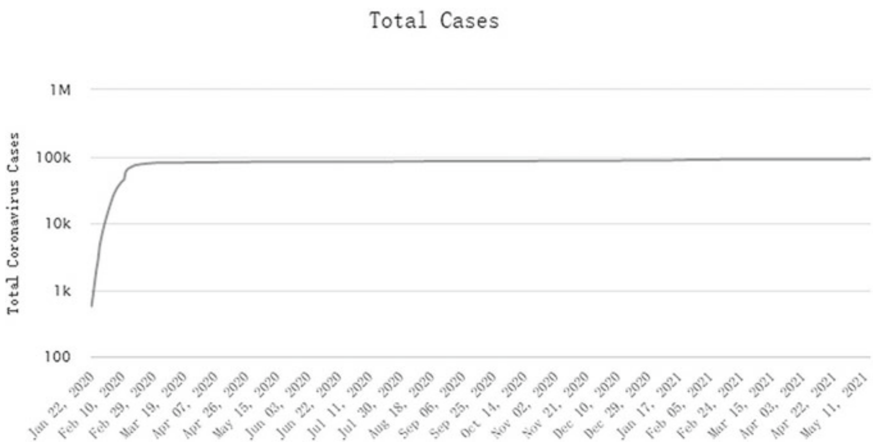

Fig. 8.1 China's COVID-19 cases curve (as of May 2021). *Source* Authors

deep learning models' development differentiates the COVID-19 from community-acquired pneumonia (CAP) (Li et al. 2020). The differentiation is done using qualitative examination on the 2D and 3D images from the chest CT scan. Hence, with China's current digital health strategies, the incorporation of AI has been useful to mitigate the effects of the pandemic. In the subsequent sections, the applications of AI as China's solution for the COVID-19 are discussed.

8.4 Cases of AI Technology Application for COVID-19 Management in China

8.4.1 Face Temperature Recognition

Biometric surveillance through AI is a proven useful tool in tracking individuals, especially in crowded areas. However, the intense use of face masks, especially in public places, makes it difficult for people to recognize the face of every individual, while taking checking for potential COVID-19 infections. However, with the incorporation of AI, face temperature recognition and storage of recorded data provide solution to the problem in contactless checking of the temperature of every individual. According to Li (2020), SenseTime, a Chinese AI startup company, was one of the companies that had developed a facial recognition product, which uses thermal sensors and cameras to determine and record temperatures. This product is similar to the one used in airports; however, the company incorporated algorithms that can detect if people are correctly wearing masks. Moreover, SenseTime features that its product has high accuracy in recognizing faces even if a person is wearing a mask. According to SenseTime's product website, its infrared thermal scanner is powered by sophisticated computer vision and deep learning algorithms. As previously noted, the deep learning approach in AI comprehensively analyzes data using patterns from simple representations. Hence, the contactless system in screening and recording temperatures, even with masks, helps in the convenient and safe assessment of individuals in public or private spaces. Additionally, whenever an abnormal temperature is recorded, the device will instantly send out an alert notification, followed by secondary (manual) checking for confirmation and diagnosis. According to the Centers for Disease Control and Prevention (2020), the following are the symptoms of an infected COVID-19 individual:

- Fever;
- Dry cough;
- Shortness of breath;
- Loss of sense of smell or taste;
- Body pains;
- Headaches;
- Sore throat.

Nonetheless, the proliferation of asymptomatic yet contagious individuals gave chances to the accidental transmission of the virus. Therefore, biometric surveillance using AI is vital as a frontline in determining feverish individuals because an elevated temperature is one common symptom of an infection, COVID-19 or not. China's infrastructure for monitoring movement control via surveillance cameras has contributed to the development of its urban biometric surveillance (Chen et al. 2020). With the country's high population, China remains focused on the processing of big data using extended AI capability. Also, the surveillance cameras, which are already in urban places, were needed to be repurposed through pairing with CCTV, facial recognition accessories, and thermal scanning capabilities. As a result, these heat-sensing technologies serve as the frontline and preliminary measures for the detection of COVID-19 positive individuals.

8.4.2 Cloud Computing

Another AI-related tool used by China to battle the COVID-19 pandemic is the use of cloud computing (coupled with edge computing) as big data are being gathered from various institutions and places. The accessibility of data is one primary concern in the emergence of this pandemic. Hence, through the help of telecommunication companies and cloud providers, the relevant information is easily retrievable using cloud servers. This information includes the personal details of each person, as well as their COVID-19 status and progress. Yuan (2020) reported that the data stored in cloud computing servers are useful for contact tracing measures. Petropoulos (2020) highlighted China's use of AI-powered smartphones and devices, wherein mobile applications are installed so that individuals can personally monitor and share their information with the local and national health authorities. These tracking and tracing capabilities of AI-powered devices help the government and healthcare professionals geographically locate a suspected COVID-19 individual.

Pham et al. (2020) define the process of big data acquisition with the term "infodemiology" because of the importance of information dissemination through various electronic and online platforms. However, governments must ensure the reliability and accuracy of the information being disseminated. Thus, the need for "infoveillance" wherein the government assigns a task force that will continuously monitor the truthfulness of the data being entered in the cloud. Hou et al. (2020) conducted one related study focusing on social media surveillance in China and correlating the data with the public's emotional and behavioral responses to the pandemic. The popular platforms used as sources of data include various search engines and e-commerce websites (i.e., Ali Express). Based on the results of the study, the authors found out that, early identification and correction of misleading information can lead to alleviation of fear and misconceptions, which sometimes trigger irrational behavior among people. Similarly, the use of AI (i.e., speech and sound analysis) through computer audition in gathering information from conversations was found to be important in the surveillance of misinformation (Schuller et al. 2020). Not only is cloud computing beneficial for the surveillance of big data, but it also helps in maintaining safety protocols, at the same time keeping the economy afloat. Alashhab et al. (2020) exemplified the cloud computing environment (schematic diagram shown in Fig. 8.2) as a utility that can be used as a virtual avenue for companies (service providers) and consumers. Through this technology, work-from-home and home-schooling arrangements can be easily carried out, resulting in keeping mobility at a minimal level. Several, if not most, services, such as utility payments, can also be handled by cloud computing environment, hence minimizing the risks of exposure, especially in the vulnerable sectors.

Hu (2020) discussed that Amazon and Microsoft are some of the famous cloud computing service providers internationally. For China, specifically, top cloud

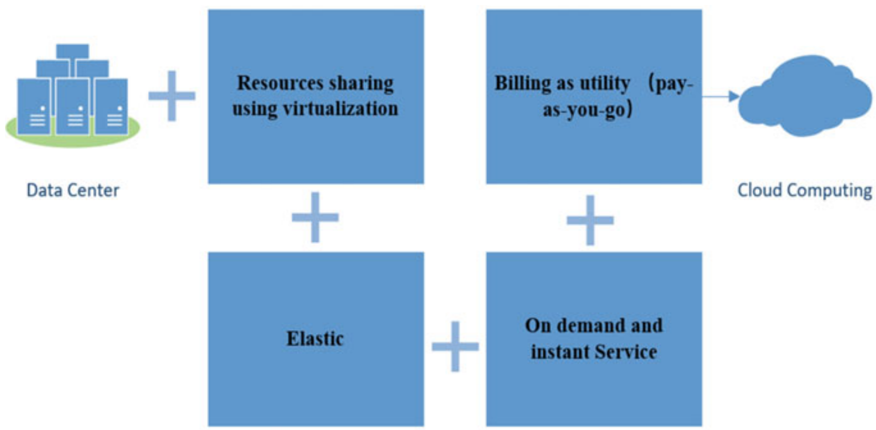

Fig. 8.2 Schematic diagram of a cloud computing environment. *Source* Authors

computing providers include Alibaba, Huawei, and Tencent. Supporting business reports showed that Alibaba garnered the majority of market share (44.5%) followed by Huawei (14.1%) and Tencent (13.9%). Nonetheless, with the persistence of the COVID-19 pandemic, the cloud computing industry is expected to proliferate as China is focusing its investments on 5G, AI, and other computer-related products and services. According to Fujita et al. (2013), cloud computing's primary goal is to enhance the accessibility of data for multiple users so that each user can collaborate with other users by inputting data to the cloud. Hence, the flexibility of data control and management because the users do not need extensive computer programs and software to access and modify the data. Similarly, Chappell (2008) discussed the three major classifications of cloud computing, namely:

- Infrastructure as a service (IaaS);
- Platform as a service (PaaS); and
- Software as a service (SaaS).

Each of these classifications has its purpose. For instance, with SaaS, web applications that can be accessed through an internet browser fall into this category. These applications include Google Sheets, Presentation, and Docs. Fujita et al. (2013) also discussed the significant advantages and disadvantages of cloud computing (Table 8.2). Businesses who plan to engage in the use of AI for data management must be aware of the pros and cons of this technology because even though the benefits are high, its costs are also risky. From the employee's perspective, the use of cloud computing in business provides convenience, especially during the COVID-19 pandemic. Telecommuting has become prevalent and highly encourage by healthcare professionals to curb the increasing rate of infection. As a result, the employees can enjoy lessened travel time and expenses and increased work flexibility. On the other hand, directly speaking, cloud computing unites research from various places around the world to share reliable information regarding COVID-19 (Drees 2020). Therefore, incorporating AI in industry, economy, and research and development indirectly and directly helps fight the COVID-19 pandemic.

Table 8.2 Pros. and cons. of cloud computing

Advantages	Disadvantages
1. Cost-efficient 2. Limitless storage 3. Seamless data backup and recovery 4. Full automation 5. Accessibility 6. Fast implementation 7. Easier scale-up 8. Up-to-date	1. Common technical issues 2. Security risks 3. Stealth risks 4. Internet connection dependence 5. Limited support

Source Authors

8.4.3 AI-Fused Logistics Services

Robotics is one of the most successful innovations in China. Ding (2018) reported that China's focus on the use of robotics and automation using AI significantly contributes to the urbanization of the country. Perhaps, the incorporation of AI algorithms to robots and drones is the most effective way to limit the exposure and infection in frontline healthcare workers. These AI-fused aerial robots, such as drones, have also been successfully employed by China through a partnership with e-commerce and logistics companies for the automation of the deliveries of essential goods (e.g., hospital supplies, food, and other essentials), especially in the remotest areas. The Chinese government's implementation of lockdowns was beneficial for quarantining areas with high cases of COVID-19 infection. The main problem was the delivery of essentials materials and supplies. Yang and Reuter (2020) explained that aerial robots could deliver a maximum of 15 packages daily. This situation happened in the former epicenter of the COVID-19, which was the province of Wuhan. China believes that social robotics serves as a catalyst of change in the country's healthcare system, thus providing intensive care (i.e., physical and medical examinations) to isolated patients through AI-powered machines.

8.5 Way Forward in Post-COVID-19

Young (2020) highlighted the challenges of the COVID-19 pandemic to supply chains. That is, delivery of goods and services has been tested because of the implementation of lockdowns around the world. Therefore, logistics providers rely on e-commerce services that can handle big data from consumers across the globe. For the consumers' perspectives, quality and fast delivery of materials are expected; therefore, businesses must optimize the time it takes to reach the consumer's place to keep up with the competition. In this regard, Loten (2020) expects that global logistics will be in-demand in the succeeding years as society recovers from the pandemic's effects. More so, there will be a significant challenge for cloud computing providers because they must overcome the disadvantages listed in Table 8.2 to keep up with the fast pace of AI industrialization in the future. To this effect, a combination of the various technologies as outlined in this chapter would be essential to creating a sophisticated environment that is controlled or supervised by AI to meet all these divergent demands.

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Chapter 9
5G and Its Implication to Communication in China

Jinling Hua and Rajib Shaw

Abstract Mobile communication basically has a generation of ten years. The first few years before each generation starts are a mature process, and there are many version upgrades during each generation. It can be said that the technology is constantly improving. It is obvious that the technology is not mature when it is just commercial, especially 5G. Development time axis of world mobile communication technology standards. The completion of 2G international standard was completed in 1987, and commercial use was in 1991. There was nearly four years in between. For 3G, 3GPP standard was completed in 1999, ITU was in 2000, and the earliest commercial application was in 2001. There was also more than a year or even two years. The completion of 4G standard and the earliest commercial use of 4G were 2009 and 2010, respectively, with an interval of one year. However, 5G commercial almost keeps pace with international standards. Therefore, in this sense, we can say that 5G is not mature enough, which is also true in foreign countries. In terms of the development of China's mobile communication, 1G is six years later than the international first commercial, 2G is three years later, 3G is six years later, 4G is three years later, 5G is synchronous. Therefore, it can be said that in the past few generations, the developed countries began to use commercial products several years later and basically used foreign products. To 3G, China began to have some domestic brands, and 4G has been greatly improved. By 4G, there is less risk of trial and error in China, because others are ahead. However, due to the later commercialization in developed countries, China has not only paid the market price but also has to bear the increased product cost due to the lag of its own patent; thus, the industrial chain has lost the opportunity to lead. The chapter will address: (1) what is the policy position of the 5G of COVID-19 in China's scientific and technological innovation, (2) how is it developed, (3) how does it drive China's economy out of the post COVID-19 era

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J. Hua et al. (eds.), *Considerations for a Post-COVID-19 Technology and Innovation Ecosystem in China*, Disaster Risk Reduction,
https://doi.org/10.1007/978-981-16-6959-0_9

and (4) promote China's economic development? These series of questions would be the key topic of concern to the future world.

Keywords 5G technology · Smart technology · Communication · COVID-19 · Chinese technology

9.1 Introduction

In ancient China, people used beacon fire and wolf smoke to convey information. After that, people transmit information through pigeons, horses, and even people. As we all know, the marathon is to commemorate the Greek Herald who ran fast for 42 km and finally killed himself. When we record the herald, we can also see how hard people have gone in communication. In that world, the speed of information transmission was limited to the speed of flying and running—until the emergence of electrical signals today. With the emergence of electrical signal, communication technology has brought tremendous changes to human beings. As a medium of information transmission, electrical signal has replaced flight and running by opening a new chapter of modern communication. Especially in the field of mobile communication, the emerging milestones also push the communication technology to a higher level.

9.2 The Development of China Mobile Communication Technology

9.2.1 1G and 2G with China Mobile Communication System Reform

In the 1960s, Bell Labs and other research institutions in the USA put forward the concept of mobile cellular system, which is the theoretical prototype of the first-generation mobile communication (1G). Subsequently, North America, Europe, and Japan started the research and industrialization process of 1G almost at the same time and gradually put it into commercial use in the 1980s (Li et al. 2019).

In 1978, Bell Laboratories successfully developed the world's first mobile phone system, Advanced Mobile Phone System (AMPS). In 1979, the predecessor of NTT DoCoMo in Japan, Japan Telegraph, and telephone company opened the world's first commercial cellular network, which is a car phone independently developed by Japan. In the following year, Sweden and other four Nordic countries successfully developed and equipped NMT-450 (Nordic Mobile Telephone) and put it into use. In 1982, AMPS was approved by the Federal Communications Commission of the USA, and 1G system was officially put into commercial operation in the USA. In 1984 and 1985, Germany and Britain started their own 1G systems, respectively.

In 1987, China's first mobile phone came out in Guangdong Province. In the next few years, in addition to some provinces and cities in Northwest China and the military adopting AMPS in the form of private network, China adopted the upgraded version of AMPS, namely Total Access Communication System (TACS) (Hu and Niu 2004; Li et al. 2019). At that time, it was basically the way that each city in the province built its own local network system according to its needs, one city initiates a set of mobile switches, and multiple cities used them together and established their own regional base stations. Roaming among provinces is set in operation, i.e., automatic roaming within the province and manual roaming between provinces (Hu and Niu 2004).

In the same year, the national penetration rate of China's fixed telephone was only 0.75 per 100 people, but the mobile phone did not get enough attention in the first few years. China Mobile market began to take off only in the mid-1990s (see Fig. 9.1) because of the high price and unstable call quality. Until 1992, the investment focus of telecommunication industry was still on fixed line telephone. At that time, public telephone kiosks could be seen everywhere in the streets and alleys. Young people wore pagers around their waists to communicate through the text messages of pagers and public telephone kiosks.

In 1992, after Deng Xiaoping's talks in the south, the telecommunications industry began to reform its system. At that time, roaming among provinces was put on the agenda. At the end of 1994, the mobile phone users' domestic automatic roaming was realized in essence through IS-41B protocol.

In the same year, China Unicom was founded, which was a breakthrough for China Telecom industry because; (1) the number of China Mobile users had reached 1 million. (2) It was the mobile communication department of the General Administration of Posts and Telecommunications of China (later renamed China Telecom) that set up China Mobile. (3) China Unicom was the first to launch GSM (Global System for Mobile communications) mobile phone service in Guangdong. Under the

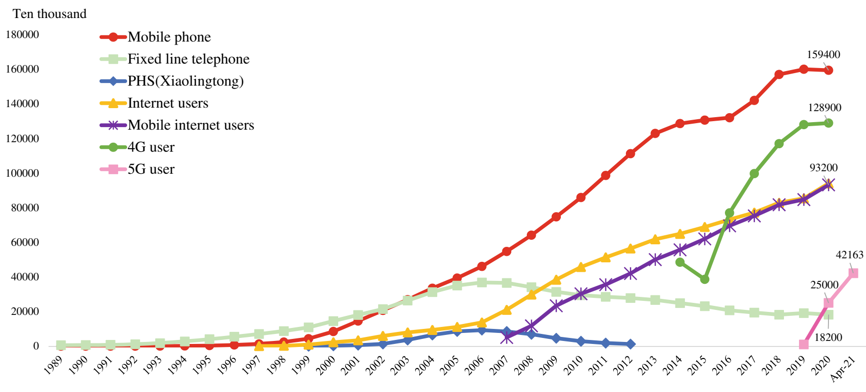

Fig. 9.1 Number of Chinese ICT user. *Source* This figure was prepared by the authors using original data from: MIIT, CNNIC and Carriers

impact of China Unicom's competition, China Telecom decided to build a nationwide GSM network in 1995 (Hu and Niu 2004). Since then, China's first nationwide mobile communication user system has been established.

GSM and code division multiple access (CDMA) proposed by Qualcomm a few years later are the mainstream technologies of the second-generation mobile communication system, which are the most representative. Different from the first-generation analog signal system (1G), GSM is already a digital communication system. After 2G, the mobile communication technology is converted into digital mode, and the input signals such as voice, SMS, text, and image are all compressed and transmitted by "1" and "0" digital signals. The first GSM system was the first demonstration system opened in Europe by the Oy Radiolinja operator in 1991, which opened the first telephone of GSM system. After that, Oy Radiolinja started operation in Finland in January 1992. In June of the same year, Germany began to operate (Marukawa 2014). As of December 1992, 13 GSM networks in seven countries have been operating in the world. Most European GSM operators had started business services, sending and receiving short messages (Li et al. 2019). As of April 2008, operators in 218 countries and regions have adopted GSM. At the same time, with the development of GSM technology, Nokia, Motorola and Ericsson rapidly grown into the three world giants (Marukawa 2021) in the world mobile phone terminal and base station market.

From the first analog mobile phone service in China in 1987 to the closing of this service in December 2001, 1G system has been applied in China for 14 years, with 6.6 million users at one time. With the development of mobile communication technology, 2G has not only the function of calling but also the function of short message. Compared with 2.4 Kbps of 1G, the maximum rate of 2G is 64 Kbps (Li et al. 2019). China Mobile and China Unicom use GSM system, while China Telecom uses CDMAOne system. In the 2G era, a more compact and exquisite mobile phone had also replaced the popular "Dageda mobile phone" in the 1G era. These mobile phones were easy to carry, more functional, adding audio playback, game functions. Mobile phone is not only a communication tool, but also great enrichment of people's lives. Throughout the 1990s, China's mobile communication market maintained an average annual growth rate of 141.8% (see Fig. 9.1).

9.2.2 Connection of 3G Mobile Phones with the Internet

Third-generation mobile communication technology (3G) standard began to formulate in the mid-1990s and was basically completed in the late 1990s. After 3G, mobile communication technology is developing rapidly. Compared with 2G, the biggest advantage of 3G is its high-speed data download capability. Initially, 3G speed peaked at 384 kbps. After that, with the continuous evolution, the maximum rate reaches 2 Mbps (Sun and Yu 2018) which realizes the combination of wireless communication and multimedia communication such as Internet.

In May 2000, the International Telecommunication Union (ITU) finally determined three international standards, including Time Division-Synchronous Code Division Multiple Access (TD-SCDMA), Wideband Code Division Multiple Access (W-CDMA), and CDMA2000, which were written into the guidance document "International Mobile Communication Plan 2000." After Japan issued 3G license in December 2000, NTT DoCoMo became the first company in the world to open W-CDMA service in October 2001. Three years later, 3G had gradually stepped out of the low ebb of its early development. Japan is one of the countries with the earliest start of 3G network in the world. China, on the other hand, issued 3G license in 2009. China Mobile adopted TD-SCDMA standard, China Unicom, and China Telecom adopted W-CDMA and CDMA2000 standard, respectively (Li et al. 2019).

The background of adopting the three standards in 3G is very complex. Japan first started to develop W-CDMA, but North America, such as Qualcomm, proposed CDMA2000 as the standard of 3G, and the two are in contention. Both W-CDMA and CDMA2000 are based on high pass CDMA, but the spectrum used is different (5 and 1.25 MHz). At this time, China put forward the third standard, TD-SCDMA. According to Marukawa (2021), the reason why China proposes a different standard is that, it has the largest mobile communication market in the world. If TD-SCDMA can develop smoothly in the domestic market and become the mainstream technology, then Chinese enterprises growing up with this mainstream technology will also have international competitiveness. Other countries are bound to adopt the TD-SCDMA standard developed by China.

In fact, in China, the communication industry has been calling for 3G since 2000, but it did not become popular until 2008. The core reason is that there are no "killer applications" in the market. It is the innovation of mobile communication equipment that really promotes the outbreak of 3G, that is, the introduction of smart phones. When it comes to smartphones, everyone thinks of jobs. Apple launched its first apple mobile phone in 2007, which set off the era of smart phones. Because of the sensational effect brought by Apple mobile phone, the apple company founded by jobs was also known by people all over the world at that time.

In the 3G era, the data service transmission speed has also been greatly improved, and more and more people began to use mobile phones to access the Internet. At the same time, a large number of Internet enterprises were also rising rapidly. E-commerce became a representative term at that time. People stayed home with their mobile phones to choose their favorite goods on the Internet, and logistics companies would also deliver goods to their homes. Short message service, which emerged in 2G, has also been replaced by some social software in 3G. Wechat and QQ, which are most commonly used in China, are more convenient and richer in content and became essential products for people to communicate (Li et al. 2019).

In 3G, the realization of interconnection with the Internet is the biggest feature of 3G. Although the I mode developed by NTT DoCoMo in Japan also realized the connection sharing between mobile terminal and Internet in 2G, I mode failed to go out of Japan and expand to the world. The upgrade from 1 to 2G was however very smooth. In 2002, ten years after 2G was launched, 95% of the world's mobile communication users were 2G users and only 2% of 1G users. In contrast, in 2012, 11 years after 3G service was launched, only 29% of the world's users were 3G users, and in the same year, 2G users still accounted for 69%. In 2012, 4G service started, and users with large amount of data began to flow to 4G. 3G users showed the most trend in 2015, but it was only 36% of the total number of users in that year and then decreased year by year. At its peak, 1G and 2G once accounted for more than 90% of the world (Marukawa 2021; Ericsson mobility visualizer 2018). Therefore, Marukawa asserts that since the second half of the 2000s, the global of 3G and 4G no longer seems to have the meaning of a generation.

9.2.3 China's Independent Innovation and Practice in 3G

As of 1998, China's mobile phone market was dominated by Motorola (28%), Nokia (28%), and Ericsson (20%), followed by Siemens, NEC, Panasonic, and Sony (20%) (Nikkei Sangyo Shimbun, 1999). As China has always been a consumer of mobile communication technology in 1G and 2G, the mobile phone market was dominated by international brands (Marukawa 2014). In 1999, the Chinese government issued two policies to support the domestic production of mobile phone terminals in China (Hua and Sigeo 2002). First nine domestic mobile phone manufacturers were designated by the state, mainly including China's state-owned wireless research institute and wireless manufacturers. As the research funds of nine manufacturers (GSM), they first invested 5% of the fixed telephone revenue after 1994, then allocated 1.4 billion RMB from the mobile phone revenue, and then set up the "digital mobile communication localization project" to invest 400 million RMB treasury bonds and 1.7 billion RMB financing. At the same time, the research center of digital mobile communication project was set up. Datang and technology is a state-owned enterprise, so Datang was required to develop the Chinese standard of core chip and next generation mobile phone before December 2000. In August 2001, nine companies were readjusted, and 19 CDMA mobile phone manufacturers were appointed (Hua and Sigeo 2002). The second policy was to restrict foreign-funded enterprises from setting up production lines in China and required that the domestic production rate and foreign export ratio of their products should be more than 60%.

These two policies directly protected and cultivated the localization ratio of China's mobile phones. On the other hand, they indirectly expanded the domestic market share for domestic manufacturers by requiring foreign-funded enterprises to sell more mobile phones abroad. This was effective. The share of domestic brand mobile phones rose from zero in 1998 to 3% in 1999 and 10% in 2000, and then to 55% in 2003. Bird, a domestic manufacturer, ranks first in mobile phone sales in China. However, the success of this policy was short-lived. After 2003, the total market atmosphere of domestic brand mobile phones dropped to less than 50%, and international brands resumed their dominant position in the Chinese market. There are two reasons. (1) Domestic manufacturers could not compete with global giants in price. (2) They lacked core competitiveness. Big domestic manufacturers like bird were also challenged by new domestic entrants. It is mainly guerrilla (Shanzhai) mobile phone manufacturers that entered the domestic market. Through this policy and five years of practice, the Chinese government realized that if it does not control the "core technology," it will not hope to become an important part of the global mobile communication industry. Hence, China began to invest resources in the formulation of global standards for 3G mobile communications (Marukawa 2014).

However, the conclusion is also disappointing. In 1997, China established the "third-generation mobile communication evaluation coordination group" (Hua and Sigeo 2002). Datang, a state-owned enterprise in China, was established to develop TD-SCDMA. The company and Siemens jointly started to develop TD-SCDMA. Among them, the Chinese government made five major measures to promote the formation of TD-SCDMA industrialization. They include (1) the TD-SCDMA alliance was established by investing 700 million RMB. (2) It provided advantages for TD-SCDMA in spectrum allocation. (3) It waited until TD-SCDMA Technology is ready to start 3G service in China. (4) Let China Mobile, China's largest operator, operate TD-SCDMA (5) tried to let Nokia, Samsung, LG, Siemens, and other international manufacturers participate in the research and development of TD-SCDMA Technology (Marukawa 2014).

Contrary to the positive attitude of the Chinese government, TD-SCDMA users grew slowly until 2012 but doubled in 2013. However, China Mobile announced that it would start 4G service in the same year. The global 3G technology standard war started among the three standards but none of them succeeded. In the tenth year after the transition from 1G to 2G, 2G users accounted for 95% of the global mobile communication users. In the tenth year after the transition from 2 to 3G, that is, in 2011, 3G only accounted for 28%, and 2G still accounted for 71%. Whether 3G can finally occupy the global market from 2G has been doubted (Marukawa 2014). The failure of TD-SCDMA and two other 3G standards was announced the end of the "technological hegemony battle" in the field of mobile communication technology.

9.2.4 Characteristics of Complementary Mobile Communication Technology After 4G Era

Specifically, in China, the 3G era combines mobile terminals with the Internet but its 4G service started in 2013. The fundamental change in the 4G era is that the network speed of 4G is almost ten times that of 3G. Its high-quality video, file, and image transmission is unimpeded. Another progress of 4G is the sharp drop of traffic charges. In 3G, the amount of traffic included in the nearly 100 RMB tariff is only 1 GB, while in 4G era, the same amount of tariff can include dozens of GB of traffic. 4G has changed people's way of communication, travel, payment, and lifestyle. The corresponding industries also began to thrive in China with the change of lifestyle (Li et al. 2019).

From the 3G era, a mobile phone could correspond to multiple technical standards. After continuous development, TD-SCDMA, W-CDMA, and CDMA2000 finally reach the technical convergence in 4G long-term Evolution frequency division duplex (LTE-FDD). The main technologies of LTE-FDD are Orthogonal Frequency Division Multiple Access (OFDMA) and Massive Input Massive Output (MIMO). After that, China Mobile, Datang, and Huawei developed LTE-TDD (long-term evolution time division duplex). LTE-TDD realizes uplink and downlink communication by switching in the same spectrum band, while LTE-FDD uses one band for uplink and downlink, respectively. The former saves spectrum resources. In addition, the technical features of LTE-FDD and LTE-TDD are completely consistent, and they can be replaced and complemented. This feature is selectively adopted and operated by 4G operators according to the actual spectrum resources. For the realization of their complementarity, the contributions of enterprises such as Qualcomm and Huawei cannot be ignored. It is precisely because these enterprises developed IC chips supporting various technologies such that mobile phones equipped with such IC cannot only correspond to 4G LTE-FDD and LTE-TDD, but also switch freely between 3 and 2G networks. On the other hand, the detailed technical standards of LTE-FDD, LTE-TDD and 5G are stipulated by the 3GPP agreement. For example, although the LTE-TDD standard comes from Chinese enterprises, China accounts for 19%, Europe 28%, the USA 23%, South Korea 17%, and Japan 10% of its technical agreements (Marukawa 2021).

So far, the technology hegemony and competition around technology industrialization in the evolution of mobile communication technology have finally come to a complete end. Mobile communication technology standards no longer focus on which country has which technology, but all countries' technology together for a global standard, which are necessary to do technical improvement and perfection.

9.3 5G Innovation in China

9.3.1 Technical Orientation of 5G

As early as 2013, China's ministry of industry and information technology (MIIT), the national development and Reform Commission jointly established the IMT-2020 (5G promotion group), whose main task was to coordinate and promote the development of 5G in China, as well as in cooperation with the European Union, the USA, Japan, South Korea and other countries and organizations. According to the overall plan of 5G formulated by the promotion group, the three years from 2016 to 2018 were 5G technology trials, which went through three stages of technical trials. The first stage is from 2015 to 2016, which is the verification of key technologies. The second phase is from the second half of 2016 to the end of 2017 for the verification of technical solutions. The third stage is from 2017 to the end of 2018, which is system verification. China started to build 5G trial network in 2018 and began to promote 5G network (Li et al. 2019) in 2019 (Figs. 9.2, 9.3 and 9.4).

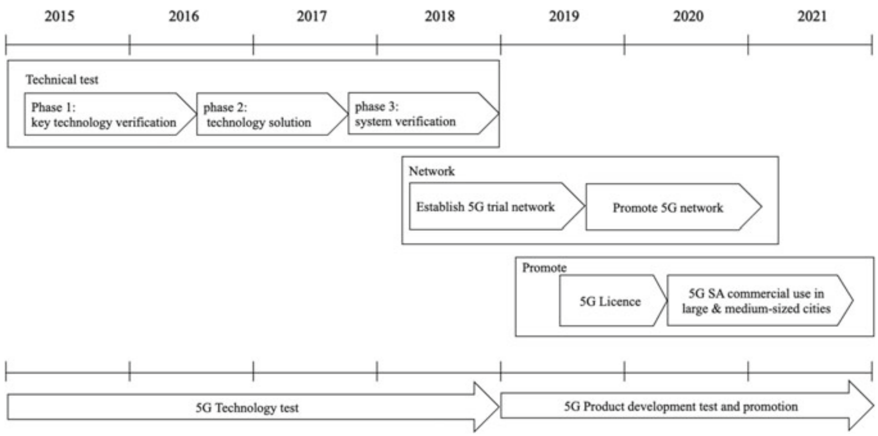

Fig. 9.2 Evolution of 5G technology in China. *Source* This figure was prepared by the authors using original data from: Li et al. (2019), State Council of China (2016a) and public information of the Chinese government

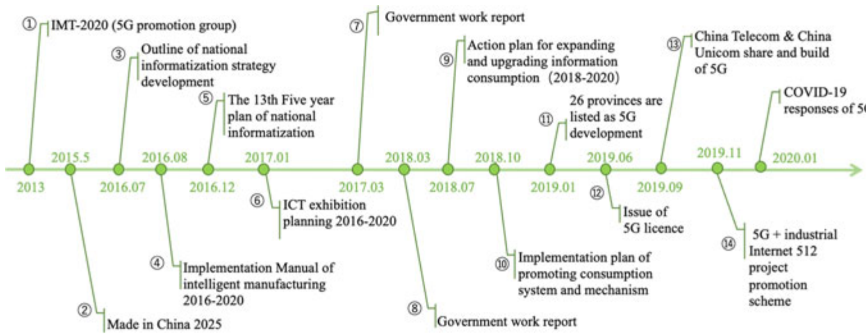

Fig. 9.3 China's 5G policy process before the end of 2019. *Source* This figure was prepared by the authors using original data from: Li et al. (2019), State Council of China (2016a) and public information of the Chinese government

China vigorously promotes 5G R&D and has major national scientific research and development projects around 5G national level, as well as numerous supporting policies. Since 2015, national development and Reform Commission, MIIT and other departments have established major national 5G scientific research projects. Through the establishment of national science and technology major special projects, MIIT has set up many projects in the aspect key devices, 5G wireless technology, 5G network technology, 5G instruments and platforms, and about 22 projects were set up in 2018 alone. In the national advanced technology research and development plan (863 plan), the government also listed 5G as a key project (Li et al. 2019).

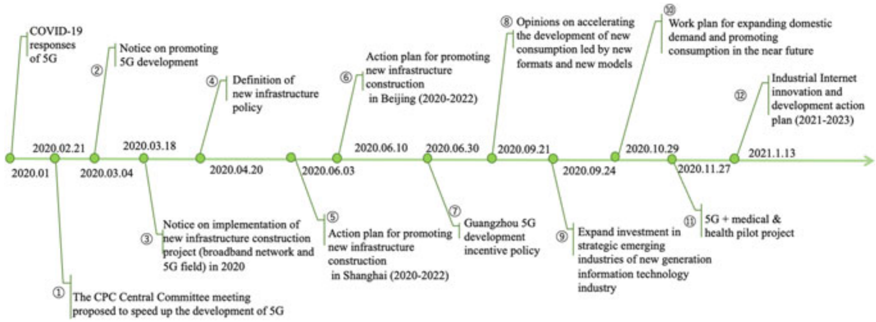

Fig. 9.4 China's 5G policy process after 2020. *Source* This figure was prepared by the authors using original data from: public information of the Chinese government

9.3.2 Policy Orientation of 5G

In terms of national policies, there are many measures on 5G technical standards, test, and innovative application. In the 13th Five-Year Plan of 2016, it was proposed to actively promote the research of 5G and clarify the planning objectives of 5G. In the government work reports in 2017 and 2018, it was mentioned to cultivate and expand the development and transformation of 5G technology, and the development direction of 5G was also established. In 2018, a three-year action plan to expand information consumption and improve the consumption system was issued. After entering 2019, 26 provinces are then selected as key areas for 5G development. On June 6, MIIT issued 5G licenses to China's four major telecom operators. After that, China Telecom and China Unicom agreed on 5G sharing and co construction, and on November 1, the three major operators opened China 5G service. At the end of November, the "5G+ industrial Internet 512 promotion plan" was introduced. These are national policy initiatives. In addition, by the end of 2019, the number of 5G policies at the local government level had reached 460 (Xiang 2019). From 2013 to the end of 2019, 5G network construction, 5G technology, 5G industry, and 5G application were extensively mentioned in these 5G policies.

In terms of the fields involved, in addition to the information industry of 5G itself, after the establishment of IMT-2000 promotion group, manufacturing industry was mentioned in Items 2 and 4 of Fig. 9.1, and the production efficiency of manufacturing industry was improved through the combination of 4G and 5G information technology and industrial manufacturing operation. Among the 9 and 10 policies, the government has instructed the whole country to increase information consumption and improve the consumption system. We can understand that this is to prepare for the consumption of 5G new technology after it is put into the market. In the month when 5G service began, "5G+ industrial internet promotion scheme" was introduced and it proposed to use 5G new technology to improve the level of industrial manufacturing and then strive for intelligent manufacturing. This is the 5G policy before the end of 2019.

Just at the end of 2019 and the beginning of 2020, the world was experiencing the unprecedented pandemic of COVID-19. Wuhan, China, was the first city to have an outbreak of the epidemic. China mobilized the national medical forces to Wuhan. Under the condition of isolation, China launched all the new technologies that could be used. The application of 5G, AI, and robot in COVID-19 show great usefulness. Since then, China's 5G policy has changed. In January 2020, when Wuhan was in the state of closure, MIIT called on major operators to provide maximum cooperation and support for COVID-19. Three operators provided government departments with reasonable location information of infected persons and close contacts and made great contributions to the prevention of the epidemic of COVID-19. It is precisely because of this epidemic that much spotlight was placed on the importance of information and communication technology.

After the improvement of the epidemic situation in Wuhan, the CPC Central Committee clearly increased the research and development of reagents and vaccines in the national conference held on February 21, 2020. It aimed to promote rapid development of medicine, medical equipment, 5G network and industrial Internet. At the next day's MIIT meeting, telecom operators were instructed to timely assess the impact of the epidemic, formulate 5G network construction plans, speed up the construction of 5G (especially the independent network), and give full play to the driving role of 5G construction investment in the industry. After that, at the meeting on March 4, it was emphasized that there should be a speed up the progress of emerging infrastructure such as 5G network and data center and pay attention to mobilizing the enthusiasm of private investment. At the special meeting on accelerating 5G development of MIIT on March 6, it emphasized that "we should fully realize the importance and urgency of 5G development, scientifically grasp the new situation and new requirements of 5G development, and pragmatically promote the accelerated development of 5G. Speed up the network construction, deepen the application, and expand the industrial ecology." From February 21 to March 6, a total of four instructions on accelerating the construction of 5G were put forward in all national meetings within 14 days. The notice on promoting 5G development was issued on March 4, and the notice on 2020 new infrastructure construction project (broadband network and 5G) was announced on March 18.

On April 20, the national development and Reform Commission held a special press conference, which clearly defined the scope of "new infrastructure construction," namely three contents. They include (1) information infrastructure, with 5G and IoT, (2) integration infrastructure, big data and AI, (3) innovation infrastructure, including technology development. The National People's Congress held in may further deepened the meaning of 5G and made it clear that different from the previous social infrastructure construction, 5G, and other new generation information technologies are the forerunner of new infrastructure construction, and "5G leads the new infrastructure construction." It also makes a lot of discussion on the specific problems in the future 5G development and construction, including 5G base station power consumption and specific charging scheme of electricity fee reform. In June, Shanghai and Beijing successively released action plans. On September 21, the national development and Reform Commission issued the policy of expanding

5G and other information infrastructure investment. In the same month, the State Council issued the policy of "expanding investment in strategic emerging industries of the new generation of information technology industry." In October, the "work plan for expanding domestic demand and promoting consumption in the near future" was announced (State Council of China 2020a). In November, the pilot project of 5G+ medical and health use was implemented to improve the application of 5G in the field of public health (State Council of China 2020b). After entering 2021, the "industrial Internet innovation and development action plan (2021–2023)" was announced on January 13 (State Council of China 2021a). This plan is different from the second one which was adopted in 2018. This new plan strongly advocates the use of 5G and other new technologies to promote the informatization of industry and manufacturing.

From a series of policies after 2020, we can see that (1) for the application of 5G and other new technologies, the direction of promoting the development of industry and manufacturing industry remains unchanged over the years. (2) 5G of mobile communication technology in China has been integrated with social infrastructure construction policy after the experience of COVID-19; hence, it is positioned as "5G leads the new infrastructure construction." At the same time, China's pace of new infrastructure construction has been accelerated due to COVID-19. (3) The new infrastructure investment led by 5G also plays the role of expanding domestic demand and promoting consumption in the stagnant period of economic development in the late stage of the epidemic.

9.4 Economic Effect of 5G

9.4.1 Investment Scale and Operator Strategy of 5G in China

In early 2020, novel coronavirus pneumonia outbreak in China, and the disease control measures such as closing the city, stopping production and shutting down production had a greater negative impact on China's economic development. The outbreak of novel coronavirus pneumonia both locally and abroad will continue to slow the consumption recovery and will also affect economic growth. Yet, 5G network construction needs a lot of capital investment, which will effectively promote the development of upstream and downstream enterprises in the industrial chain, thus driving economic growth. Since the issue of 5G license in June 2019, the three major domestic operators have made efforts to build 5G network. In the second half of 2019, the total investment in 5G network construction of the three major domestic operators is 41.17 billion yuan. In 2020, with the new infrastructure policy, 5G network construction investment of the three major operators is expected to reach 180 billion yuan (Figs. 9.6 and 9.7). 5G network construction is a continuous process. In the next 4–5 years, operators will continue to invest heavily to achieve national coverage.

Since the 3G license was issued in 2009, the three operators have invested about 578.8 billion yuan in four years. Since the 4G license was issued in December 2013, the three major operators have invested about 830 billion yuan in the construction of 4G network in six years. Compared with 4G network construction, 5G network needs more base stations, and the cost of single station construction is higher. Therefore, the overall investment will be higher than 4G network construction. In the next few years, high investment in 5G new infrastructure will continue to drive economic growth.

The capital expenditure changes periodically from 2008 to 2019 (see Figs. 9.5 and 9.6), which is closely related to the iteration of mobile communication technology.

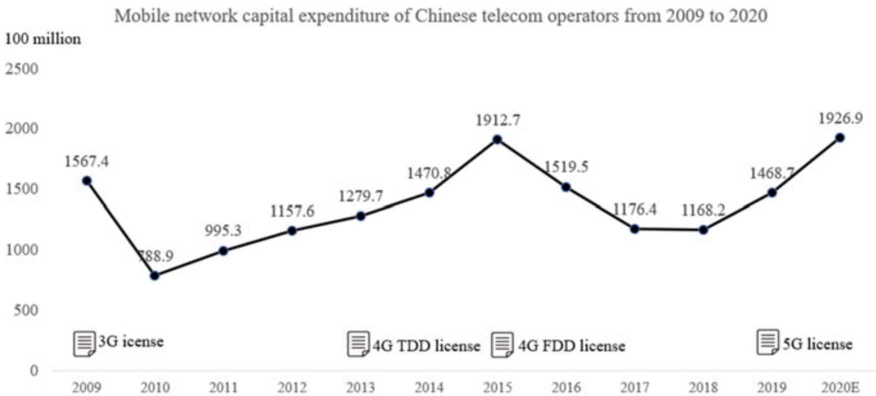

Fig. 9.5 Mobile network capital expenditure of China Telecom operators after 3G in China. *Source* This figure was prepared by the Authors using original data from: MIIT and iResearch Institute. **Note* 2020E = estimates

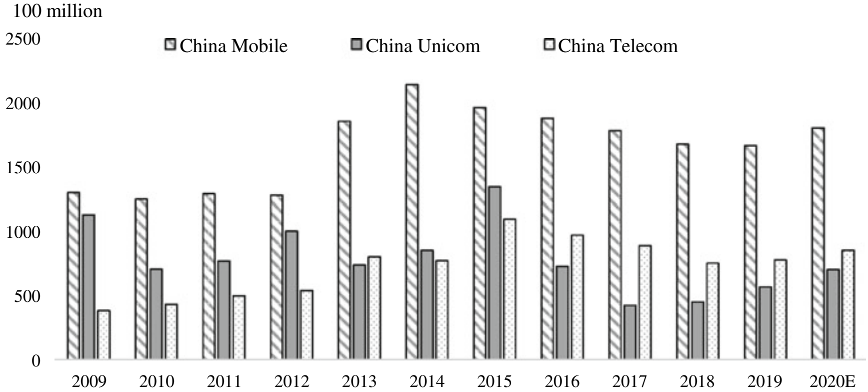

Fig. 9.6 Total capital expenditure of three major telecom operators in China. *Source* This figure was prepared by the Authors using original data from: China Mobile, China Unicom, China Telecom and Qianzhan Industry Research Institute. **Note* 2020E = estimates

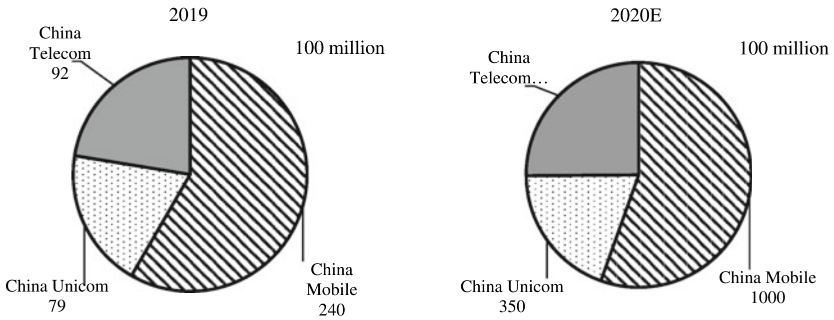

Fig. 9.7 5G related capital expenditure of China's three major telecom operators. *Source* This figure was prepared by the Authors using original data from: China Mobile, China Unicom, China Telecom and Qianzhan Industry Research Institute. **Note* 2020E = estimates

The capital expenditure of China Mobile, China Unicom, and China Telecom in 2019 was 165.9 billion yuan, 56.42 billion yuan, and 77.56 billion yuan, respectively, of which 5G related investment is 24 billion yuan, 7.9 billion yuan, and 9.2 billion yuan, respectively. The proportion of 5G related investment budget of the three operators in 2020 is basically the same as that in 2019, which is about four times of that in 2019 (see Fig. 9.7).

9.4.2 5G Construction Status and Market Effect

5G will promote the high-speed and sustained growth of the upstream and downstream of the industrial chain and drive the transformation of China's real economy. China academy of information and communications technology (CAICT) predicted that 5G will drive about 484 billion yuan of direct output in 2020 (Fig. 9.8) and will

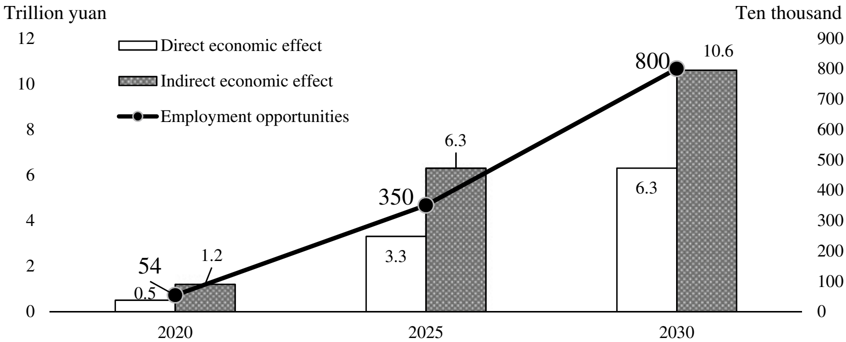

Fig. 9.8 Effect and employment opportunities driven by 5G in 2020–2025. *Source* This figure was prepared by the authors using original data from: CAICT

grow to 3.3 trillion yuan and 6.3 trillion yuan, respectively, in 2025 and 2030. In terms of indirect effect, it will grow to 1.2 trillion yuan in 2020, 6.3 trillion yuan in 2025 and 10.6 trillion yuan in 2030. In terms of stimulating employment, 540,000 jobs will be created in 2020 and 3.5 million will be created in 2025, mainly from 5G related equipment manufacturing and telecom operation. By 2030, 5G will create 8 million jobs, mainly from jobs created by telecom operators and Internet service enterprises.

Figure 9.10 shows the Internet traffic and discharge of usage (DOU) of China Mobile. We can see the explosive growth of traffic and Dou after 2015. In 2020, DOU reached 10.4 GB, which is 26 times of 2015. The total traffic is also close to 40 times that of 2015. The iteration of mobile communication technology promotes the rapid development of mobile Internet, and the endless applications are changing the

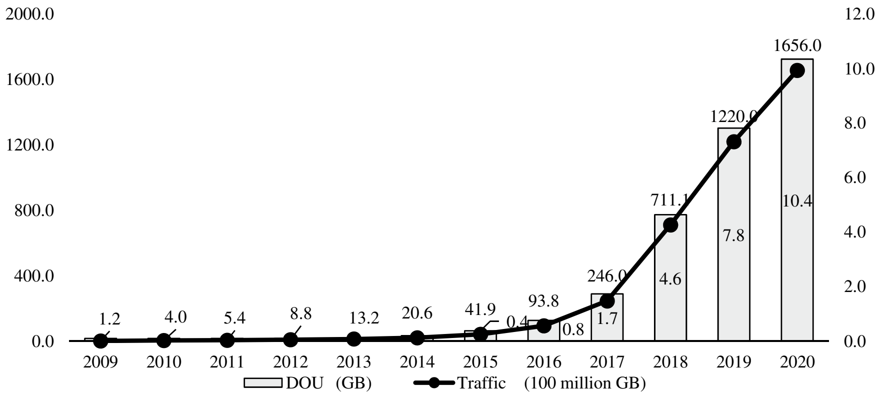

Fig. 9.9 China Mobile Internet traffic and DOU growth in 2009–2020. *Source* This figure was prepared by the authors using original data from: MIIT

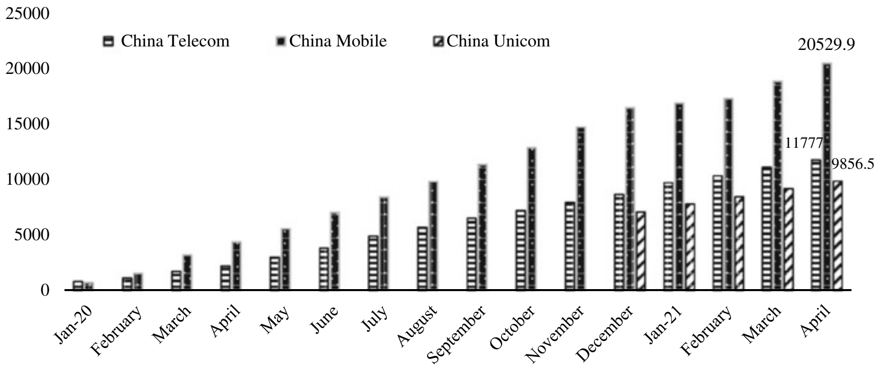

Fig. 9.10 5G user of China Mobile, China Telecom, and China Unicom (ten thousand). *Source* This figure was prepared by the authors using original data from: China Mobile, China Telecom, and China Unicom

way of people's consumption, payment, and entertainment. From 2 to 4G, the network speed becomes faster, and more and more mobile Internet applications are supported. We have witnessed the development of mobile Internet from text information, picture information to video information. With the development of Live-commerce, short video, cloud games, and other video applications, the traffic of user DOU and mobile network is rising sharply. According to the information statistics annual report of MIIT 2020, 99.7% of Internet access devices come from mobile Internet, which brings great challenges to 4G network.

Online education and online office work are becoming more and more normal, bringing greater pressure to the mobile network. After 5G commercial use, 5G user volume and DOU in China continue to rise. In terms 5G, its DOU users have reached twice that of 4G users, and in December 2019, the DOU of 5G users of China Mobile reached 16.9 GB. In May 2020, China Telecom 5G user DOU has also reached 14.1 GB. In terms of the number of users, the total number of April 2021 is close to 430 million. The prospects of the 5G user market in China have been impressive since the service started in November 2019 and has been in the past 18 months.

9.5 Significance of 5G to China

With the past 1G–4G technology follow-up and innovation practice experience, China seems to have learned how to carry out 5G innovation and application. In recent times, more and more countries have started 5G service and are learning and groping about its use and service mode. It can be said that China has successfully achieved a smooth transition from 4 to 5G. In terms of the development situation in the past 18 months, China's 5G development route has been successful. The reasons being that (1) 430 million users and markets have been created. (2) Its successful application for COVID-19 management. It is mainly reflected in the construction of two hospitals in ten days after the outbreak of the epidemic in Wuhan, rapid realization of 24-h live broadcast of hospital construction, and the successful popularization of online medical and online education during the epidemic period. The large capacity communication of 5G communication technology can carry more information communication. 5G has become an indispensable part of China's information society infrastructure. It serves the majority of users but also serves the social needs of all walks of life for new information technology. At the same time, it also plays the role of expanding domestic demand and guiding China's economic development in the late stage of the epidemic. (3) 5G integrates more new technologies to form an information line and deliver services to more people in need. 5G is a communication platform and a new lifeline of social development. Mobile communication technology is considered to be the most effective way to improve the level of Internet access. The urgency of COVID-19 has accelerated the development of global information and communication technology applications and has also accelerated the pace of 5G development in China. 5G is of great significance to today's China and its application shoulders an important task of improving the digital divide between urban and rural areas in China and also has the potential to expand universal services in a larger scope.

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Chapter 10
Evolution from IoT to IoE Era in China

Jinling Hua and Rajib Shaw

Abstract China's IoT has been booming since 2009 and has gradually become an important part of China's new social infrastructure and the key to supporting the development of China's digital economy. Its technology and application innovation emerge in endlessly and occupy an important position in the development of smart city. According to the latest data, the proportion of smart cities in China's IoT industry is the largest, followed by industrial IoT with 20%, smart home with 18% and IoV with 16%. Looking forward to the future IoT, IoV is an important part of national transportation development and personal travel. China's IoV adopts LTE-V2X cellular communication technology and gradually transits to 5G-V2X through NR-V2X. With the development of China's IoV, China has made great achievements in automobile manufacturing, communication and information, and road infrastructure construction. On the other hand, China is playing a more and more important role in the formulation of international C-V2X, 5G and other new generation communication standards. By the end of October 2020, the total number of automatic driving patents in the world has exceeded 70,000, of which the overall authorization rate of automatic driving patents in China is close to 42%. In 2020, smart home accounts for 43%, IoV 11%, public health 8% and smart agriculture 7%. The most important connection center of personal IoT in family scene is mobile phone. The most important connection center of personal IoT in work scenario is PC. College students are mainly connected around personal intelligent products in the campus scene. In the scene of going out, users usually swipe their cards in public transportation and subway through personal intelligent products. About half of the people in sports choose to use smart bracelets/watches to improve their sports efficiency. China's IoT connection content is also constantly enriched, more and more toward the development of the era of IoE.

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J. Hua et al. (eds.), *Considerations for a Post-COVID-19 Technology and Innovation Ecosystem in China*, Disaster Risk Reduction,
https://doi.org/10.1007/978-981-16-6959-0_10

Keywords IoT · IoE · Chinese technology · Smart technology · Smart city

10.1 Introduction

Internet of things (IoT) is the extension of telecommunication network and Internet. It uses sensing technology and intelligent devices to perceive and identify the physical world and realizes the information interaction between people and things, things and things through network transmission. IoT is becoming more and more interconnected, that is Internet of everything (IoE). The definition of IoT in Chinese national standard is "an intelligent service system that can process and respond to the information of physical world and virtual world by sensing devices and linking objects, people, systems and information resources according to the agreed protocol" (SAMR 2017). In China, IoT started in 2009 and began to be written into China's "government work report" the following year. In the past decade, IoT has gradually become an important part of China's new social infrastructure and the key to supporting the development of China's digital economy. Its content, technology and application innovation are constantly enriched endlessly, which play important roles in the development of smart cities.

According to the analysis of Zhongshang Industry Research Institute (Zhongshang 2019), the scale of China's IoT industry has maintained a high growth rate in recent years. In 2013, it was 500 billion yuan, an increase of 36.9%, of which the sensor industry exceeded 120 billion yuan, the RFID industry exceeded 30 billion yuan; in 2014, it exceeded 600 billion yuan; by the end of 2015, it increased to 750 billion yuan. After 2016, IoT industry entered a steady growth, reaching 1.77 trillion yuan in 2019. It is estimated that by the end of 2020, it will have exceeded 2 trillion, with an average annual growth rate of 25% (see Fig. 10.1).

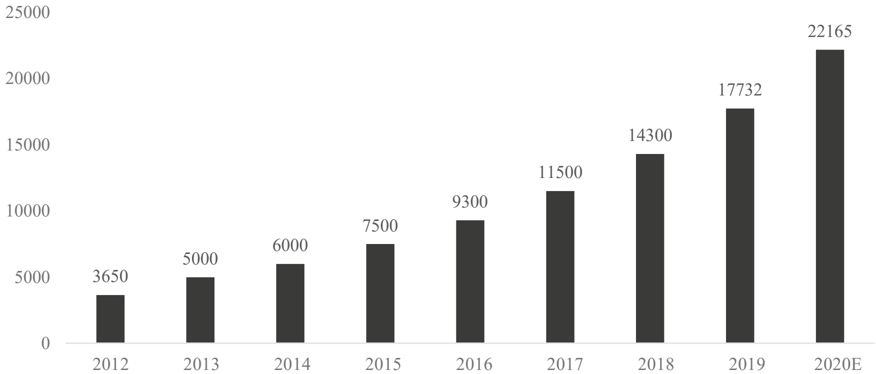

Fig. 10.1 Scale of IoT in China (100 million yuan). *Source* This figure was prepared by the authors using original data from Zhongshang Industry Research Institute. **Note* 2020E = estimate

Zhiyanzixun's market analysis of China's IoT industry shows that in 2019, the proportion of smart cities in China's IoT industry is the largest, accounting for 31%, followed by 20, 18 and 16% of industrial IoT, smart home and Internet of vehicles (IoV) Fig. 10.2. On the other hand, according to the survey results of IoT users by IoT white paper (CAICT 2020), smart home accounts for 43%, IoV 11%, public health 8% and smart agriculture 7% (Fig. 10.3).

The Ministry of industry and information technology announced that China's Internet of things end users will reach 1.154 billion in February 2021, a year-on-year increase of 10.6%, and a net increase of 18.27 million compared with the end of last year. The total number of intelligent transportation end users including the Internet

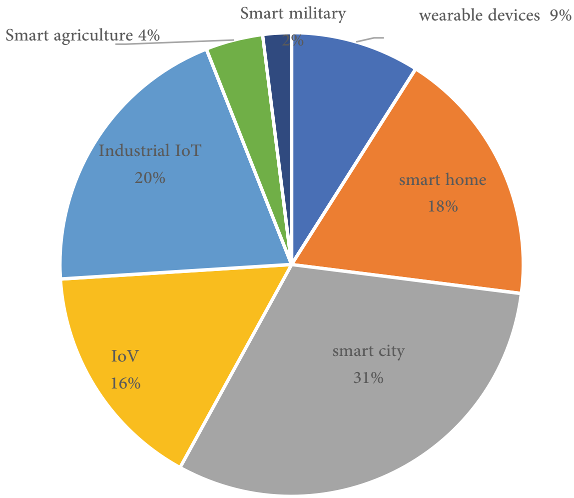

Fig. 10.2 Industry distribution of IoT in China (2019). *Source* This figure was prepared by the authors using original data from Zhiyan Research

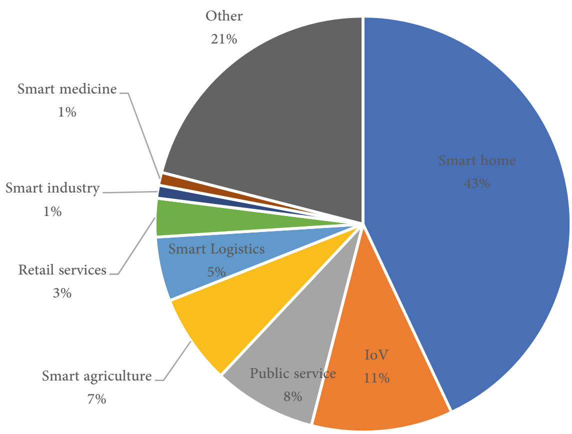

Fig. 10.3 IoT usage in China (2020). *Source* This figure was prepared by the authors using original data from CAICT

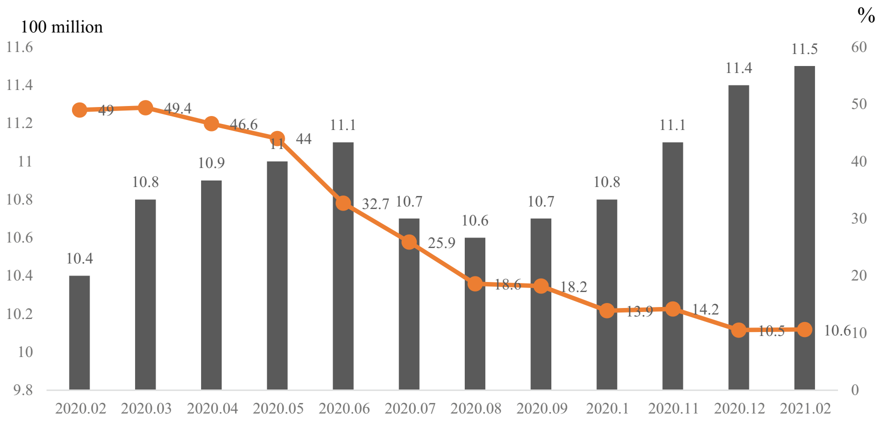

Fig. 10.4 IoT end users in China. *Source* This figure was prepared by the authors using original data from MIIT

of vehicles to be increased by 29.6% year on year, with the most prominent growth trend (MIIT 2021) (see Fig. 10.4).

10.2 Development Status of IoV in China

IoV is the ultimate answer to the transformation in the future. Its essence is the comprehensive co-evolution of road network vehicle cloud. The content of Internet of vehicles (V2X) is rich in meaning. According to the connected objects, it can be divided into vehicle to vehicle (V2V), vehicle to infrastructure (V2I), vehicle to network (V2N) and vehicle to pedestrian (V2P). The essence of the Internet of vehicles is a comprehensive evolution of the four main elements, road, network, vehicle and cloud. Its goal is to achieve a more efficient, safer and more intelligent traffic structure through vehicle road collaboration (CITIC 2020). Specifically, the evolution direction of the four elements of the Internet of vehicles is as follows:

- The road: intelligent road has three characteristics: feeling—the network of transportation infrastructure that can be fully perceived; thinking—intelligent decision-making after data collection and analysis; speaking—from passive bearing to active sensing, more closely cooperating with vehicles.
- The car: the basic feature of smart car is that it has the ability of "network connection," which can realize the information interaction with the road and cloud. At the same time, it also has the ability of "intelligence," which can process and analyze the important information received.
- Net: the evolution direction of communication network is to support and guarantee the real-time and all-round information exchange between vehicle, road and cloud.

- Cloud: facing the open and complex transportation system, a cloud based urban transportation brain is needed to dispatch, control and organize.

China attaches great importance to the development of technologies and industries related to IoV. At present, China is in the stage of promoting key technologies, industries and policies. Miaoyu, former Minister of MIIT, said at the 11th Caixin Summit on November 14, 2020 that 20% of China's 5G applications are for individual users and 80% are for business. Besides the information exchange between people, the biggest applications of 5G are IoT and industrial Internet. IoV is probably the largest part of IoT and industrial Internet. In recent years, Chinese people are no longer satisfied with IoV and are gradually developing toward the multifunctional intelligent connected vehicle (ICV).

The three major telecom operators in China actively carry out the pilot of IoV application platform. They are (1) China Mobile in Beijing, Wuxi, Shanghai, Ningbo, Liuzhou and other places, (2) China Telecom in Xiongan, and (3) China Unicom in Changzhou, Chongqing and other places. The three operators actively deploy MEC service platform to support the IoV business. For the application of 5G in the Internet of vehicles, China Mobile carries out the 5G based application. The application test of Internet technology between V2V, V2P and IoE; China Telecom, together with Nokia, Ericsson and other equipment manufacturers, have carried out the test of intelligent transportation, self-driving and other applications in Nanjing and other pilot cities. China Unicom, together with Bell, Intel, Tencent, Benz and other manufacturers, have also carried out test of many 5G based Internet technologies. The application of IoV and IoT is now verified (CITIC 2020).

10.2.1 IoV Policy

China started to build the first national level IoV pilot zone in Wuxi City in 2017. In November 2018, MIIT issued the IoV dedicated spectrum (MIIT 2018), and the Cellular Vehicle to Everything (C-V2X) working group of IMT-2020. (5G) promotion group held the IoV Application Exhibition and issued the "IoV industry development action plan." In 2019, after MIIT issued 5G commercial license to telecommunication operators, it began to support pilot areas of Wuxi and Tianjin and verified the C-V2X communication security and technology. 2019 is a pilot demonstration year for major breakthroughs in IoV. In 2020 however, the Chinese government issued the "ICV innovation and development strategy," which states that China's standard ICV is the development direction, and the ICV power is the construction goal. Six major arrangements are made to promote the large-scale development of the industry. At the same time, it also successively launched the "outline for the construction of a transportation power" and "notice on promoting the accelerated development of 5G." The notice stressed the need to promote the development of 5G+ IOV. On March 11, 2021, China ICV-2035 promotion group was established. The goal was to solve the problems in China's ICV development, promote the development pace of IOV industry, and deeply implement the new energy vehicle industry development plan (2021–2035). On the 17th of the same month, MIIT, together with the Ministry of transport, issued the notice on "intelligent transportation" guidance for the construction of national IoV industry standard system, further updating the corresponding guidance for 2017, 2018 and 2020, respectively. The guide proposes to formulate 20 standards in the field of intelligent transportation infrastructure and transportation information to improve the application of ICV, traffic management and market demand.

10.2.2 China's Evolution to C-V2X Technology

IoV standard system can be divided into two parts: wireless and communication. At present, the mainstream IoV in the world includes wireless technology IEEE802.11p and cellular communication technology C-V2X. IEEE802.11p is based on Wi-Fi standard, which is standardized in IEEE. C-V2X is a rising star. It is an IoV technology based on cellular communication and terminal direct communication. Its standard work is carried out in 3GPP. C-V2X includes LTE-V2X and NR (New Radio)-V2X based on LTE. LTE-V2X was first proposed by Datang of China in May 2013, led by Chinese enterprises such as Datang and Huawei and international companies such as LG. 3GPP officially released R14 and R15 versions of LTE-V2X standards in March 2017 and June 2018, respectively. In June 2020, R17 research started after R16 standard was formed (CIC 2020a).

The application of C-V2X involves automobile, transportation and other industries. China adopts LTE-V2X communication technology and gradually transits to 5G-V2X through NR-V2X. In recent years, China has made great progress in automobile manufacturing, communication and information, and road infrastructure construction. The overall scale of automobile industry continues to lead in the world. The markets share of independent brands is gradually increasing, and the core technology is constantly making breakthroughs. A number of world-class leading enterprises have emerged in the field of information and communication, and communication equipment manufacturers have entered the world. It also plays a more and more important role in the formulation of international C-V2X, 5G and other new generation communication standards. In terms of national infrastructure construction, broadband network and expressway network are developing rapidly, ranking first in the world in scale. Beidou satellite navigation system can provide high-precision space–time services for the whole of China. The country already has the basic environment to promote the development of c-v2x industry, which can further promote the industrialization and application of c-v2x technology. By 2020, China's ICV demonstration zone system had begun to take shape, forming 10 national level ICV test demonstration zones, which is more than 30 city level and enterprise level test demonstration sites, and more than 10 smart expressways to carry out ICV pilot work. Among them, the national demonstration areas are mostly concentrated in the areas with rich automobile industry resources (CIC 2020a).

10.2.3 Patent Situation of IoV and C-V2X

As of July 2020, the total number of global IoV patent applications had reached 115,013, of which 34,892 was applied in China (CIC 2020b). The top 15 applicants for IoV patents in the world are mainly auto companies and auto parts suppliers. Denso of Japan holds the most IoV patents, focusing on automatic driving technology. Through research, investment, joint venture and other means, Denso has laid out high-quality expertise in vehicle control technology such as automatic vehicle control and driver status monitoring, communication technology such as millimeter wave radar and lidar, and AI chip technology of automatic vehicle driving (see Fig. 10.5).

From the perspective of technology flow of global patent applications, China, the USA and Japan are the main technology original countries and target market countries of ICV. Foreign countries have more patents in China, while China has less patents abroad. Japan's market is relatively closed, mainly occupied by domestic technology. From the perspective of technology types, Huawei, ZTE and other Chinese local telecommunication enterprises have made a relatively large-scale layout around the patents of on-board communication technology and on-board communication terminal equipment. Huawei's patent applications for IoV are mainly concentrated in the C-V2X, but from 2019 to 2020, Huawei's patent applications were mainly in the C-V2X. In terms of newly published patents, some of Huawei's patents on automatic driving and vehicle positioning technology have been gradually disclosed, and a small number of electric vehicle power management patents are also being applied, which shows that Huawei's research and development focus has extended to the vertical field.

The main types of applicants in China include local communication enterprises, foreign communication enterprises, foreign automobile enterprises, foreign auto

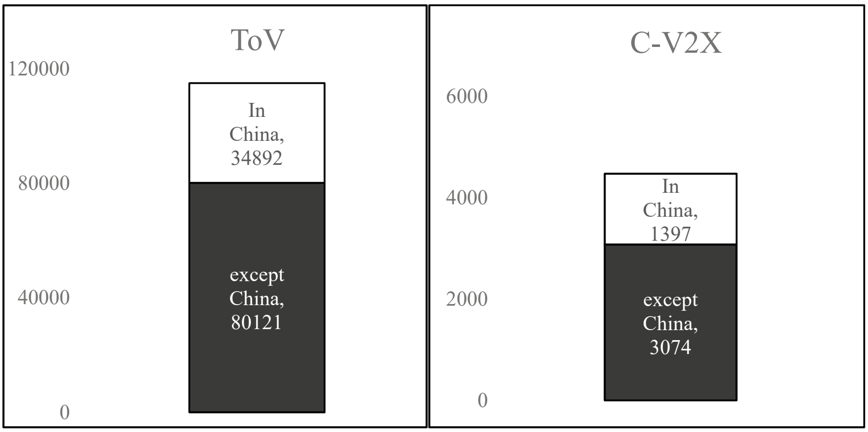

Fig. 10.5 Regions and number of patents accepted by IoV and C-V2X. *Source* This figure was prepared by the authors using original data from CIC (2020b)

parts manufacturers, domestic automobile enterprises, domestic Internet enterprises and start-up technology companies focusing on IoV. Ford has always attached great importance to patent applications in China, and the distribution of its IoV technology patents in China is close to 300, mainly focusing on automatic driving, communication between vehicles, vehicle safety control and some vehicle management platform technologies.

As at July 2020, the number of patent applications for C-V2X worldwide was 4471, and the number of applications accepted in China was 1397 (CIC 2020b). The largest number of C-V2X patents is in the USA and China, followed by Europe and Japan. China is the largest patent accepting country and target country of C-V2X. European car companies and communication companies have a certain number of applications to China. Huawei, ZTE and Datang are the main Chinese enterprises applying for overseas patents of C-V2X. The total number of patent applications in the top 10 is more than 1800, which is close to 50% of the total number of applications. The holding of leading enterprises is also relatively concentrated, followed by Huawei (about 510), ZTE (about 390), LG (about 210), Datang (about 200), Ericsson (about 160), Qualcomm (about 150), Samsung (about 70), at & T (about 60), Intel (about 40), interdigital (about 30) (CIC 2020b).

Meanwhile, on the contrary, the applicants of C-V2X accepted in China are mainly communication enterprises, and the number of patents of foreign enterprises in China is scattered, and only Samsung (about 40) enterprises enter the top 10 applications in China. Huawei (about 510), ZTE (about 390) and Datang (about 230) have taken the obvious advantage. China Mobile is the fourth with about 60.

10.2.4 Self-driving Technology

Self-driving relies on the cooperation of artificial intelligence, visual computing, radar, monitoring device and global positioning system through computer system. Self-driving intersects with IoV, but it does not belong to IoV. By the end of October 2020, the total number of Self-driving patents in the world has exceeded 70,000. According to the regional distribution of global patent acceptance, China is the most important country of patent acceptance, accounting for one-third of global patent acceptance. The overall licensing rate of self-driving patents in China is close to 42%, which is higher than that in 2019. From the perspective of the main applicants of global patent applications, they are mainly car companies and Internet companies, especially Internet companies such as Baidu and Google. Baidu has applied more than Ford, Toyota, Honda and other auto companies (see Fig. 10.6).

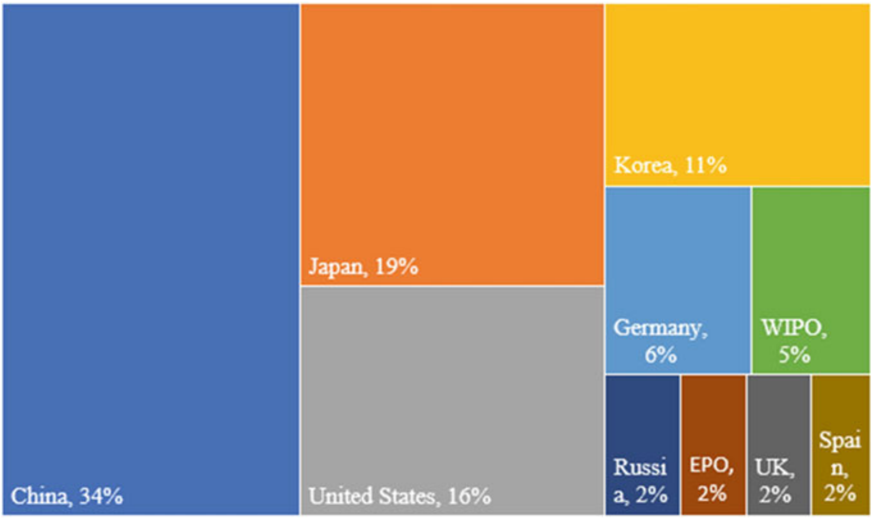

Fig. 10.6 Proportion of self-driving patents in the world. *Source* This figure was prepared by the authors using original data from CIC (2020b)

10.3 Smart Home IoT in China

In 2020, the number of Internet users in China reached 989 million. The penetration rate of Internet users will reach 70.4%, and the number of mobile Internet users reached 986 million. Optical broadband access users reached 454 million, accounting for 93.9% of the total fixed Internet broadband access users (CNNIC 2021). With the Internet entering more families, the home Internet infrastructure will be gradually improved (see Fig. 10.7).

In 2019, China's smart home IoT market reached 353.2 billion yuan, an increase of 2.6% over the previous year. Smart home appliances include refrigerators, air conditioners, washing machines, televisions and other high price products, accounting for 85% of the smart home IoT market. Home security, intelligent connection control and intelligent lighting account for 7.6%, 6.5% and 0.9%, respectively. In 2020 however, this was greatly affected by the COVID-19, and the market scale reduced by 6.3%. However, the household security will still maintain a high growth in the epidemic situation, and the intelligent lighting market will be accelerated (see Fig. 10.8).

Smart home appliances market includes four important parts: intelligent video, refrigerator, air conditioner, washing machine, other household appliances and kitchen appliances. In 2019, the scale of China's smart home appliance market exceeded 300 billion yuan for the first time. With the intelligent rate of large household appliances getting higher and higher, the market increment space becomes smaller, and the overall growth rate of intelligent household appliances is slowing down. On the other hand, due to the increase of income, consumers are more willing to pay for small household appliances that can improve the quality of life. The future

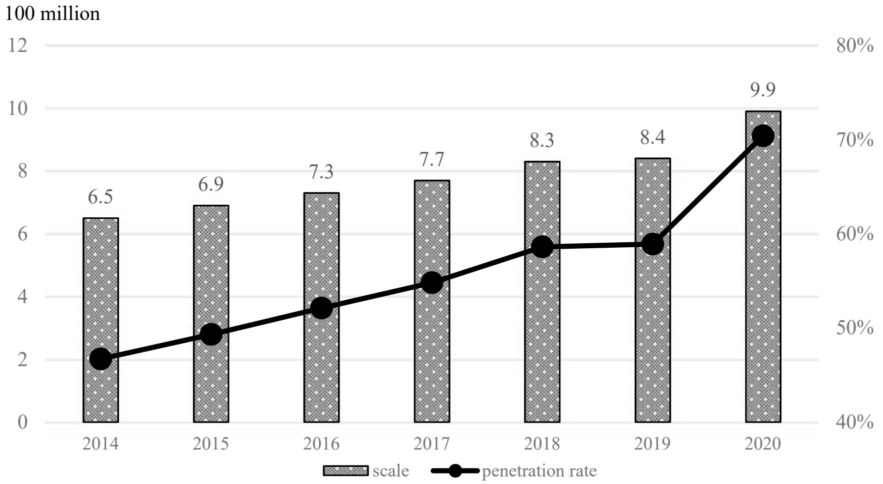

Fig. 10.7 Scale and popularity of internet users in China. *Source* This figure was prepared by the authors using original data from CNNIC (2021)

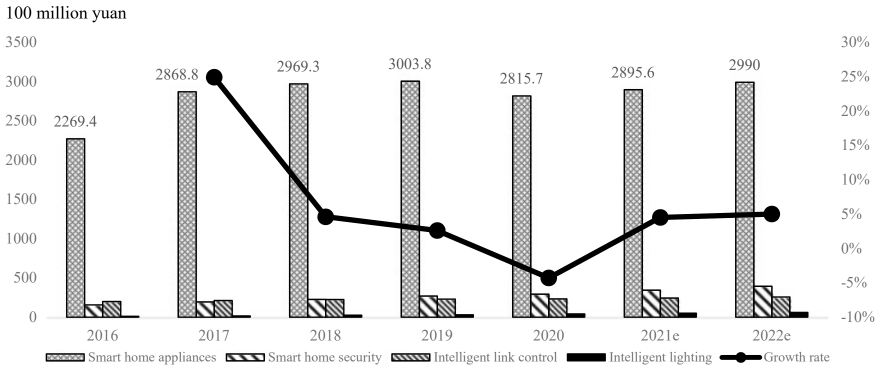

Fig. 10.8 Smart home IoT market in China. *Source* This figure was prepared by the authors using original data from iResearch (2020). *Note* 2020e, 2021e = estimates

development prospects of household appliances and kitchen appliances are good. It is estimated that there will be a growth of 7–9% from 2021 to 2022 (see Fig. 10.9).

Since 2016, the sales volume and market scale of China's household security products have maintained a sustained growth. In 2020, the sales volume of smart camera, smart door lock and visual doorbell reached 58.13 million, 13.6 million and 2.15 million, respectively, and the sales volume of household security products increased by 20%. The market scale rose by nearly 20%. In recent years, smart home security products have made great progress in technology level and product maturity, with more and more application scenarios. The further reduction of product cost will

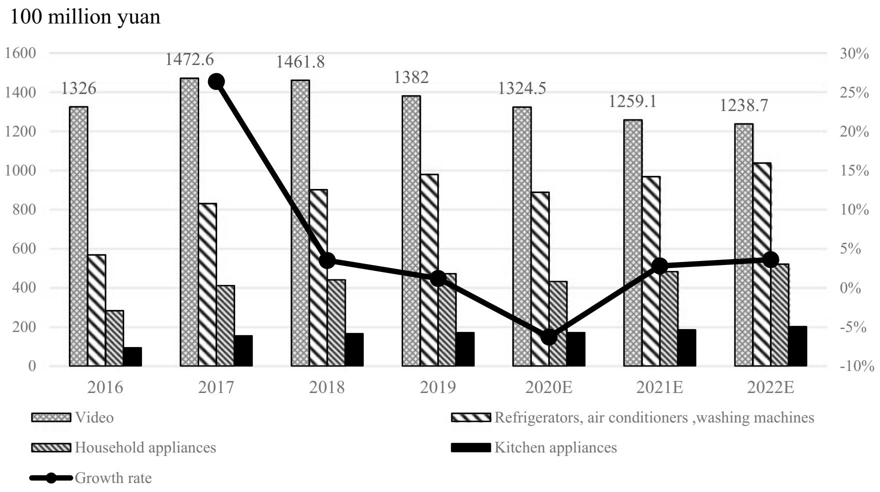

Fig. 10.9 Smart home appliance market in China. *Source* This figure was prepared by the Authors using original data from iResearch (2020). **Note* 2020E, 2021E, 2022E = estimates

continue to promote the popularization of smart home security, and the market scale is expected to reach 39.29 billion yuan by 2022.

Intelligent connection control is the cornerstone of smart home IoT development. Intelligent connection control market is composed of intelligent router, intelligent gateway and other equipment market, which plays the basic connection role in smart home IoT ecology. There is relatively rigid demand in the market. Its growth trend is relatively stable as a whole, and the possibility of explosive growth is relatively small. In 2019, the market scale of China's intelligent connection control was 22.9 billion yuan, an increase of 2.6% compared with the previous year. In 2020, the growth rate slowed to 1.5% due to the impact of the epidemic. However, it is expected that the growth rate of intelligent connection control market will gradually recover to about 5% in 2021 and 2022, and the market size will reach 25.74 billion yuan by 2022 (Fig. 10.10).

10.4 Personal IoT

Personal IoT is a kind of intelligent service which takes individual users as the center, connects people, things and other information resources through personal intelligent devices and meets the high-quality and convenient life needs of individual users. Its coverage scenes include family, workplace and all the process from morning to home, involving home, travel, office, education and sports scenes. At the beginning of 2021, the proportion of mobile Internet users in China reached 99.7%, the penetration rate of smart phones reached 95.6%, and the number of IoT connections in China

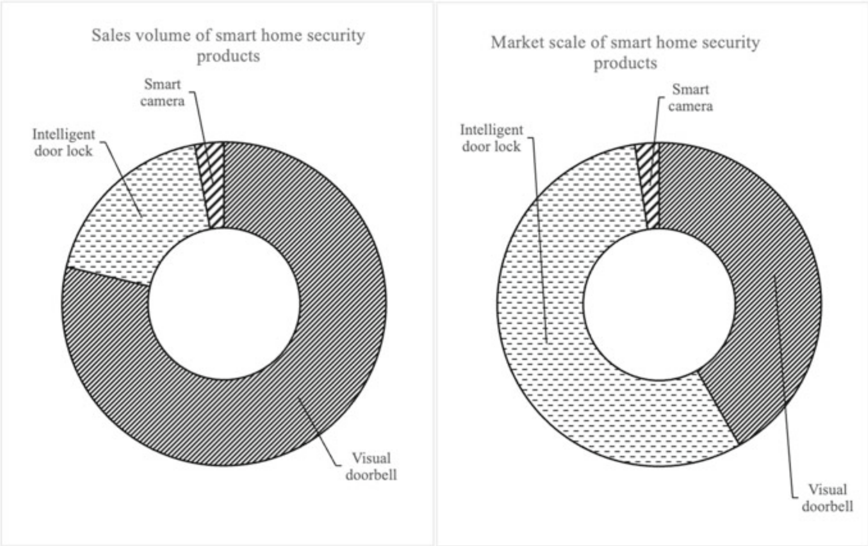

Fig. 10.10 Sales volume and market scale of smart home security products in China. *Source* This figure was prepared by the authors using original data from iResearch (2020)

reached 5.5 billion (CNNIC 2021). Smart phones occupy a dominant position in China's mobile phone market. It has become a personal network with more and more devices, and its use scenarios are more abundant. With the gradual maturity of mobile Internet, personal IoT will extend more personal intelligent devices based on smart phones, opening the post mobile era.

In January 2021, iResearch (2021) conducted a detailed survey and analysis of 1600 Chinese users of personal intelligent products. According to the survey, most of the users' budgets for buying mobile phones are between 3000 and 8000 yuan (85.1%), with an average budget of 4887 yuan. Compared with the purchase of mobile phones, there is a big budget difference in the purchase of smart watches and smart Bracelets: nearly 40% of the users who buy smart watches hope to buy less than 500 yuan, and about 30% are willing to spend 500–1000 yuan and 1000–3000 yuan, respectively; about 30% of the users who buy smart bracelets are willing to spend 201–300 yuan, and more than 20% are willing to spend 301–400 yuan. As the functions of smart watch and smart bracelet are similar, with the continuous upgrading and optimization of Bracelet functions, the substitution relationship between them will be stronger. In the future, the middle and low-price products of smart watch will form a fierce competition with smart bracelet, competing for high price sensitive users, while the high price products need to rely on more powerful product attributes to attract users to buy (see Figs. 10.11 and 10.12).

The most dependent personal devices are mobile phone (4.71), smart Bracelet/watch (4.17) and Bluetooth headset (3.92). More than 70% of users think they are very dependent on mobile phones. For smart Bracelet/watch, Bluetooth

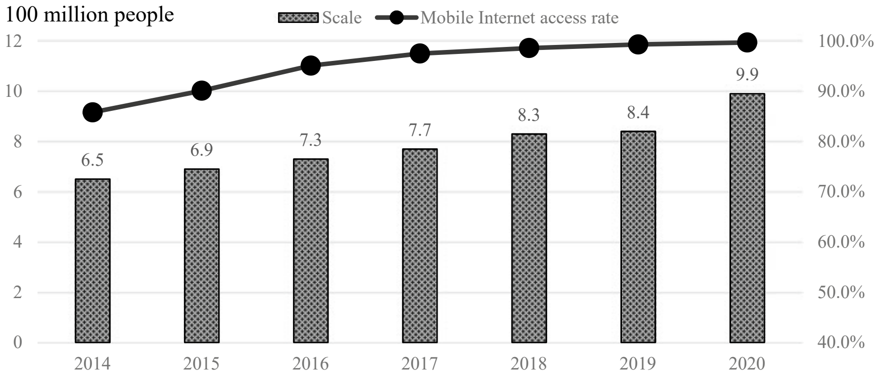

Fig. 10.11 Scale and penetration of mobile internet users in China. *Source* This figure was prepared by the authors using original data from CNNIC (2021)

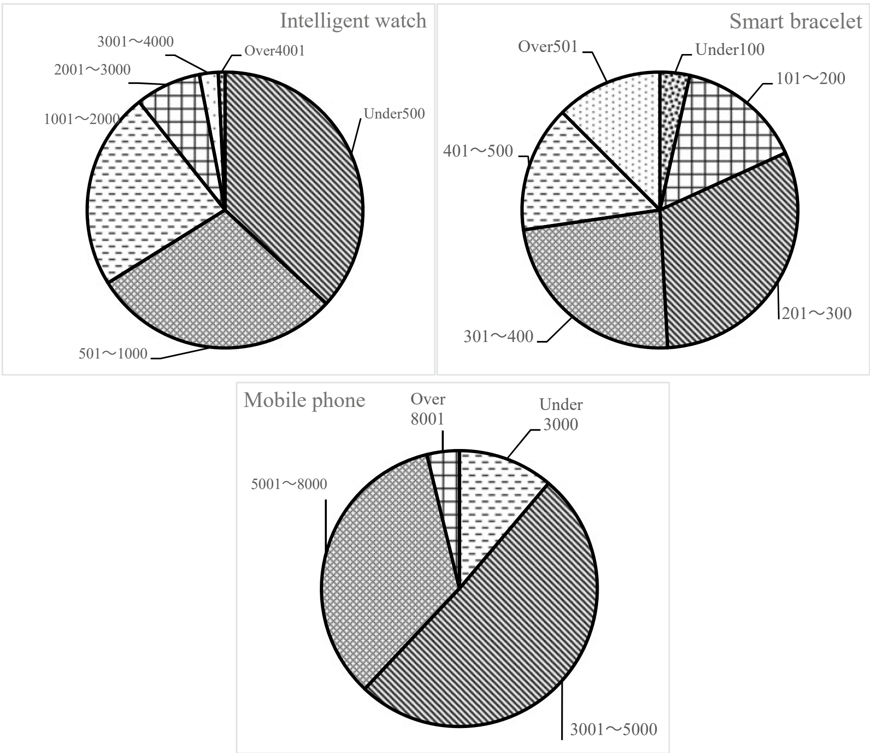

Fig. 10.12 Purchase budget of personal intelligent products in China. *Source* This figure was prepared by the authors using original data from iResearch (2021)

headset, notebook computer and tablet computer, the proportion of users with strong dependence is quite different. The proportion of users who think that they are "very dependent" on products is as follows: smart Bracelet/watch (31.3%), Bluetooth headset (23.1%), notebook computer (15.1%) and tablet computer (9.0%). However, the proportion of users who think they are "average" is not very different, and they are all about 50%. At this stage, users' recognition and purchase intention of smart glasses, smart running shoes and other products are still far behind those of mobile phones, bracelets, earphones and other products, and the performance of such products still has great room for improvement, so the user dependence is low (see Figs. 10.13 and 10.14).

From the perspective of mobile phone use, the daily use was mainly 3–6 h (40.2%) and 6–9 h (26.2%). Among the users who bought bracelet, more than 60% of them used it every day, most of them use it for 6–9 h (37.3%) and 24.1% of them used it for more than 12 h. According to previous article, users who purchase bracelets are

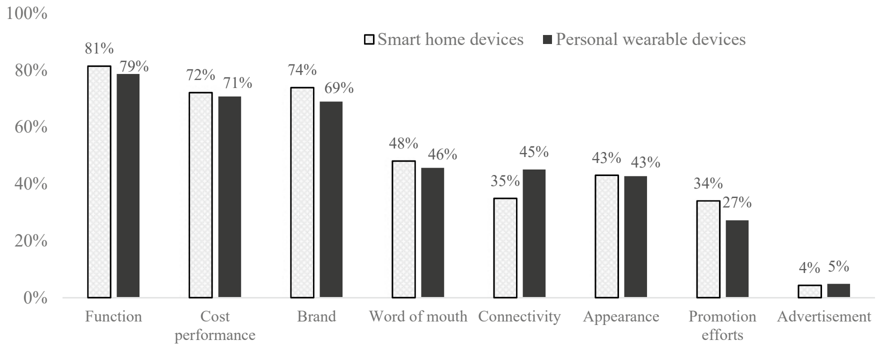

Fig. 10.13 Personal intelligent products who consider when purchasing in China. *Source* This figure was prepared by the authors using original data from iResearch (2021)

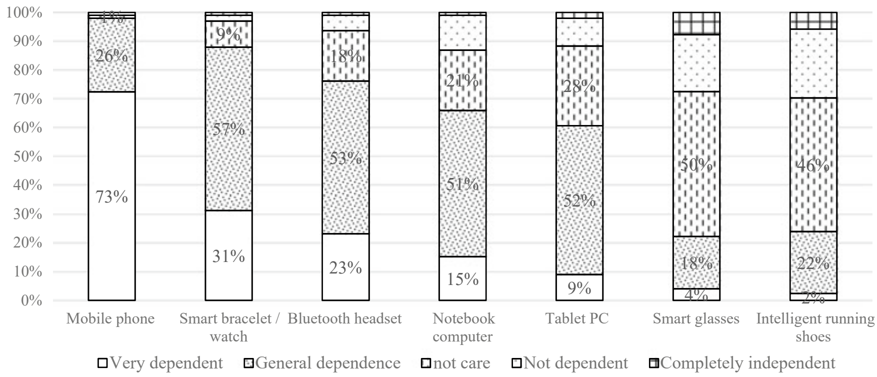

Fig. 10.14 Users' dependence on products in China. *Source* This figure was prepared by the authors using original data from iResearch (2021)

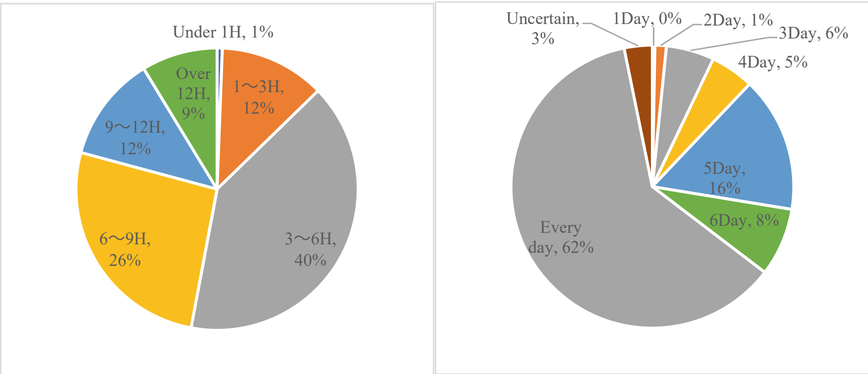

Fig. 10.15 Mobile phone daily usage in China. *Source* This figure was prepared by the authors using original data from iResearch (2021)

willing to use them and highly dependent on them. For many users, bracelets have become the most important personal intelligence product besides mobile phones (see Fig. 10.15).

In the family scene, the most important connection center of personal IoT is mobile phone. Due to the relatively fixed working hours, the leisure time of employees after work is concentrated in 2–5 h (81.3%). The majority of student users are college students, most of them stay at home in winter and summer vacations. Compared with professionals, family leisure time is longer. On the whole, when users are at home, mobile phones are the longest used devices, followed by computers and TVs. At home, users prefer to connect headphones and TV through mobile phones, followed by laptops and Bluetooth speakers, and their willingness to connect smart home products (such as smart lamps, smart humidifiers and sweeping robots) is relatively low (see Fig. 10.16).

In the work scene, the most important connection center of personal networking is PC. iResearch's user survey shows that 66.0% of employees work 8–9 h, and 62.4% of employees use computers for more than half of their working hours. Computers are important work tools for employees (iResearch 2021). For example, employees use computers configured by the company, which have strong personal attributes because they are used by individuals in actual work. Therefore, in work, the connection center of personal networking is mainly PC. Professionals mainly used computers to connect projection (34.9%), TV/large screen (32.2%) and other devices for content presentation, or computers to connect high-definition cameras (29.8%) for video conferencing (see Fig. 10.17).

Campus scene: connect around personal intelligent products; going out scene: among the student users who mostly conduct bus and subway card swiping research through personal intelligent products, their willingness to connect in classrooms and dormitories is mainly around the interconnection between personal devices, such as mobile phones and earphones (57.2%), laptops (41.7%) and smart bracelets/watches

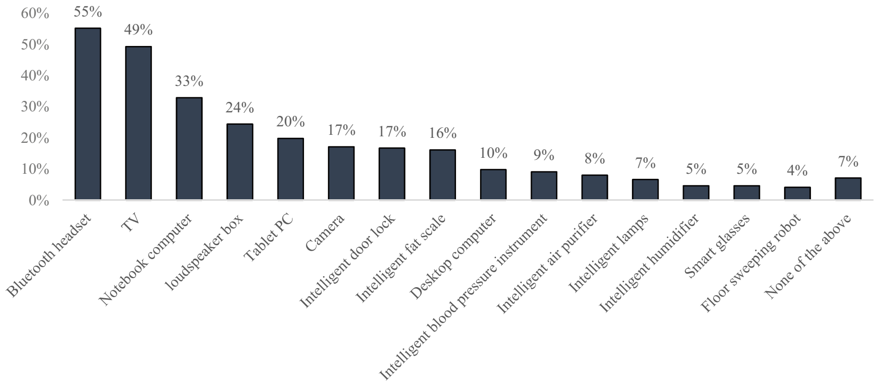

Fig. 10.16 Connection of mobile phone users—family scene in China. *Source* This figure was prepared by the authors using original data from iResearch (2021)

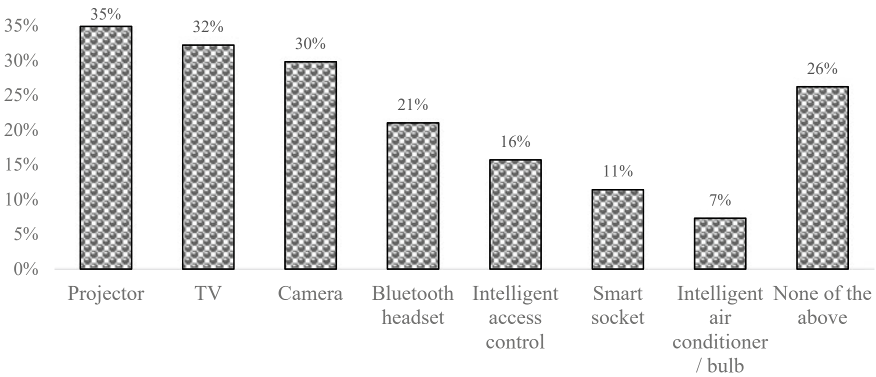

Fig. 10.17 Connection of mobile phone users—working scene in China. *Source* This figure was prepared by the authors using original data from iResearch (2021)

(31.0%), while the application of personal networking in campus scenes is relatively less (see Fig. 10.18).

When going out, there are relatively few devices that users can connect to, and their willingness to connect is mainly through mobile phones, smart wristbands/watches to swipe cards in public transportation (57.2%), subway (53.8%) or mobile phones to connect Bluetooth headsets to listen to music, watch dramas and play games on public transportation (see Fig. 10.19).

About 90% of the users surveyed by iResearch have exercise habits. Among the users with exercise habits, 52.2% choose to use smart bracelets/watches when they are exercising. On the one hand, users choose to use smart devices to improve the efficiency of sports (see Fig. 10.20).

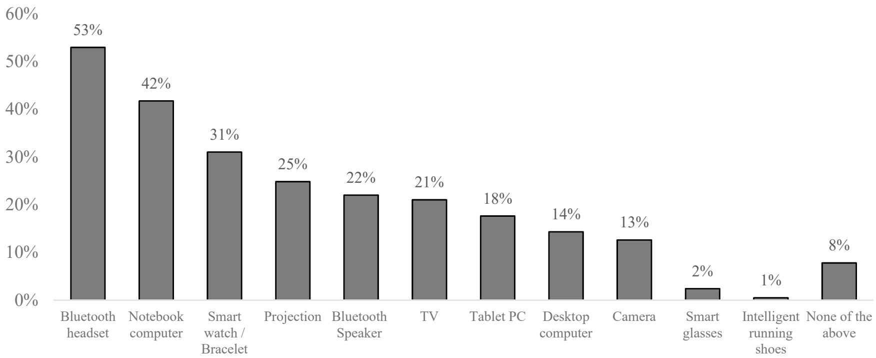

Fig. 10.18 College students' mobile phone connection—campus scene in China. *Source* This figure was prepared by the authors using original data from iResearch (2021)

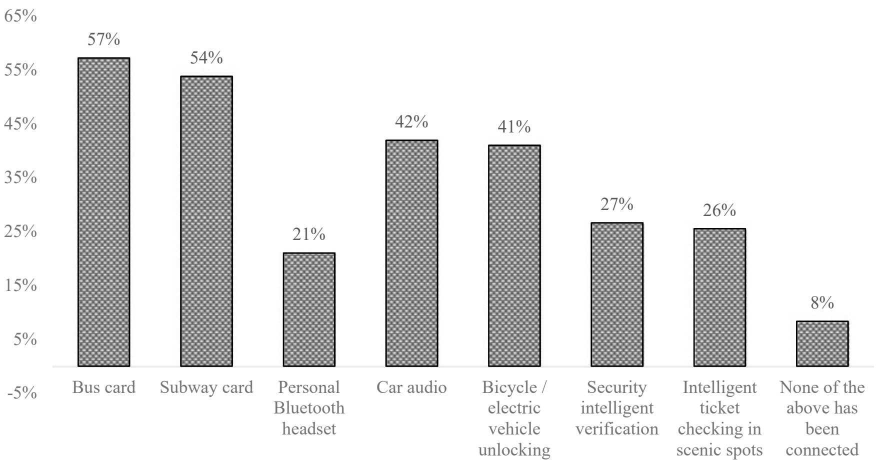

Fig. 10.19 Mobile phone, smart watch/bracelet connection—out scene in China. *Source* This figure was prepared by the authors using original data from iResearch (2021)

On the other hand, when using smart bracelets/watches, the most concerned function is sports index monitoring (78.6%) (iResearch 2021). Specifically, smart wristband/watch users are most concerned about step statistics and heart rate changes during exercise. It can be seen that the combination of smart Bracelet/watch products and sports scenes is relatively mature, and the user recognition is high. Intelligent running shoes and other products are still in the initial stage in terms of performance improvement and market education. iResearch (2021) believes that new intelligent sports products will bring more innovative sports experience to users in the future, with huge market potential.

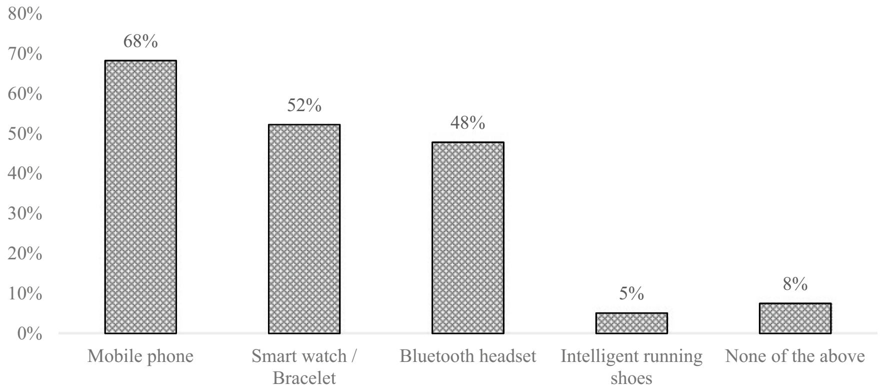

Fig. 10.20 Personal equipment for sports in China. *Source* This figure was prepared by the authors using original data from iResearch (2021)

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Chapter 11
Going Beyond the "Norm" in Technology and Innovation Apparatus in Emergency Situation: A Post-COVID-19 Society

Bismark Adu Gyamfi, Jinling Hua, and Rajib Shaw

Abstract Timely, efficiency, and accuracy are the many attributes widely associated with the performance, utilization and functionality of cutting-edge tools employed within the technology and innovation spectrum. The advancement of these tools has initiated a new norm of human life where artificial intelligence (AI), augmented and virtual reality (AR, VR), blockchain (BC), Internet of things (IoT) and other sophisticated autonomous mechanisms have become part of the society and are deployed in complex, challenging phenomena such as the management of COVID-19 pandemic. However, the urgency for workable management plans for the pandemic control suggests a new frontier to these technology and innovations such that some societal norms may be threatened with boundary complications. This chapter looks at some of these issues using literation reviews technique. It is evident that the urgency to control the pandemic is creating a new society that where safety supersede all aspects of lives and the need to pull all innovation into their fullest to control the pandemic is gradually blurring the line between pandemic control and issues of ethical, security and human rights concerns. Therefore, if measures are not put in place for definite scope and boundaries of the application of the technologies, a post-COVID-19 society could be marred with difficulties in countertrolling some aspects of the society.

Keywords New normal · COVID-19 pandemic · Destructive technologies · COVID-19 innovations · Future society

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J. Hua et al. (eds.), *Considerations for a Post-COVID-19 Technology and Innovation Ecosystem in China*, Disaster Risk Reduction,
https://doi.org/10.1007/978-981-16-6959-0_11

11.1 Introduction

The quest for collective initiatives, approaches and effort to combat social, economic, and environmental challenges have until December 2019, been a major concern for researchers, policy makers and other stakeholders. It witnessed the formulation of ambitious goals, policies, frameworks and implementation guidelines all aimed at streamlining development process efficiencies through smart and circular production methods. However, the outbreak of a novel SARS-CoV-2 virus in Wuhan in the Hubei Province, China, during the late 2019 opened a new frontier of consensus that centered on calculated efforts to avert potential health crises. Hence, initial approach restricted population movements within the city of Wuhan, isolated suspected patients, grounded transportations systems and provided intensive controlled-health-checks for some transient and permanents inhabitants (Tian et al. 2020). Despite these innovative countermeasures, the rate of infection kept increasing across China and other parts of the world, and for the purpose of communication and identification clarities of this new SARS-CoV-2 strain virus, the World Health Organization (WHO) on February 11, 2020, announced its name as coronavirus disease 2019, abbreviated as COVID-19 (WHO 2020b) and later declared it a Global Pandemic on March 11, 2020, after a series of infections and fatalities. Although transmission modes, and methods of many infectious diseases have been extensively studied over the years (Carmichael 2006; WHO 2003), some elements of the origin, the precise mode of transmissions and other characteristics of COVID-19 still remain mystery (MacIntyre 2020; BBC 2020). This has driven many to refer COVID-19 pandemic as the most lethal virus-related health emergency, when compared with other pandemic influenza viruses (Petersen et al. 2020). Hence, latest statistics suggest a total of more than 120 million infection cases and a staggering 2.8 million deaths (Hopkins 2021).

The speed of infections and the rate of related deaths have led to further stringent countermeasures across the world. These include restrictions on population movement, changes in working conditions and inter-personal relations, community lockdowns and others. These have significantly affected many economies and caused severe uncertainties embroiled in fear, rage and frustrations. These uncertainties have propelled decision-making characteristics in this era to be swift, calculated, timely, accurate and above all, flexible to meet current and future challenges from COVID-19. Yet, the effectiveness of this enhanced process is characterized by a considerable utilization of technologies and other innovations. That is, the uncertainties for socioeconomic recoveries paths, management of the pandemic, research into vaccine development, as well as the overall future development trajectories require scenarios which are developed on the premise of sophisticated methodologies that are timely, efficient, accurate, cost effective, robust, easy to use, scalable and capable of meeting both the current and post-COVID-19 societies. As such, artificial intelligence (AI), fifth generation (5G) wireless network, Internet of things (IoT), big data, augmented and virtual realities (AR, VR), blockchain (BC) and other innovations such as robotics and drone technology have become handy to meeting these specifications. The above technologies are usually identified under a broad term of disruptive technologies and innovations (DT&I) (Sivell et al. 2008). They already possess the reputations for being deployed in complex and challenging phenomena initially deemed impossible. Thus, their relevancy has become exceedingly revered in all scenarios targeting emergency management, public health and economic development nexus in the current and post-COVID-19 future.

It must be emphasized however that the design, development, deployment and application of such technologies have over the years been engaged in discussions based on principles aligned along security, operational ethics and an overall human rights concern. That is; many hold varied opinions on the use of such technologies because of some associated infringements, accountability and lack of development clarities. Therefore, developmental fields utilizing the technologies have defined the scope, framework or regulating bodies to manage and address some of these issues, through guided principles, laws, policies and regulations (Australian Human Rights Commission 2018). For instance, in the health sector, one guiding principle for robotic technology is that "*it must remain in the service of patients and not become a means to exploit or control them without their knowledge*" (Ars 2016). Again, one principle of AI application is that "*there should be transparency and responsible disclosure around AI systems to ensure that people understand AI-based outcomes and can challenge them*" (OECD 2019). All these have ensured consistencies in the technologies which can now be found in various sectors and communities. Nevertheless, the urgency for COVID-19 vaccine, and the uncertainties in future development paths, point to some scenarios that suggest that, the working scopes of DT&I must "deliberately" be infringed to be able to manage the pandemic. Therefore, how could a lax in the principles affect or shape development and application of DT&I in a future without a pandemic. The following sections discuss these further.

11.2 Defining the "Norm" in Destructive Technologies Application

The Merriam-Webster dictionary defines norm as "*a set standard of development or achievement usually derived from the average or median achievement of a large group,*" and for decades, many societies have thrived on establishing various norms to shape people's behavior, attitudes and approach toward almost everything (Michaeli and Spiro 2015). A general acceptance and utilizations of norms have over the years penetrated many disciplines as such norm and its origins in law, sociology, economics, mathematics etc. are some areas extensively examined by Mcadams (1997). Hence, studies now identify several areas of its application and categorize them to include legal, social, technical, economic and bureaucratic or institutional norms (Hydén and Svensson 2008).The transitions that occur between norms and the blurry lines that exist between them and other concepts such as culture and values have necessitated many scholars to identity some traits that distinguish them. According to (O'Neill

2017), the characteristics of a norm manifest in different folds but can generally be identified through certain categorization such that norms may have some level of "*formal features,*" have a "*content,*" express a "*domain or context*" and have a solid grounding mechanism the provides justifications for people to defend it as well as give indications of how people should respond to its "*violation or compliance.*" These environments that shape norms are what (Hydén and Svensson 2008) also describe further as "*cognitive context.*"

However, our world in recent times has been overwhelmed with improved connectivity between production of goods and services, management decisions and other aspects of lives that indicate that the categories of norms complement each other in the context in which it is applied. For instance, in a production of goods or services, technical norms may be required to guide specifications and standards for the commodity. But there are other stakeholders in the value chain which apply a number of other norms. This same scenario applies to the norms in DT&I.

Destructive technologies and innovations are by their definitions, transform and revolutionize the methods and processes of undertaking tasks traditionally deemed complex or impossible. The characteristics of these technologies and innovations are said to be (i) rapidly advancing or experiencing breakthroughs, (ii) have a broader scope of impact, (iii) can significantly affect economies and (iv) have the potential to dramatically change status quos. Several examples as highlighted earlier show the broad range of secretum in their applications (Manyika et al. 2013). This indicates that what is deemed a norm in DT&I may also involve a set of standard development that has a content applied within a domain and possesses abilities to people to respond in events of violations or compliance.

11.3 The Ecosystem of Norms in Destructive Technologies and Innovations

Destructive technologies and innovations have tremendously penetrated all aspects of development including the economy, social, medical, security and other environments. While their applications have enhanced productivity and increased efficiencies, concerns have always been raised about their development and scope of use. For many, it is on the basis of security and ethical concerns, as well as human rights issues. Furthermore, some aspects of their use have been also been met fierce opposition because, such technologies create or enhance biases, diminishes privacies, causes digital addictions, disinformation and to some extent inequalities and marginalization (Brundage et al. 2020; University of California—Berkeley 2019). Therefore, moral/ethical and human right campaigners have over the years fronted crusades against technology applications that breach the concerns. Hence, a number of stakeholders including governments, companies, researchers, etc. have formulated or are formulating principles and guidelines to regulate various contextual operations of the technologies. For instance, the European Union's (EU) white paper on AI (*artificial* *intelligence: a European approach to excellence and trust*), its report on *safety and liability implications of AI*, *the Internet of things and robotics*), and additional report on *ethical guidelines for trustworthy AI*, all set out to acknowledge some of these concerns and makes recommendations on guidelines and principles that are based on existing sectors policies/laws to curtain or minimized them (European Commission 2020).

Beside initiatives from the EU, the United Nations, Nordic-Baltic cooperation and regional blocs have all made the efforts to set out principles and reforms to guide development and use of the technology. Furthermore, more than thirty-five countries also have various degree of initiatives which in one way or the other, found common ground for the deployment of the technology in various sectors (Future of Life Institute 2019). These notwithstanding, private and public entities involved in the development of the technology have equally articulated and incorporated ethical guidance and principles to guide responsible technology development (Brundage et al. 2020). The above case is no different from the eight Chinese AI governance principles released in 2019, which sought to promote harmony and friendliness, ensure fairness and justice, enhance inclusivity and sharing, pay respect and attention to privacy, promote shared responsivity, open consideration and promote agile government of the system (MoST 2019).

Upon these efforts, technologies have become part of existing societal norms because they have been applied in various areas in the societal setup. Table 11.1 gives examples of the kind of norms many societies have created through DT&I applications.

11.4 The New Norm in COVID-19 Era with Destructive Technology Application

One evidence of COVID-19 transmission mode is through contact with an infected person. Therefore, a new normal that has been widely accepted by many is the "keep distance" or "social distancing" with an accepted 1–2 m interval, as well as personal hygiene ethics. As precautionary measure, companies, workers and many organizations switched to remote working while other essential workers developed various strategies to reduce their risk of infections. This move has particularly enhanced the digital environment and accelerated the application, development and advancement of destructive technologies. These are particularly advanced in China and much of these acceleration and changes can be found in all the previous chapters of this book. The comprehension of this fact is again reiterated by the boast from changes in working environment such that a survey conducted by Slack (an online business communication platform) in 2020 revealed that after the declaration of COVID-19 as pandemic, more than 16 million knowledge workers in the USA switched to remote or teleworking (Slack 2020). Beside this new phenomenon of teleworking, noncontact (remote) health prognosis, robotic delivery systems, remote studies and

Table 11.1 DT&I applications in societies

Sector	Type	Example
Transportation	Smart transportation: the application of variety of destructive technology and innovations to collect, evaluate, monitor transportation systems in communities to promote safety and efficiency	Masdar city mobility: this model city applies technology and other innovations to improve transportation system. E.g., a specially designed Eco Bus that is environmentally sustainable, autonomous vehicles relying IoT to provide better managed, safer, efficient and cost-effective transportation in the city
Health	IoT health care service: healthcare activities conducted on the backdrop of internet connected sensors, software and other technologies for patients, physicians, health facilities and other stakeholders	Telecare service that relies on IoT devices such as *Confirm Rx*™ *ICM* to monitor heart rates/beats through smart devices via the internet
Energy	Smart Grid: a revolutionary in the power sector relying on sensors to gather and transmit efficient and effective electricity	The Puducherry smart grid: distribution and utilization of smart meter system for households in the city to monitor electricity currents, voltages and others, aimed at ensuring efficient power supply and utilization
Building and housing	Building information modeling (BIM): the technology of generating near real world representation of physical designs and their functions	The Baku national stadium in Azerbaijan is a typical example of the application of BIM technology
Water	Smart water management: A mechanism for the utilization of information and communication technology to process real time data for the management of water systems	Water leaks detection sensors used by many water supply organizations
Manufacturing	3D printing: the creation of 3 dimensional objects from computer aided designs	These include 3D spare parts used in vehicles, computers etc.

Source Authors

many others are part of the daily life now, with many regions declaring partial or total community lockdowns. Despite the evidence of the effectiveness of lockdowns and stringent restrictions to prevention infection rates (Lengel et al. 2019), others have also suggest otherwise (Kepp and Bjørnskov 2021). With negative economic growth in many countries, the need arises to find balanced alternatives to controlling the spread of the virus, whiles ensuring economic recovery. The calls to reopen economies and societies from the stringent restrictions mean, allowing flow of people and the movement of goods and services. This has motivated governments to adopt new surveillance and monitoring system carved around health statuses of the population. These are mainly administered through the issuance of digital health certificates or a show of health status, and contact tracing mechanisms. They are aimed at knowing COVID-19 status of a person and whom the person may have been in contact with (in case infections are detected). The following explains the functionally and approach of the systems.

11.4.1 Issuance of Health Certificates

Health certificate and other affiliated acronyms refer to "*documents—in paper or digital format—that certify a person is unlikely to either catch or spread a disease*" (Thomson Reuters Foundation 2021). Therefore, taking a cue from some existing health certificates like a proof yellow fever vaccination when traveling to or from highly exposed countries, others have called for the issuance of similar proof for COVID-19 status. Some have labeled it health passport, digital health certificate, health pass, COVID-19 immune passport and many others. Nevertheless, each type contains digital attribute which relies on the internet and in particular, smart device application. Within the European Union, this system is called the Digital Green Certificate. It gives proof of a person's vaccination status against COVID-19, negative test results or records showing a recovered status (if ever contracted COVID-19) (European Commission 2021). Although this is still in its infancy, other countries have however, implemented their version of such approach. Israel for instance, released its vaccine passport, also called "Green Pass" on February 2021 so that people who have been vaccinated against COVID-19 can get a "Green Pass" once they download the application onto their smartphones or tablets.

In similar instances, China on March 9, 2021 launched its digital health certificate; the "International Travel Health Certificate" against COVID-19 to ease the flow of people across jurisdictions within the country. Available via WeChat and other smartphone application platforms, users sign up with their passport numbers and verifications are undertaken through facial recognitions applications. An encrypted individual QR code serves as the certificate which contains the holder's information on nucleic acid test and serum antibody results, vaccine inoculation and other information. This health certificate is a follow-up to the already running QR health code system that is able to track user's locations and assigns color coding from green—good health (allow to travel after temperature check), yellow—(14 days home quarantine) and red—health risk (to be quarantine at the hospital immediately) (CGTN 2021). Other countries like, Bahrain and many others have issued similar passports or certificates. On the other hand, there are several smartphones' applications all sharing similar traits of giving indication of a person health status which are controlled or backed by governments. These include; the UCC are app of Colombia, BruHealth from Brunei, TracVirus of Malaysia, Pass Track of Pakistan, US COVID Check, Wabash COVID in the USA, COVID19-DXB Smart from UAE, An toàn COVID-19 from Vietnam, reopen from South Africa and many others. Further information of this application in China can be found in Chaps. 6 and 8 of this book which talk about big data and artificial intelligent in China.

Beside the applications backing governments efforts, private organizations are also looking into developing such methods to ease working conditions. Example include the IBM Digital Health Pass aimed at helping the tourism and traveling, sports and entertainment, employers and others sectors to ease working restriction of their members, customers and employee. According to statistics, there were over sixty-five health certificate applications as January 2021 with combined downloads exceeding nineteen million (TOP10VPN 2021).

11.4.2 Contact Tracing Mechanisms

Contact tracing mechanisms are one approach highlighted by to the WHO as a key strategy to preventing chain of transmissions of COVID-19 virus (WHO 2020a). The mechanism works in such a way that, once a case is detected, the infected person is immediately isolated, then followed with a rigorous attempt to find anyone who may have come in contact with the suspected case. This involves finding out where the infected person may have visited, while isolating whoever may have come in contact for a period of fourteen days. After showing no symptoms, negatively tested contacts are allowed to leave their quarantine confinements but with certain other precautionary measures. Conversely, a positive test person is made to undergo treatment and other protocols. This process may seem tiring and the sheer fact that it involves massive resources creates logistical challenges. The most applicable approach is the use of smart devises and mobile phone applications. Again, this approach has highly been implemented by many governments across the globe in partnership with other entities. Figure 11.1 shows a sampling of fifty of those smartphone applications identified through our literature and on Google Appstor and the number of downloads as at March 29, 2021. It also gives a glimpse of the national organizations in charge of the application.

Figure 11.1 shows total downloads of more than 180 million contact tracing apps available in many countries. The Aarogya Setu app of India has the highest with more than 100 million downloads, whereas the lowest among the sample has a total of more than 100,000 downloads; equivalent to the entire population of Waterloo, Ontario-Canada and Flint in Michigan, USA. Other national government affiliated applications also include TraceTogether app of Singapore, CovidSafe of Australia, Stop Corona from Austria, GH Covid-19 Tracker App of Ghana, VirusRadar of Hungary and many others.

Although there seem to be many people using these applications, not much can be said about the achievement of their intended purpose. Challenges have ranged from lack of coordination among stakeholders, technical malfunctioning, implementations challenge among others.

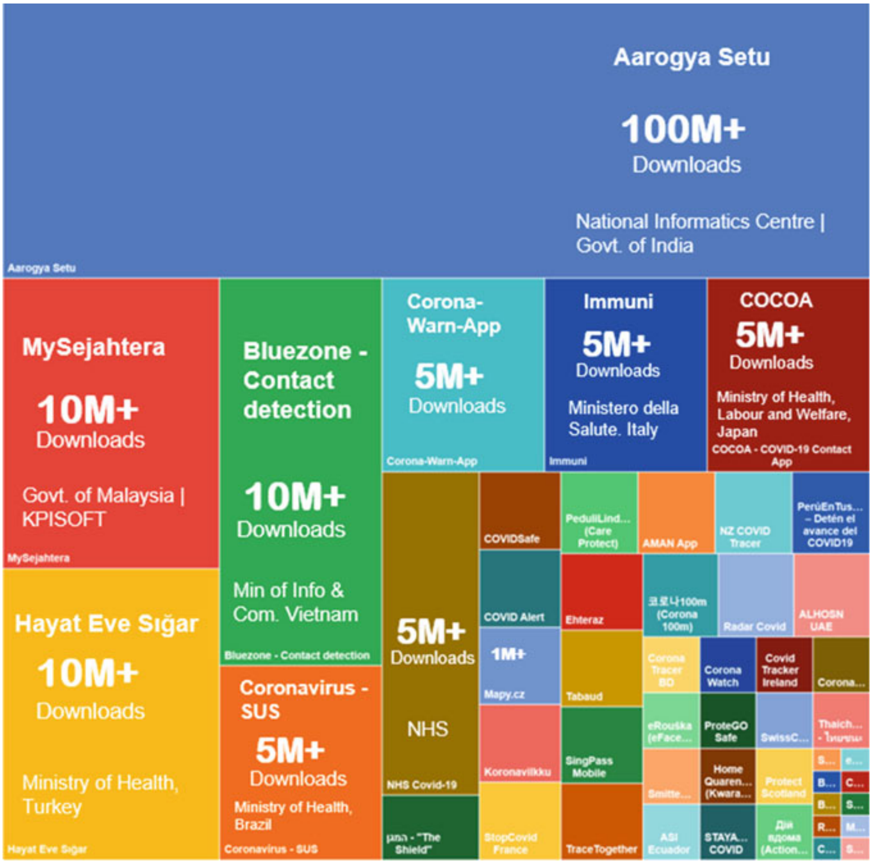

Fig. 11.1 Contact tracing apps and downloads. *Source* Authors

This notwithstanding, the use of this technology has chalked many successes. For instance, data from the Department of Health and Social Care, UK, suggests that, over 1.8 million users of its NHS COVID-19 contact tracing app across Wales and England received notifications of isolations following a close contact with suspected positively infected persons, while further analysis suggests the prevention of over 600,000 cases (NHS 2021). Similar success cases can also be found in South Korea, Singapore, and many others.

11.5 Pandemic Setting Precedence for Human Rights, Security and Operation Ethics Complications

As discussed in earlier sections, the new norm under the COVID-19 pandemic is the issue social distancing. This has put strains on certain tasks and occupations that initially required personal contacts. Therefore, drones (*see* Chap. 3 *for examples*), robots (*see* Chap. 7 *for examples*) and other automated technologies particularly; smart device applications (*see previous chapters for examples*) are highly embraced in this era. However, this phenomenon seems to be blurring or creating a thin line between privacy, safety and what is deemed acceptable. Looking back again at the realization of a potential need and utilization of various technologies to managing and controlling the spread of the virus, civil society organizations, and other parties in the early days, cautioned and offered some recommendations as to need to place data security and rights of people as a center piece of any intended use of technology in during the pandemic. Figure 11.2 chronicles some of these initiatives as released by some civil society organizations initiated from the early times around March 2020 throughout to December 2020.

Nevertheless, the pandemic period has witnessed series of misunderstanding and confusion as to whether the priority should be on safety of the people or maintaining the rights of people. To many, keeping the people safe transcends all other issues, while others advocate for a balance between the two. The challenge then arises where to draw the boundary between using technologies for the sake of securing the safety of the people and infringing on the rights. Survey from more than thirty-one European countries, conducted by DLA Piper (a global law firm) indicates that, since January 2020 to January 2021, a total of USD193.4 m fines were imposed on firms and other organizations for various degrees of data breaches, representing an increase of 39%, compared to previous periods (DLA Piper 2020). The findings from this report coincide with other studies that suggests that about 82% of smartphone applications for health certificates have privacy policy issues, while several COVI-19 tracking application simply do not have any privacy policies (TOP10VPN 2021). However, the response from the public may indicate positive reactions aligned toward safety than the concern of data or information safeguard. Table 11.2 depicts some

Fig. 11.2 Data protection caution by organization. *Source* Authors

Table 11.2 Relationship between right concerns and population feedback

Approach	Example	Content of data	Protest/concerns	Management response	Feedback
Smart device application	Aarogya setu app	Name; phone number; age; sex; profession; and countries visited in the last 30 days (Source: Aarogya Setu developer policy. Privacy policy (swaraksha.gov.in))	Protest in a letter of concerns from civil society organizations to the Prime Minister of India Office, raises issues of ethics, lack of consent, lack of data minimization, lack of transparency, unauthorized data sharing and risk of external data transfers (Source: thewire.in)	Government released a statement that, "this is by design and is clearly detailed in the privacy policy. Reproducing the same for everyone's benefit. We fetch a user's location and store on the server in a secure encrypted, anonymized manner" (Source: https://t.co/JS9ow82Hom" /Twitter)	App rating 4.3 out of 5
	My Sejahtera app	User registration name, address, identity card number/passport number, phone number, date of birth, email address, gender	Written report to the Minster of Health of Malaysia includes lack of documentations of the app, lack of transparency, lack of privacy against government/mon government intrusion, legality with regards to Personal Data Protection Act 2010 of Malaysia (Source: Sebastian, 2021)	"Protection of data on the Ministry of Health's (MOH) Covid-19 management and contact tracing mobile app follows provisions under the Personal Data Protection Act (PDPA) 2010 and it's confidential under the Medical Act 1971" Deputy Health Minister Dr Noor Azmi Ghazali (source: galencentre.org)	App Rating 4.4 Out of 5

(continued)

Table 11.2 (continued)

Approach	Example	Content of data	Protest/concerns	Management response	Feedback
AI-powered management practices	Key logger software for employees	Installed on company's equipment either with or without the consent of an employee to records during teleworking	Concerns for limited legal protection on the use of keyloggers on devices by organization as chronicled in several legal battles even before the pandemic (E.g. Rene v. GF Fishers, Inc.)	Employers in the United States are allowed to use keyloggers on their employees in	
	Hubstaff time tracker	These applications show the status of an employee as to when last seen online, check-ins	The concern from the European Trade unions is that, "there are current trends of surveillance and datafication could mean that COVID-19 data of today is at risk of being used for much more punitive and negative purposes by employers …." (ETUC 2020)	"We use automatic data collection and analytics technologies to collect aggregate and user-specific information about your equipment, domain name, patterns of use, communication data and the resources that you access and use on the Services, including your IP address, browsing and navigation patterns…". (Source: Hubstaff Privacy Policy)	Active user 70 K+

(continued)

Table 11.2 (continued)

Approach	Example	Content of data	Protest/concerns	Management response	Feedback
Tracking Gadgets	Care predict device	AI to learn and follow daily habits such as eating, walking, location pattern, eating duration	Although all claim some anonymity to users' data storage, studies suggest the difficulty to anonymize data (Ohm 2010)	World's most trusted digital solution to mitigate the spread of COVID-19 This is how leading brands are protecting employees and operations	Consumer technology association innovation award 2021
	Safezone device	Tracking locations and time			In use by more than 300 companies

Source Authors

varied opinions on the use of some technologies during the pandemic. In as much as the content of data taken from users include personal information, the feedback offers an insight to some level of acceptance by the level of their ratings to the applications, number of people using them and the awards schemes to honor such some innovations, despite some concerns or protests raised.

11.6 Lessons for Post-COVID-19 Future

The prolonged emergency of the COVID-19 pandemic can be said to be enhancing and accelerating technology development and applications. For instance, projection for drone delivery market revealed a drastic acceleration in market value due to the high patronage during the COVID-19 pandemic (Fortune Business Insights™ 2020). Furthermore, the pandemic is also creating an environment where governments, entities and people work together to ensure common goals (*see* Chap. 6 Sect. 1.2 *for some examples*). Many of the apps and gadgets developed to prevent the spread off the virus have had sound backing and collaborations from many stakeholders; inclusion governments (*see examples previous chapters*). In as much as there seem to be harmony in the fight against the pandemic, one issue may be important to point out. That is, where do we draw the line between ensuring the safety of the society and potentially setting precedence for control challenges. As discussed in this chapter, what is elements for categorizing norms keep may be difficult when applied in complex context but with certain stipulated guidelines and principles, they are able to keep in check. COVID-19 pandemic has therefore shown how critical situations can also form justifications for certain behaviors to be potentially accepted as normal or relevant (*see for example sharing of person and other data across services providers, governments and other in Sect. 4.2 of* Chap. 8). Now, many people seem satisfied with the collection of private data, for the purposes of tracking and informing them to refrain from certain places. Again, it is COVID-19 pandemic has provided the willingness for people to accept close contact with autonomous devices, give permissions for AI and other algorithms to monitor, predict and monitoring our movements through various devices such drones, robots, CCTV cameras and smartphone applications. Typical cases can be found in the inclusive discussion in Chaps. 7, 8 and 10 of this book.

So, it sets to ask the question; when will surveillance, data collection stop and what could be of this process after the pandemic? As already examined by Datta (2020), Radhakrishnan (2020), COVI-19 has enabled governments to intrude in the home of people through constant monitoring now referred to as self(ie)-governance. If these issues are not resolved amicably before the pandemic ends, a post-COVID-19 may resume with the following;

- Some levels of confusion and distrust between stakeholders: As outlined by some right campaigners such as the Electronic Frontier Foundation, there would not be a consensus if governments around the world continue to gather surveillance and personal data and that new laws should be promulgated against the backdrop of these data gathering as a result of COVID-19 excuse (Electronic Frontier Foundation 2020).

- Potential loss of control of electronic information acquisition and accessibility: for this moment, it seems right for many digital companies and entities to collected data either on the premise of training some technologies for better situation analysis or predictions for decision making on pandemic progression and development paths which are in dire need by governments. These data collection as argue by many have sometimes been marred by confusion and disagreements between some people/entities and the data handlers on the actual use of the data, its collection methodologies, storage and security mechanisms, and timelines to the end of the process. However, due to the urgency to control the pandemic and the need for rapid vaccine development, governments from Israel, Sangare, South Korea and many others who are have had concerns about private data acquisitions through contact tracing mobile applications. However, Apple Company and FBI encryption disputes over the years should serve as a level should boundaries and data acquisition methods overlooked. Apple has over the years refused to decrypt the data from the phones of convicted felons, citing its policy as a defense (McLaughlin 2016). This protected polities or ethics could also crop up in the future to deny, enhance or alter data use between governments and technologies companies who are the fronting personal data collection on behalf of governments.
- Community vigilantism through disinformation and stigmatization: recent study shows how fake news have reported in the lynching of people especially in India, while people with certain ailments and certain conditions face constant stigmatizations. A leak in the data gathering of the new technologies in the pandemic can aggravate these situations should personal information about such group of people leak or targeted

It is hoped that these concerns raised may be considered to create a post-COVID-19 society that conforms to majority accepted new norms which are devoid of marginalization and disunity because we forgot to uphold the implementation of existing guidelines and principles.

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