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DIGITAL HEALTH

Tackling COVID-19 Pandemic through Integrating Digital Technology and Public Health: Linking Experiences in China to the World

The ROCKEFELLER FOUNDATION

ACCESS health international

CONTENT

Executive Summary

The Covid-19 pandemic has turned into a global public health crisis, evolving at an unparalleled speed and scale, debilitating economies and health systems across the globe. It became imperative for governments and organizations across the globe to take immediate actions to protect their people.

China was the first country impacted by the novel virus, facing rising infection rates as it urgently worked to contain and control the spread. While fear and panic permeated the country, China's government, from central to local leaderships, rapidly mapped out their outbreak response strategies and coordinated their epidemic control plans. Technology, especially digital technology, was an instrumental part of their strategy implementation. Vast technology infrastructure quickly took action, deploying tools for information access and dissemination, population tracking and contact tracing, access to daily necessities, and many more.

After close to three months of containment measures, rapid mobilization of medical resources, and stringent quarantine measures, China's Covid-19 outbreak somewhat stabilized. Today, China is the first market in the world to recommence business following the Covid-19 outbreak. The speed with which China has dampened the impact of Covid-19, from the identification of the first case, to outbreak, to containment, to recovery and resumption of a post-Covid-19 living, is remarkable. This progress, albeit via drastic measures, is unprecedented. The

roles of public and private sectors and digital technologies played throughout this journey were critical in the country's success. Covid-19 outbreak. The speed with which China has dampened the impact of Covid-19, from the identification of the first case, to outbreak, to containment, to recovery and resumption of a post-Covid-19 living, is remarkable. This progress, albeit via drastic measures, is unprecedented. The roles of public and private sectors and digital technologies played throughout this journey were critical in the country's success.

As the Covid-19 pandemic continues to devastate many countries across the world, documenting and sharing experiences of effective preventative actions and containment strategies for the outbreak have become crucial in fighting against the global outbreak. As such, the report wishes to humbly offer governments and business leaders around the world with some observations and insights from China's experiences in tackling Covid-19, to further enable effective response to fight the virus.

Through a combination of desktop research and key informant interviews used in this study, the report documents and analyses the impact and implications of government actions and digital technology solutions. The report offers an in-depth understanding of the actions and strategies implemented by the government, the roles digital technology played, the technologies used, and the impact made across six outbreak response categories. The categories are: fast

Executive Summary

response, epidemiological studies, diagnosis and treatment, supportive activities, long term management and comprehensive disease control system. In total, the report delves into 12 digital technology case studies and provides a comprehensive view of how each case enabled and empowered the public and the private sectors, the health system, the general public in helping to flatten the epi curve, based on their respective categories. The roles and impact of the digital technology interventions are summarized into the following five aspects:

1) **Improvement of quality and efficiency in governmental decision-making** in response to public health emergencies by assisting the government in managing epidemic prevention and control, such as integrating data, analyzing outbreak progression, identifying and tracking high-risk groups.

2) **Accelerated the research of gene sequencing and protein structure of Covid-19**, the prediction of the scale of transmission and epidemic trends, improved understanding of the virus , enhanced the diagnosis and treatment capabilities of the medical system, and assisted pharmaceutical companies to accelerate the development of drugs and vaccines.

3) **Realized telemedicine and remote health management**, minimizing cross-infection among patients, effectively improved the diagnosis and

treatment capacity and efficiency of frontline healthcare providers and alleviated the shortage of medical services and resources.

4) **Established a platform for efficient communication between the government and the general public**, establishing reliable platforms for medical supplies and donations, and provided supp-ort for the more vulnerable and elderly population groups.

5) **A powerful management tool in supporting work and production resumption, and community management**, becoming an indispensable in helping the government to reopen the economy, accelerate social and individual recovery.

The impactful applications of digital technology in the Covid-19 pandemic successfully helped mitigate and overcome many hardships. Through many years of expertise accumulation and technology developments and reforms, the solutions are able to effectively help fight against the pandemic. The report documents the key success factors across three levels: 1) government, 2) society, and 3) enterprise (See below Table).

The pandemic accelerated digital innovation in emergency response management. From outbreak to containment and to recovery, digital technology solutions improved effectiveness and efficiency in information

Executive Summary

dissemination, population tracing, health services, resources mobilization, daily living and business continuity, community management, and many more. However, in order for all of the aforementioned aspects to be supported via digital technology, few conditions are critical in ensuring the solutions can be applied. The report describes four key necessary aspects:

1) **User adoption:** The extent of the application of digital technology in pandemic prevention and control is dependent on the level of public awareness, acknowledgment, and cooperation.

2) **Technological foundation:** The technological foundation is essential to promote digital response. Over the past two decades, China has experienced large-scale digital transformation. The accumulation and usage of these technologies prompted the rapid participation of digital technology in the fight against the pandemic.

3) **Data foundation:** The informatization of data is the most basic element for the application of digital technology. The ability to aggregate and analyze the various sources of data, while ensuring data security and privacy provided a foundational environment for the epidemic response using digital technology.

4) **Governmental support:** The Covid-19 crisis has been a battle that requires unity among all. It requires leadership from the government levels to guide and control the pandemic responses.

Although there are still challenges ahead, as the Covid-19 battle is far from being won, digital technology has become a powerful and indispensable tool for the government, the health system, businesses, and general public. The solutions continue to help different stakeholders to stay connected and informed, pushing forward towards recovery.

Finally, the report is not meant to be a recipe for success. Rather, a reference and an inspiration for the regions in need. Understanding the requirements and benefits these digital technology interventions brought, assessing the feasibility and conditions for replicability would be informative to countries in different stages of the pandemic. As Covid-19 pandemic transmits across borders, impacting the most vulnerable, we hope this report can inspire more collaborations across market, geographic, and cultural boundaries.

Executive Summary

Levels		Key Success Factors
Government	Policy Guidance	At the onset of the outbreak, National Health Commission clarified the important role of information system in epidemic prevention and control. In President Xi Jinping's speech on February 14, 2020, he reinforced the importance for local authorities and departments to apply digital technology in strengthening the epidemic responses. This reinforcement laid a solid foundation for promoting the in-depth application of digital technology in epidemic prevention and control.
	Ground Support	During the outbreak, the Chinese government continued to proceed with various prevention and control measures to ensure the smooth implementation of the digital technology. For example, the National Health Security Administration and the National Health Commission issued relevant guidelines at the end of February, announcing that the "Internet Plus" follow-up services for common and chronic diseases were to be included in the scope of medical insurance payment.
Social	Foundation of Information System Development	In recent years, many cities in China are exploring the establishment of medical information systems. In the process of participating in the fight against Covid-19, many medical technology companies, such as We Doctor, United Imaging, rebuilt and connected original information systems, and effectively ensured the rapid successful implementation of the digital solutions.
	User Trust	Since China entered the Internet era at the beginning of the 21st century, digital technology has been used in many aspects of society, such as social media, ecommerce, and mobile payment. This development become the foundation for digital technology to quickly obtain user participation and cooperation during the fight against Covid-19.
Enterprise	Quick Decision-Making and Input	Faced with the evolving outbreak situation, many Chinese technology companies have reacted quickly. Enterprise leaders immediately mobilized their employees to fight against the epidemic, and many companies donated many resources such as hardware equipment and software technologies, unconditionally to facilitate the rapid spread and support the overwhelmed health system.
	Technology Accumulation	Technology accumulation is an important success factor for many technology companies when providing digital solutions for combating Covid-19. In the event of a public health emergency, in order to ensure that various types of digital technology can be applied rapidly and effectively to support prevention and control measures, the company's own accumulation of technology and application experience become critical.

Table. Key success factors at various levels

Acknowledgements

BACKGROUND

Background

1.1

Introduction

The Covid-19 outbreak started in Wuhan, China at the end of 2019. It became an international public health emergency in January 2020, and within two months, the outbreak was declared a pandemic by the World Health Organization (WHO). As of July 1, 2020, Covid-19 has affected 213 countries, infecting over 10.3 million people, and taking away more than 506,000 lives . As one of the first countries severely impacted by Covid-19, China has taken urgent and unprecedented measures in an effort to contain and control the scale of the outbreak since the beginning of the year.

Through a combination of multi-level governmental efforts and heavy leverage of technological solutions, China has demonstrably controlled a large-scale outbreak. The number of new cases in the country has dropped significantly since the beginning of March , which gave hope and lessons for the world to overcome the pandemic. This has been done using a variety of solutions: political, social, medical, and technological, especially the **digital health solutions. During China's** epidemic prevention and control process, both the central and local government leadership have implemented an extensive use of digital technology to empower the disease control measures and to fulfill the unmet needs of patients, doctors, and the public.

spread of Covid-19 and its resonating impact. However, systematic studies on the roles and benefits of digital solutions in pandemic surveillance and containment is currently very limited. As the Covid-19 outbreak continues to evolve internationally, learning and sharing experiences of countries that have effectively contained the spread of the **outbreak have become China's epidemic** prevention and control process, both the central and local government leadership have implemented an extensive use of digital technology to empower the disease control measures and to fulfill the unmet needs of patients, doctors, and the public.

Many technology providers have launched new services and products to mitigate the spread of Covid-19 and its resonating impact. However, systematic studies on the roles and benefits of digital solutions in pandemic surveillance and containment is currently very limited. As the Covid-19 outbreak continues to evolve internationally, learning and sharing experiences of countries that have effectively contained the spread of the outbreak have become crucial in fighting against the global pandemic. This report aims to provide an in-depth understanding of the roles digital technology played and the different technologies used throughout the epidemic. Specific objectives of the report include:

- To document the actions made by makers in response to the outbreak, and the implications of each strategic decision;

Background

- To design an adapted integrated disease surveillance and response framework, consists of core elements such as fast response, epidemiological studies, diagnosis and treatment, supportive activities, and long-term management;

- To map out the key solution providers, and survey them on their current and future programs and solutions in response to the Covid-19. Collect and analyze the applications, impact and prospects of digital technologies in times of epidemic crisis;

- To analyze the remaining opportunities, key barriers, and policy gaps for the digital solutions, as well as and the necessary conditions to replicate these solutions in any location

- To generate policy recommendations on how digital technologies could augment public health in China, as well as recommendations to the industry stakeholders.

1.2

Framework

The Severe Acute Respiratory Syndrome (SARS) outbreak between 2002 to 2003 left a resonating impact in China and other East Asia countries. This was the last time China was paralyzed by a serious epidemic. However, this experience accelerated the development of technology, e-commerce to healthcare sectors in China. Since SARS, China has gone through a socioeconomic reform and digital transformation.

Compared with the SARS epidemic 17 years ago, digital technology has become an integral element in the fight against Covid-19 and played an instrumental role in all aspects of the epidemic prevention and control. This report intends to explain the role and impact of digital technology solutions in the prevention and control of an epidemic outbreak from six aspects:
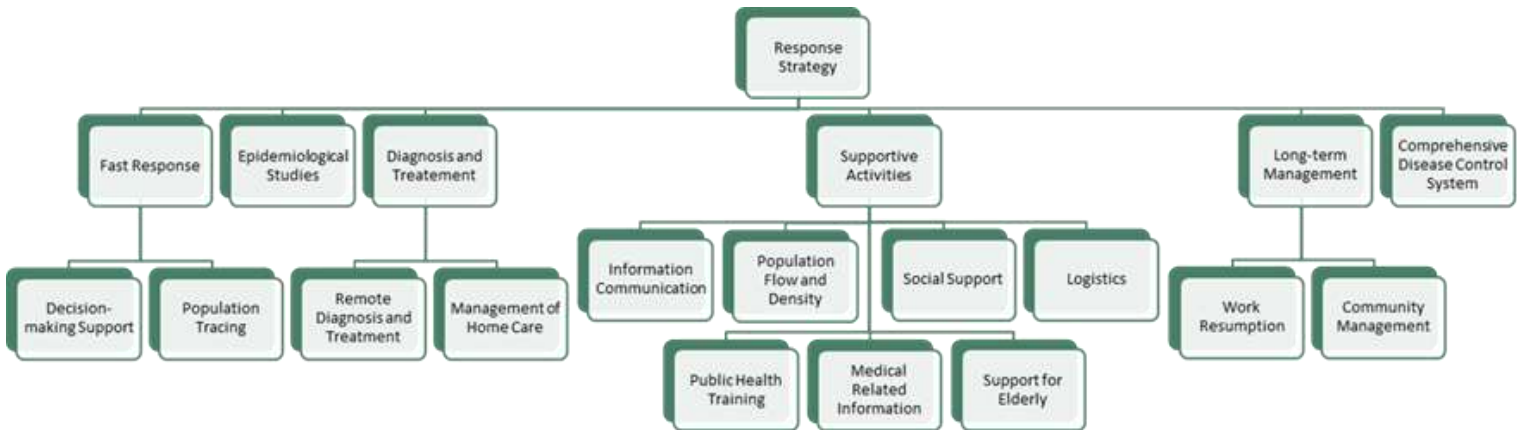

Figure 1. Framework linking outbreak response strategies to digital health interventions

Background

Fast Response: Epidemic outbreak requires rapid response and timely decisions made based on reliable information for effective prevention and control measures. In the case of Covid-19, fast response is even more critical. Utilizing information platform, big data analysis, and artificial intelligence technologies, data from all channels can be rapidly collected, integrated and analyzed. The information helps national and local governments quickly screen, identify and trace high-risk cases, monitor population flow and key locations, and predict outbreak development, enabling key decision makers to make fast and informed decisions.

Epidemiological Studies: Understanding the virus is the one of the most critical steps in fighting an epidemic outbreak. Leveraging on technologies such as artificial intelligence, big data, supercomputing, to conduct research on the diagnosis and treatment of Covid-19, mutation prediction, transmission mode and transmission scale, and spectrum of clinical severity to help predict the trend of epidemic situation and drugs and vaccines development. Early investment in studying the virus' characteristics will greatly improve the epidemic response.

Diagnosis and Treatment: As Covid-19 is contagious and transmissible, decrease in contact and social distancing are critical measures in containing and controlling the spread. This also applies to essential health services, as these procedures usually require close or direct contact. The applications of artificial intelligence,

5G technology, and Internet platform can not only help medical personnel conduct teleconsultation for patients with Covid-19 or suspected carriers of Covid-19, but also provide follow-up services for the ones at home, and for patients with other diseases such as chronic diseases. Psychological consultation and counseling services were also offered using digital technology during the outbreak.

Supportive Activities: During an epidemic outbreak, aside from fast response and diagnosis and treatment, there are many other epidemic prevention and control measures. Digital technology played an integral role in activities such as artificial intelligence and data analytics in population tracing, Internet platforms in medical personnel capacity building and medical resources mobilizing, and 5G technology, Internet of Things and communications platforms in community management and special groups support.

Long-term Management: As Covid-19 stabilized and normalized, economy slowly opened and pre-Covid-19 daily life cautiously resumed in China. Through Internet, Internet of Things, communications platforms, companies reopened, and employees returned to work, remotely. To closely monitor the outbreak, community management and risk management must be implemented stringently. Using Internet platforms, Internet of Things, artificial intelligence, big data analysis and other technologies can efficiently collect information, conduct screening and monitoring, and send alerts through automation.

Background

Comprehensive Disease Control System:

A comprehensive disease control system connects disease control systems, medical institutions, residents, and communities, and offers various epidemic-related services under one service platform. This platform used digital technologies such as Internet platforms, cloud service, big data analysis, and artificial intelligence, to provide integrated information and solutions for government and general public, achieving high multifunctionality, structure efficiency, and accessibility.

In this report, a total of 12 representative cases were selected, corresponding to the framework described above. A combination of desktop research and key informant interviews was used in this study. In each chapter, we will provide a comprehensive background and the applications of digital technology in the respective category. We will showcase the relevant case study(s), offering an in-depth description and analysis of the technology, the challenges faced, as well as the key enabling factors. Finally, we will conclude the chapter with key insights, highlighting the values, challenges and limitations of the digital technology in respect to each category. Table below is a breakdown of the 6 categories, the relevant sub-categories and their respective case studies.

Background

Category	Sub-category/Case studies		
Fast Response	Digital China Health		
Epidemiological Studies	No Case Selected		
Diagnose and Treatment	United Imaging		
	WeDoctor		
	Zuo Shou Yi Sheng		
Supportive Activities	Information Communication	DXY	
	Public Health Training		
	Population Flow and Density	Baidu Map	
	Medical Related Information	Tencent	
	Social Support		
	Logistics	Beijing Viewhigh Technology	
	Support for Elderly	IZhaohu	
Long-term Management	Resumption Management	Mininglamp Technology	
	Community Management	JD Digits	
Comprehensive Disease Control System	Alibaba		

Table 1. Representative case studies for six categories

DIGITAL TECHNOLOGY RELEVANT POLICY

2

DIGITAL TECHNOLOGY RELEVANT POLICY

Since the emergence of Covid-19 in December 2019, the national government has been placing great importance on the essential role of information systems and digital technology in the fight against the epidemic. There are three main phases: 1) Initial applications at the onset of an epidemic outbreak, from the onset of outbreak to February 14, 2020; 2) Diversified development of digitalization in the fight against the epidemic, February 14, 2020 to May 7, 2020; 3) Applications and improvements in epidemic management during stabilized phase, from May 7, 2020 to present.

On February 14, 2020, President Xi Jinping delivered a speech at the 12th Session of the CPC Central Commission on Comprehensive Deepening of the Reform, emphasizing the crucial role of digital technology in the fight against the Covid-19 epidemic, which was especially evident during the first two phases of the outbreak. Evidently, digital technology has and continues to play a crucial role in keeping our society functional and resilient and will have a long-lasting impact beyond Covid-19.

2.1

Development of Digital Technology Relevant Policies in **Different Phases of China's Fight** Against Covid-19

2.1.1 Initial applications at the onset of an epidemic outbreak, from the onset of outbreak to February 14, 2020

At the onset of Covid-19, there was full awareness at the national level regarding the importance of data collection and information systems in containing the spread. The National Health Commission (NHC) and related departments actively explored digital technology solutions to tackle the accelerating outbreak. The government further promoted and provided strategic policy guidance on utilizing digital technology in the country's fight against the Covid-19 epidemic.

On January 22, 2020, the NHC issued the

Protocol on Surveillance of Novel Coronavirus Pneumonia Cases (2nd Edition) and the *Protocol on Epidemiological Surveys of Novel Corona-virus Pneumonia Cases (2nd Edition)*, as attachments to the *Protocol on Prevention and Control of Novel Coronavirus Pneumonia (2nd Edition)*. These attachments specified the requirements for case reporting based on information systems and indicated the essential role of information systems in the fight against the epidemic.

Later, on February 3, 2020, the NHC issued a *Notice on Strengthening IT-Supported Prevention and Control of Novel Coronavirus Pneumonia*, which, for the first time, provided a comprehensive guidance centering around information technology (IT) support for the disease prevention and epidemic control efforts. It is clearly stated in this document that the supporting role of IT in enhancing areas such as epidemiology research,

innovations in diagnosis and treatments, and service efficiency should be fully exercised. Further, the Notice states that there should be applications to strengthen data collection, and analysis and applications, to vigorously promote telemedicine, to standardize Internet-based diagnosis and treatment **consultation services, to deepen "Internet Plus" governmental services, and to** strengthen foundation and security. As the first comprehensive national guideline on fighting epidemics with digital technology, this document explicitly provides guidance for the local governments, **reflecting the State's priority and urgency** in applying digital technology in disease prevention and control measures. It rapidly motivated the local governments to work with digital technology companies, while promoting the nationwide use of digital technology in the fight against the Covid-19 epidemic.

A series of policy documents were soon issued by the Cyberspace Administration of China (CAC) and the NHC with respect to areas involved in standardizing and advancing the applications of digital technology in disease prevention and control in detail. Among those documents released, the *Notice on Protecting Personal Information and Utilizing Big Data to Support Joint Prevention and Control*, released on February 4, 2020, focused on the fundamental role of data informatization in disease prevention and put forth further requirements on data usage and security. On one hand, the Notice states that personal information collected for disease prevention and

epidemic control should not be used for any other purposes. It provided instructions on how to protect personal information of local residents such that personal information can be safely collected and used. On the other hand, the CAC encourages companies to fully leverage big data, analyze and predict the flow of key population groups, such as confirmed and suspected cases, and contact tracing, providing additional support in disease prevention and control.

On February 7, 2020, the NHC issued the *Notice on Performing Internet-Based Diagnosis and Treatment Consultation Services in Disease Prevention and Epidemic Control*, specifying the use of digital technology in disease prevention and epidemic control across different sectors. This Notice acknowledges the important role of teleconsultation, including diagnosis and treatment, to provide timely health services to the public, while still emphasizing on its supervision. The goal for this Notice is to alleviate pressure for the overwhelmed hospitals and medical personnel, decreasing close contacts and reducing risk of transmission.

It is now evident that at the onset of outbreak, relevant government departments rapidly began to provide guidelines and detailed measures regarding the ways to fight against the Covid-19 epidemic with the support from digital technology. This reflects the concept of advancing with times in the national level of disease prevention and **control, opening a fresh chapter in China's**

practice of digital enabled disease prevention and epidemic control.

2.1.2. Encouragements from President Xi Jinping, on February 14, 2020

On February 14, 2020, President Xi Jinping presided over the 12th Session of the Central Committee of the Communist Party of China (CPC) on Comprehensive Deepening of the Reform. He emphasized the need to improve the disease prevention and epidemic control system and the national public health emergency management system. In his speech, President Xi stressed the need to encourage the use of big data, artificial intelligence, cloud computing and other digital technologies to better support epidemic surveillance and analysis, virus tracing, prevention, control and treatment, and resource mobilization. This not only affirms the achievements made in digital applications in the early phases of the epidemic, but also reflects the high importance and support the country finds in the use of digital technology in disease prevention and epidemic control. President Xi's encouragements strengthened the confidence in the local governments and departments to use digital technology to empower disease prevention and epidemic control. The speech received enthusiastic responses from the local governments and every sector of society, significantly promoting depth and breadth of digital technology applications in prevention and control measures.

2.1.3. Diversified development of tackling epidemic outbreaks with digital technology, February 14, 2020 to May 7, 2020

Entering the second phase of the outbreak, the epidemic control started to be more comprehensively and multifaceted in its deployment, with a significant increase in digital applications. The Ministry of Industry and Information Technology (MIIT) took the lead by issuing the *Notice on Utilizing New-Generation Information Technologies to Support and Serve Disease Prevention and Epidemic Control and Work Resumption* on February 19, 2020. The Notice responded positively to the instructions of President Xi on February 14, 2020, stressing the need to fully utilize new-generation information technology to strengthen support for comprehensive epidemic control, and specifying support areas, such as disease prevention and epidemic control, work resumption and service guarantees. This Notice further describes the guiding role in outlining the subsequent digital technology empowered disease prevention and epidemic control. In the areas of data and communications, the MIIT issued two important Notices, focusing on network security and promoting the accelerated development of 5G during epidemic control, balancing both short-term needs and long-term goals. On February 18, 2020, the *Notice on Urging the Information and Communication Industry to Effectively Guarantee the Network Security During the Period of Disease Prevention and Epidemic Control* promulgated and emphasized

DIGITAL TECHNOLOGY RELEVANT POLICY

the importance of effective network security support and employment assurance for disease prevention and epidemic control. Aimed at the specific scenario of outbreak prevention and control, the Notice set out two tasks for the information and communication industry. First, the network system security of key locations and users should be guaranteed, specifically from technical support and monitoring and protection aspects. The goal is to make command and control dispatch, and medical personnel support as convenient as possible. Second, information security and network data protection need to be strengthened, safeguarding against Internet fraud and misinformation. Issued on March 24, 2020, the *Notice on Promoting the Accelerated Development of 5G* especially put forth the goal to deploy and promote innovative development of "5G+ healthcare", with emphasis on the construction of the 5G smart medical system. The Notice calls for further optimization and popularization of 5G applications in the fight against Covid-19, such as remote medical examinations, teleconsultation, and medical assistance, to promote medical resource sharing.

The medical services sector is the utmost priority in the Covid-19 prevention and control. It is also the core connection between digitalization and the fight against the outbreak. From February 21, 2020 to April 10, 2020, the ministries and commissions issued a series of six notices and speeches, encompassing all aspects of medical services, fully demonstrated the importance of digital technology

enabled medical services at the national policy level. A separate Notice was released by the NHC, focused on consultation, treatment, and post-discharge health management of Covid-19 patients. This Notice called for steady and solid establishment of a national teleconsultation platform center, incorporating case data platform and video system, as well as the popularization of relevant operating procedures. The Notice highly stressed the importance of formulating and implementing a peopled-centered health management program for discharged Covid-19 patients supported by "Internet Plus" and information technology. The Notice jointly released by the NHC and the Comprehensive Group of the State Council on the Joint Prevention and Control Mechanism for Covid-19, in which the informatization of medical services were highlighted. The Notice provided concrete instructions on how to alleviate stress for the medical services in Hubei via online services such as telemedicine, smart diagnosis, traditional Chinese medicine (TCM) diagnosis and treatment, and mental health support. The Notice further requested medical institutions to leverage information-based approach for triage and risk management, such as staggered schedules and teleconsultation, and fully reinforced applying information technology to empower hospitals' examinations, diagnosis and treatment capacity and capability. Furthermore, digitalization of medical services also gave rise to new policy implementation. On February 28, 2020, the National Healthcare Security

Administration (NHSA) and the NHC jointly issued the *Guidance on Promoting the Implementation of "Internet Plus" Medical Insurance Services During the Period of Covid-19 Prevention and Control*, requesting the social health insurance **operators to refine various "Internet Plus"** healthcare operating services. The Guideline proposed, for the first time, to **include "Internet Plus" follow**-up services for common and chronic diseases in social health insurance coverage, encouraging designated pharmaceutical institutions to innovate their delivery methods, such as providing contactless drug delivery services. The following day, February 29, 2020, Vice-Premier Sun Chunlan lead the central steering group to Hubei and investigated the scientific researches that had been made for disease prevention and epidemic control. During this visit, Vice-Premier Sun emphasized the following tasks: establishing a green channel for scientific researches, intensifying screening and R&D of drugs with higher clinical efficacy, give full play to the advantages of Traditional Chinese Medicine (TCM), continuously improving diagnosis and treatment approach and guidance, and defeating the epidemic with science.

Lastly, information technology-based prevention and control in communities is a crucial link in community disease prevention and epidemic control. It also plays an important part in the diversified development of digital technology empowered fight against the epidemic. The *Guidance on Information-Based Construction and Applications for Covid-19 Prevention and Control in Communities*, issued on March 2, 2020, set out the objectives and basic ideas of information-based construction and applications for Covid-19 prevention and control in communities. The guideline stressed the integration features must be applicable, convenient, safe, and with advanced hindsight, it must also strongly support data connectivity, and focus on population group management, information reporting, and environmental improvements. Later, in the *Guidelines on Precise and Refined Covid-19 Prevention and Control Efforts and Services in Communities*, issued on April 14, 2020, information-based construction and applications for Covid-19 prevention and control in communities are further refined for communities at different risk levels, with emphasis on the inspection and use of epidemic control health codes.

2.1.4. Applications and improvements in normalization of outbreak management, from May 7, 2020 to present

As the epidemic situation normalized in China, the relevant governmental departments specified the application of digital technology in the planning of outbreak management, and summarized the experience in fighting the epidemic with digital technology to further improve and standardize the application of digital technology in long-term epidemic management.

On May 7, 2020, the Comprehensive Group of the State Council on the Joint

DIGITAL TECHNOLOGY RELEVANT POLICY

Prevention and Control Mechanism for Covid-19 released the *Guidance on Effectively Implementing Normalized Prevention and Control of Covid-19*. The Guidance emphasizes that big data should play a role in normalized prevention and control. In particular, it highlights the need to comprehensively promote the implementation of a "health code" in all regions across the country. Local communities' screenings such as nucleic acid and serum antibody test results, and information of key persons must be shared in a timely manner. Also, a special version of the "health code" for incoming persons should be introduced to ensure the safety and the movement of population groups.

Subsequently, the NHC released the *Notice on Standardizing Technical Specifications and Financial Management for "Internet Plus Medical Services" Items of Public Medical Institutions* and the *Notice on Further Improving the Medical Appointment System and Strengthening the Construction of Smart Hospitals*. The Notices instructed the hospitals to further standardize "Internet Plus" medical services, to establish and improve the medical appointment system, to strengthen the construction of smart hospitals, and to speed up the forming of the new medical service model featuring online-offline integration.

2.2

The Impact of National Policies

On February 28, 2020, the NHSA and the NHC jointly issued the *Guidance on Promoting the Implementation of "Internet Plus" Medical Insurance Services During the Period of Covid-19 Prevention and Control*. The following were proposed in the Guidance for the very first time:

- Internet-based hospitals that have been established under the approval of healthcare administration authorities, or medical institutions designated for healthcare security, whose Internet-based diagnosis and treatment activities have been approved by healthcare administration authorities, may voluntarily include "Internet Plus" follow-up services for common and chronic diseases.

- These services will be covered by the social health insurance. "Internet Plus" follow-up services of designated non-public medical institutions may also be covered partially, based on the pricing and payment policies for designated public medical institutions.

Once the Guidance was issued, provinces and municipalities responded rapidly, and implemented real-name online registration and medical services system. They also supported the establishment of an online prescription audit system and a medical conduct regulation mechanism, all in an effort to actively promote local

Development Phase	Features	Issuing Date	Major Policy Documents	Issuing Department	Key Points
Phase 1: Initial applications in the onset of the epidemic outbreak	Explorations on the importance of fighting the epidemic with IT support, and attempts for initial applications of digital technologies	January 22, 2020	Protocol on Prevention and Control of Novel Coronavirus Pneumonia (2nd Edition)	NHC	Suggest information collection and the use of information systems in the Surveillance Protocol and the Epidemiological Survey Protocol
		February 3, 2020	Notice on Strengthening IT-Supported Prevention and Control of Novel Coronavirus Pneumonia	NHC	Give comprehensive guidance on how to fight against the epidemic with IT support for the first time, covering digital applications such as data collection and analysis, telemedicine, and Internet-based medical services
		February 4, 2020	Notice on Protecting Personal Information and Utilizing Big Data to Support Joint Prevention and Control	CAC	Suggest protection for personal information collected during the epidemic, and encourage big data applications in epidemic prevention and control
		February 7, 2020	Notice on Performing Internet-Based Diagnosis and Treatment Consultation Services in Disease Prevention and Epidemic Control	NHC	Encourage and standardize the applications of Internet-based medical consultation services during the epidemic
Milestone: Encouragements from President Xi Jinping		February 14, 2020	Speech of President Xi Jinping at the 12th Session of the CPC Central Commission on Comprehensive Deepening of the Reform	/	The use of digital technologies to support the fight against the epidemic was encouraged by the President
Phase 2: Diversified development of digitalization in the fight against the epidemic	Comprehensive prevention and control	February 19, 2020	Notice on Utilizing New-Generation Information Technologies to Support and Serve Disease Prevention and Epidemic Control and Work Resumption	MIIT	Identify application scenarios of IT in scientific prevention and control of the epidemic and in acceleration of work resumption
	Data and communication	February 18, 2020	Notice on Urging the Information and Communication Industry to Effectively Guarantee the Network Security During the Period of Disease Prevention and Epidemic Control	MIIT	Respond to the CAC document, and emphasize safety protection for key network infrastructure as well as personal information and data during the epidemic
		March 24, 2020	Notice of the Ministry of Industry and Information Technology on Promoting the Accelerated Development of 5G	MIIT	Promote the innovative development of "5G+ healthcare", and popularize excellent 5G applications in the fight against the epidemic
	Medical services	February 21, 2020	Notice on Carrying out National Teleconsultation for Severe and Critical Covid-19 Patients in the National Telemedicine and Connected Health Center	NHC	Provide scheme instructions on how to leverage telemedicine to improve the treatment of critical Covid-19 cases
		February 26, 2020	Notice on Carrying out Online Services to Further Strengthen Disease Prevention and Epidemic Control in Hubei	Comprehensive Group of the State Council on the Joint Prevention and Control Mechanism for Covid-19, NHC	Provide concrete scheme instructions on how to relieve the medical service stress in Hubei through online services

(Continued)

Phase	Category	Date	Policy	Issuing Authority	Content
Phase 3: Applications and improvements in epidemic management during stabilized phase		February 28, 2020	Guidance on Promoting the Implementation of "Internet Plus" Medical Insurance Services During the Period of Covid-19 Prevention and Control	NHSA, NHC	Initially put forward the plan to include qualified "Internet Plus" medical services into the medical insurance payment coverage
		February 29, 2020	Investigation from the central steering group for field work in Hubei, led by Sun Chunlan, on the scientific researches that had been made for Disease Prevention and Epidemic Control	/	Sun Chunlan highlighted the following tasks: …establishing a green channel for scientific researches, intensifying efforts in tracing virus origins, clarifying transmission mechanisms, improving medical treatment, screening for effective drugs and developing vaccines, …, and defeating the epidemic with the weapons of science
		March 13, 2020	Notice of the General Office of the National Health Commission on Issuing the Protocol on Health Management of Discharged Covid-19 Patients (for Trial Implementation)	NHC	Suggest "Internet Plus" supported health management services for discharged patients
		April 10, 2020	Notice on Further Consolidating Achievements and Improving the Abilities of Medical Institutions for Covid-19 Prevention, Control and Treatment	Comprehensive Group of the State Council on the Joint Prevention and Control Mechanism for Covid-19, NHC	Encourage medical institutions to step up information-based construction and carry out appointment-driven medical services at staggered hours and Internet-based medical consultation
	Prevention and control in communities	March 2, 2020	Guidance on Information-Based Construction and Applications for Covid-19 Prevention and Control in Communities	MCA, CAC, MIIT, NHC	Propose the basic ideas of information-based construction and applications for epidemic prevention and control in communities
		April 14, 2020	Guidelines on Precise and Refined Covid-19 Prevention and Control Efforts and Services in Communities	MCA, NHC	Further refine information-based construction applications for epidemic prevention and control in communities
	Normal prevention and control	May 7, 2020	Guidance on Effectively Implementing Normalized Prevention and Control of Covid-19	Comprehensive Group of the State Council on the Joint Prevention and Control Mechanism for Covid-19	Identify the supporting role of big data in normalized epidemic management
	Improvements to specifications and systems	May 8, 2020	Notice on Standardizing Technical Specifications and Financial Management for "Internet Plus Medical Services" Items of Public Medical Institutions	NHC, NATCM	Further set out the specifications for "Internet Plus medical services"
		May 21, 2020	Notice on Further Improving the Medical Appointment System and Strengthening the Construction of Smart Hospitals	NHC	Instruct hospitals to establish and improve the medical appointment system, strengthen the construction of smart hospitals, and speed up the forming of the new medical service model featuring online-offline integration

Table 2. Policies Related to China's Fight Against Covid-19 Using Digital Technologies

implementation of this new policy. The implementation of the policy varied across different regions due to different levels of digitalization, governance scope and objectives of the medical institutions. In some provinces, municipalities directly under the central government and autonomous regions – namely Shanghai, Chongqing, Shanxi, Shandong, Fujian, Jiangxi, Jilin, Anhui, Hunan, Guangdong, Hainan, Sichuan, Yunnan, Gansu, Inner Mongolia, Ningxia, and Xinjiang – the **policy of including "Internet Plus" follow**-up services into medical insurance was rolled out through trial implementation in batches across the provinces (cities) under the leading and unified planning of the provincial level Healthcare Security Administration. In provinces and autonomous regions such as Zhejiang, Henan, Hubei, Guizhou, Guangxi, and Tibet, this policy was implemented citywide, led by the municipal level Healthcare Security Administrations. In Beijing and Tianjin, designated hospitals had the option to submit applications **voluntarily to include "Internet Plus"** follow-up services into social health insurance. The policy of incorporating **"Internet Plus" follow**-up medical services into social health insurance coverage profoundly enhanced the development of social health insurance payment and Internet-based medical services. Since the integration, Hebei Province (**Xiong'an** New Area), Zhejiang Province, Fujian Province, Guangdong Province, Chongqing, and Sichuan Province became the designated national pilot zones for innovative

development of digital economy. As the national pilot zones, the provinces began to explore and promote the first social health insurance covered teleconsultation system and appointment and triage system. The implication is significant. First, the scope of social insurance coverage increased considerably, and was supported by large-scale informatization of the social health insurance payment system. Second, the policy of including **"Internet Plus" follow**-up medical services in social health insurance is a recognition of Internet-based medical services, indicating that they are valuable and are worth being promoted nationally. The **excellent performance of "Internet Plus"** supported services, including teleconsultation, remote diagnosis and contactless drug purchase services throughout the epidemic have demonstrated the that Internet-based medical services have their unique values and great development potential. Moreover, by incorporating some services into medical insurance has strongly **promoted the linage of "health care + medicine + health insurance", further** promoting the development of more medical services to be digitalized and conducted remotely, ultimately creating a one-stop medical service that is not only practical, but convenient and efficient.

FAST
RESPONSE

3

Fast Response

As the natural leader for overall outbreak prevention and control, governments from all levels need to make coordinated and concerted decisions, and deploy measures within a short period of time at the onset of an epidemic. To achieve fast response, timely and reliable data, and information, support is critical. Therefore, rapid information platform construction, and data collection and monitoring are essential for the government to implement effective strategies to increase epidemic preparedness and mitigate the impact of the outbreak.

3.1

Digital Technology in Fast Response

3.1.1 Assist the government in collecting and analyzing epidemic data to support decision-making

In the early stage of the epidemic, the government needed to grasp key relevant information such as clinical data, disease control data, and public reactions, to coordinate the prevention and control measures scientifically. Driven by these needs, an integrated data platform was developed. The platform is able to aggregate, manage, cleanse, store and analyze multiple sources of data into various comprehensive reports. The aggregated data empowers the government to make informed assessment and calculated decisions, such as local medical resources allocation, predictions on the future trends of the epidemic, allowing an effective and efficient response.

For instance, Digital China Health built an integrated data platform for Honghu County government in Hubei Province. The platform integrated local residents'

health information, clinical data, and epidemiological data, realizing individual information tracking, clinical early warning decision making, and efficient resource allocation management. The platform provided the core support for scientific policy decision-making on Covid-19 outbreak measures in Honghu County.

3.1.2 Assist the government in identifying and tracking high-risk groups to implement prevention and control measures with precision

Covid-19 is highly contagious, and thus the identification and tracking of high-risk groups are especially important for governments to implement precise prevention and control measures.

With the consent for information authorization, many companies utilized artificial intelligence and big data analysis to promptly provide the local government with population tracking analysis of both permanent and mobile population, based on geographic information systems and location-based services. The companies helped the local government to quickly initiate different levels of management strategies based on the actual situation, in

a timely and appropriate manner. At the same time, through establishing a monitoring platform, key locations such as hospitals, shopping malls, schools, railway stations, and airports helped provide real-time alerts to the public. Warnings such as the wearing of masks, population flow, and abnormal body temperature are all conducive to providing real-time outbreak status.

For instance, China's three major state-owned Internet service operators, namely China Telecom, China Unicom, and China Mobile, along with Mininglamp Technology, and Inspur Group, all established monitoring and tracking platforms for local governments to achieve precise outbreak prevention status and control measures from macro level to micro level, offering real-time monitoring and population flow data.

3.2

Case Study I: Digital China Health

ABOUT Digital China Health

Digital China Health (DC Health) is an innovative healthcare IT and Big Data company. DC Health is committed to develop an independent technology system, with the goal to not only continuously enhance the overall level of China's healthcare informatization, but also to drive the reform and innovation in the development of healthcare big data, globally.

DC Health has in-depth focus across four areas, healthcare big data, medical cloud services, healthcare informatization and precision medicine. It offers comprehensive and integrated informatization solutions such as Healthcare Big Data platform and Hospital IT Integration. DC Health has a global leading team specialized in a variety of fields in Healthcare Big Data, ranging from data structuring, data standardization, quality control, security and privacy protection, multi-data fusion analysis, and real-world evidence (RWE) research. With these expertise, DC Health provides services to the government, hospitals, research institutions, pharmaceutical companies, and medical technology companies. DC Health is dedicated to utilize its in-depth expertise and solutions to empower and further enable public health management, smart clinical decision, hospital operational management, clinical research, RWE, and drug development.

[1] BACKGROUND: Integrated Data System Facilitated Timely Government Decision-making and Epidemic Analysis

Integrated data system integrates clinical case data from the medical system, epidemiological data from the public health surveillance system, and all other general epidemic data, into one standardized framework. The integrated data system then conducts a series of data analysis. During the Covid-19 outbreak, infected cases rose rapidly, putting tremendous pressure on medical and disease control departments across

Fast Response

all levels of governments in China. As the lead commander of epidemic prevention and control, the government had to quickly obtain a multitude of data related to Covid-19 in order to formulate a comprehensive prevention and control strategy. Medical personnel were also in urgent need of updated information and data on Covid-19, especially clinical data from case treatments and patient management, to effectively triage patients and carry out appropriate treatments. Further, public health information with timely dissemination and announcements are crucial in times of pandemic crises. Providing updated information for the general public can effectively help mitigate widespread panic and fear. Therefore, under such circumstances, building an integrated data system is extremely critical in the early onset of an epidemic for timely government decision-making and epidemic analysis. The system and its analytic methodologies can also become a reference for other countries and regions who are undergoing the same epidemic crisis.

[2] CHALLENGE: Regional Prevention and Control Efforts Lacked a Timely and Integrated Data System

The Covid-19 outbreak in China coincided with the Chinese New Year, the period with the largest human migration, annually. Originating from Wuhan City, the virus quickly spread to nearby cities.

One in particular is Honghu County. Honghu County is located in the southern central region of Hubei Province, and is under the jurisdiction of Jingzhou City. Honghu County has a population of around 950,000 and is only 120 kilometers away from Wuhan. According to estimates, around 49,000 people returned from Wuhan to Honghu County just before the Chinese New Year holiday, returning home with many imported Covid-19 cases. In fact, as of February 12, 2020, before the Guangdong Medical Aids Team's arrival, the cumulative confirmed cases in Honghu County had already reached 262, with severe and critically ill patients accounting for about one quarter of the county's confirmed cases, making Honghu County's situation the direst in the entire Jingzhou City. Honghu County faced two main challenges at the early stages of Covid-19 outbreak:

[2.1] The lack of Covid-19 data integration

Data aggregation was slow at the beginning of the outbreak since there was no integrated data System available. The Novel Coronavirus Prevention and Control Command Center of Honghu County faced shortage in collecting Covid-19 related information from residents, suspected patients and confirmed patients, and was thus unable to make informed policy decisions and delegate specific tasks to other agencies. Therefore, it was critical for the Command Center to gain access to timely information on Covid-19. Based on the integrated and updated information, the Command Center can further allocate responsibilities for each government department and ensure that the prevention

and control strategies were both efficient and effective.

[2.2] Data collected is unable to indicate and predict Covid-19 developments in a timely manner

As neither aligned data collection formats nor reporting mechanisms were established across different medical institutions, and between medical institutions and local Center for Disease Control (CDC), it was difficult to match data from different population segments, such as healthy population, high-risk population, and suspected cases. This made it difficult to trace data and produce analytics that were vital to government decisions.

[3] SOLUTION: DC Health's Integrated Data System

Given the aforementioned challenges, described in the previous section, DC Health built an integrated data system that enabled Honghu County government to be fully informed and properly respond to a variety of complex issues during Covid-19 outbreak.

[3.1] Working with the Guangdong medical team to support Honghu County

On February 12, 2020, the Guangdong Medical Team entered Honghu County. As part of the Medical Team, DC Health was in charge of building an integrated Covid-19 data system. On February 14, 2020, within 72 hours, the DC Health team built the system.

Upon receiving the task appointed by the local government, DC Health promptly gathered a team of forty experts. The team consisted of 30 engineers, responsible for building the data system, and 10 data analysts, responsible for producing the analysis reports. Together, the team must provide timely reports to the government based on its requests, with an average turnaround time of around two hours. However, due to travel restrictions during Covid-19 outbreak, the DC Health team had to stay in their Beijing office, supporting the project remotely. To ensure data security, DC Health hired an independent data security auditor to **safeguard the system's data. Dr. Gong** Mengchun, the Vice President of DC Health, was physically in Honghu County to oversee the entire project, and to be in close communications with Honghu County government. Four experts from Nanfang Hospital also provided technical support for the construction and operations of the integrated data system, with three working remotely and one on-site.

As the project lead, the Honghu County government was in control of the integrated data system. The Mayor of Honghu County directly coordinated the resources required to build and operate the data system. Honghu County Health Bureau aligned the data systems across the different hospitals, while Honghu County Big Data Bureau oversaw data collection, such as improving the rate of information reporting, conducting on-site verification, and resolving data related issues when they arise.

Fast Response

The Three platforms that forms Honghu County's integrated data system

[3.2.1] The resident health data WeChat reporting platform

DC Health established a WeChat-based resident health data platform, using a public WeChat account as an information collection portal for the local residents. This platform was designed to survey and monitor local residents' health status across different population groups. The monitoring targets include the general population, inpatients and discharged patients, high-risk groups (i.e. people with Wuhan travel history, people with contact history of diagnosed patients, or medical observers who received patients at quarantine locations), medical personnel (such as doctors, nurses, public health experts and social workers). The data collection survey was designed by infectious disease experts at Nanfang Hospital and revised jointly by local government officials, local clinicians, public health officials, and information technology experts. On March 2, 2020, as the epidemic situation gradually stabilized and the government began to encourage back to work, the data collection survey was then adjusted to include content on job search support.

There were several reasons DC Health selected WeChat as its data collection platform. First, WeChat has a high market penetration rate within China, allowing residents from both urban and rural area

of Honghu County to access the survey. Second, in order to gather a wide and detailed range of personal health information, the survey had to be published by a credible agency. Honghu County Publicity Department has set up an official WeChat public account, "Honghu Today", providing the necessary credibility. The account became an influential and trustworthy source of information for the local residents, with regular news updates and Covid-19 information. Under the support of the local government, DC Health built a health status input portal under "Honghu Today". Once residents logged into the public account, they could easily enter their personal health information. Another reason for selecting WeChat is its backend system. WeChat provided DC Health with reliable resources, allowing DC Health team to access a relatively more open-ended backend system and a wide range of functions. The pre-existing collaboration between DC Health and WeChat has laid a solid foundation for this platform.

Initially, when Honghu County launched this platform, the voluntary resident's daily response rate was only around 25%. However, as the local government began to strengthen its administrative efforts, monitoring daily response rate, assessing the community performances, and urging for improvements through community administrators, the daily response rate successfully rose to over 95% within a very short time.

Fast Response

[3.2.2] The clinical data platform

The clinical data platform collects, processes, and analyses clinical data from electronic medical records (EMR) from nine hospitals, and thus became a clinical database covering various platforms and hospitals. The platform also encompasses a critical illness decision-support function. Based on a mortality risk prediction model **created with China's Covid**-19 data, the Platform is able to generate mortality risk figures for confirmed Covid-19 inpatients on a daily basis. This allows hospitals to take corresponding clinical management **actions given each patient's mortality risk.** Introducing the mortality risk prediction system improved the quality and effectiveness of clinical and patient management, thereby lowering mortality rate across the hospitals. This attempt in Honghu **County was China's first** application in using the mortality risk prediction system on Covid-19 patients.

The fact that not all the nine hospitals were equipped with the Hospital Information System (HIS) made it difficult for the data to be transferred outside of the hospital. Urged by the local government, the hospitals with-out HIS quickly installed HIS during the initial outbreak, and completed the data inputs. With the support of local government, DC Health was also able to bypass complicated processes and directly extract raw clinical data from hospitals and integrate them into its platform. Through the processes of data aligning, structuring, and analysis, DC Health was able to provide relevant epidemic and

clinical data. In addition, DC Health had taken necessary measures for data security and maintenance.

[3.2.3] The epidemiological data platform

The epidemiological data platform integrates data from three locations: 1) a third-party polymerase chain reaction laboratory, 2) a third-party antibody research laboratory, and 3) the CDC.

[3.2.3] The epidemiological data platform

The epidemiological data platform integrates data from three locations: 1) a third-party polymerase chain reaction laboratory, 2) a third-party antibody research laboratory, and 3) the CDC. Because the calculation of daily case figures from CDC is a closed-door process, the DC Health platform simply extracted **those figures from CDC's public releases** and combined those case numbers with testing results from, the two laboratories, rather than merging its platform directly **with the CDC's.**

DC Health's integrated data system prioritized the deep integration of epidemiological data and clinical data. It does so by extracting raw data and integrating them into the system using DC **Health's semi**-automatic technology. The integrated data system also continues to monitor a plethora of information through **the entire outbreak, from residents' health** status, suspected morbidity, diagnosed, referrals, mild symptoms treatment, critically-ill treatment, death or recovery

from discharge, mental health, to the resumption of labor. By analyzing data from each stage of the outbreak, DC Health was able to produce figures on Covid-19 trends and compare between towns and villages. These results informed policy making, supported clinical decisions, mobilized medical resource distributions, and ultimately met various needs requested by the local government throughout the outbreak.

[3.3] Cloud services ensured the successful construction of Honghu County's integrated data platform

In terms of hardware selection, DC Health decided to use cloud services for the following reasons: 1) The system's data came from various different platforms, institutions, regions, and sources. For instance, there were data from patients, hospitals, and public health officials, yet in various formats. Without cloud technology, these various forms of data could not be properly integrated nor translated. In addition, data integration is time consuming, the hardware used would need to have the flexibility for expansion and hardware upgrades; 2) With the travel restrictions and quarantine policies in place, it was not practical nor feasible to purchase and install physical hardware across Hubei Province; 3) Given the physical constraints during the outbreak, it was also difficult to assemble a technical team to be based locally. The cloud technology allowed experts across the
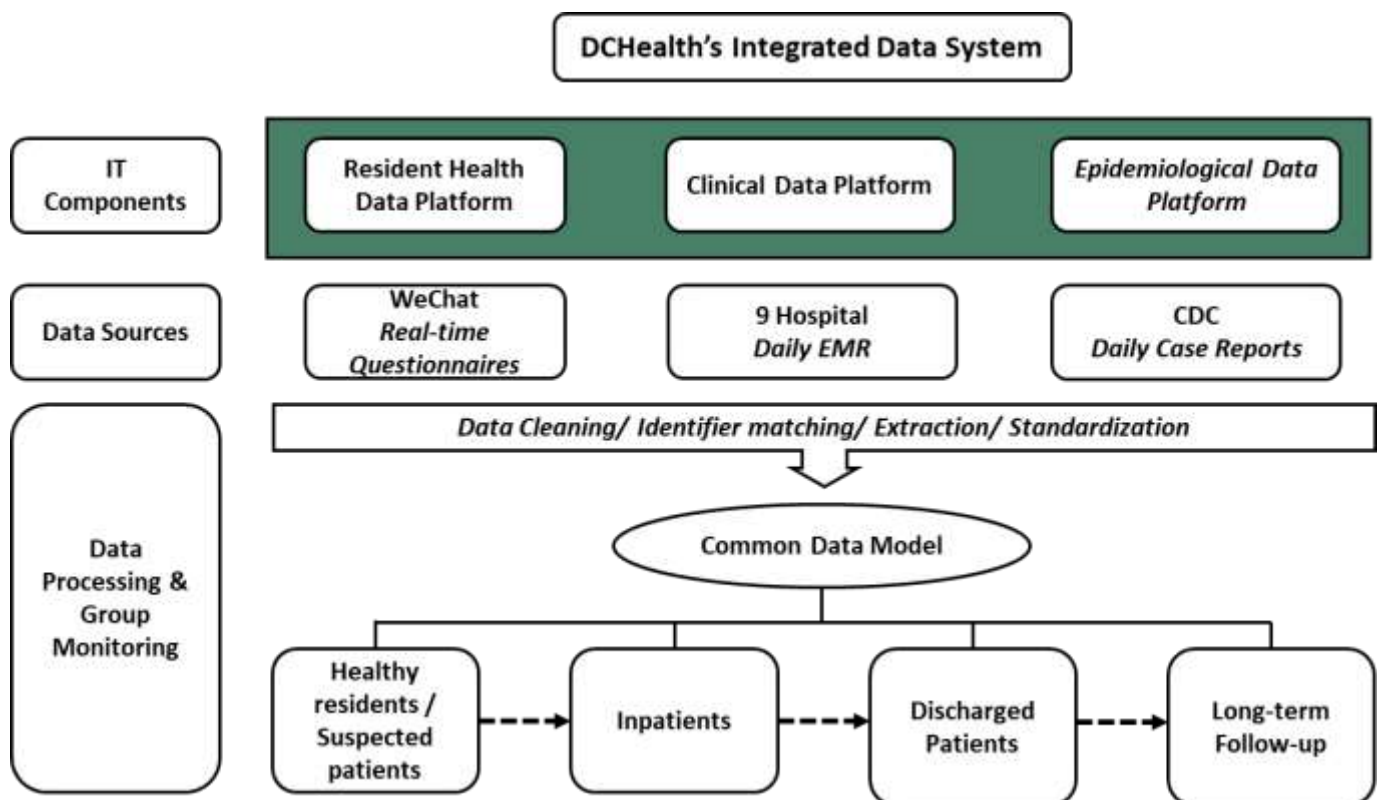

Figure 2. DC Health's Integrated Data System

Fast Response

country to work and collaborate remotely. As a result, the cloud technology became DC Health's natural first choice.

In terms of the process of building a cloud service platform, Honghu County government purchased cloud service from a mobile operator. Honghu County Big Data Bureau oversaw the security management of the operator. Once the purchase was complete, DC Health's team, along with the technical team of the cloud service provider, spent between three to five hours on the initial set up of the system. DC Health's team then spent three days to refine the cloud system until it reached stable operation. Once the cloud service was able to operate stably, DC Health transferred the cloud service's passkey back to the government. In the process of this transfer, DC Health also provided training for the government officials in personal data protection and relevant safety measures. In other words, Honghu County government has complete control over the hardware behind the database, thereby eliminating the government's concerns over data security.

Under the joint effort of DC Health and various stakeholders, Honghu County's resident health data platform eventually reached 97% response rate (among current residents) and received over 700,000 responses on a daily basis. As of March 16, 2020, the cumulative health status self-reporting reached 17.5 million. Through door-to-door visits or phone calls, social workers were able to track over 10,000 positive Covid-19 cases, of which 30 cases were asked to be quarantined and tested. These response rate suggests that it is possible to conduct population tracing on a centralized platform. Monitoring the fluctuation of daily reported cases and tracing confirmed patients' behaviors and travel histories, these data provided the local government tremendous evidence and confidence in its decision making.

[4] DISCUSSION

[4.1] DC Health's key success factors

During the Covid-19 outbreak, DC Health's team, along with the Guangdong Medical Team, worked under tight time constraints and tremendous pressure. The team, however, was able to quickly respond to tackle the challenges. The following factors were critical to DC Health's success in establishing an integrated healthcare data system in Honghu County.

[4.1.1] Strong government support in policy implementation and resources

Honghu County government provided tremendous support to the DC Health team and took a leading role in the entire project in a concerted attempt to control and contain the virus. In the early stages of the project, for instance, the local government quickly deployed local technicians to support the DC Health team, purchased the cloud service, and supported DC Health during the development and design of the system. Once the system began to operate, different agencies within local government worked together to collect and compile data. The local health bureau, for instance,

Fast Response

coordinated the extraction of data from hospital HIS and assisted hospitals without HIS to install the system. The Big Data Bureau, on the other hand, helped solve problems that each community faced, and encouraged communities to voluntarily report health status information. DC Health and Honghu County government worked in tandem. With the government's support, DC Health was able to quickly complete the project, and the project in turn informed the government's policy decisions.

[4.1.2] Expert input and on-the-ground personnel sped up the database construction process

In working with the Guangdong Medical Team, DC Health received tremendous support from experts at the Nanfang Hospital, where most of the Guangdong Medical Team members were drawn from. Specifically, Nanfang Hospital deployed four experts to work with DC Health's Vice President, Dr. Gong Mengchun, who was stationed in Honghu County. Dr. Gong express-ed in his interview that the four experts from Nanfang Hospital, who helped coordinate and communicate with other stakeholders on the ground, were indispensable to building the data system within just 72 hours.

[4.1.3] DC Health's temporary strategy to solve the blockage of hospital data circulation

In the process of collecting clinical data from hospitals, DC Health faced several problems: the data formats were often inconsistent, the quality of data varied drastically from hospital to hospital, and database at CDC was inaccessible. As these problems were difficult to solve within a short time span, DC Health decided to extract raw data directly from the HIS system in each hospital. The team then manually keyed in and analyzed those data. While the temporary strategy was able to effectively solved technical challenges with data extraction, it was incredibly labor intensive.

[4.1.4] DC Health's safeguarding of data security and compliance

At the early stages of building the data system, Honghu County government was very concerned about data security and privacy. To dispel worries from the government's side, DC Health actively communicated with government officials and designed a series of data protection protocols with the local government. It was ensured that the government ultimately had ownership and control over the data system by DC Health returning the password back to the government after completing cloud service construction. In addition, Nanfang Hospital was responsible to conduct ethical evaluations of the project, and its high reputation helped ease government concerns over data security.

Data security during the operation of cloud service was also a key concern, and the quantification of the reidentification risk after data desensitization is an important reference index for the protocols.

Fast Response

Fortunately, DC Health is specialized in desensitizing medical data. Within conventional network security regulations, DC Health also ensured that it conducted through auditing and employed data desensitization technology in the process of operating the integrated data system.

DC Health also trained all employees who would come into contact with the data system. Due to the urgency of the situation, DC Health's team had to directly extract raw data, manually key in those data based on a pre-determined data structure and upload them onto the government's data platform. Therefore, prior to the launch of the project, DC Health team used an entire afternoon to conduct a data security training for all the employees, each of whom then signed an agreement which laid out basic protocols, clear boundaries of data security, and corresponding penalties for breaching the agreement. In addition to the training, an independent data security auditor was stationed locally to monitored daily operations, correcting wrong practices and reporting to the management team on a daily basis.

[4.1.5] Donations simplified purchasing process

There are operational problems such as compliance and procurement process in retrieving data from various systems. The fact that the whole cost of this assistance was borne by DC Health itself categorized the assistance as a donation, which directly simplified the bidding, procurement and compliance processes

during data collection. This was one of the key reasons DC Health was able to quickly act and build the data system.

[4.2] Necessary conditions to replicate DC Health's solutions

Key factors that led to DC Health's success in Honghu County are outlined above. The following few passages describes necessary conditions for similar projects to launch in other countries or regions:

[4.2.1] A social media network or data platform with high market penetration

WeChat is a social media tool with existing high market penetration and user volume in China. It is also extremely user friendly, which enabled DC Health to closely monitor citizen health status and to reach near 100% response rate. Other countries trying to execute similar projects should consider whether such a platform exists within the community. If not, they could consider building a platform for targeted population segments during such pandemic outbreak or crisis situation.

[4.2.2] Hospitals need to be equipped with HIS system

Although DC Health had to manually collect data during the outbreak in Honghu County, it was important for hospitals to have HIS systems in place for data collection to even be possible in a very short period of time. Medical personnel in hospitals should also be equipped with updated HIS system-related knowledge in order to ensure that raw data across hospitals can be standardized.

Fast Response

[4.2.3] Government coordination

The government's ability and willingness to coordinate actions across sectors is the most important condition. In Honghu County, the establishment of the big data bureau laid a solid foundation for DC Health's project, and allowed the government to centrally manage the situation during a public health crisis while assigning tasks beyond pre-designated roles. Other governments can consider doing the same through establishing a central command center during a pandemic outbreak or similar level of crisis.

3.3

Value of Digital Technology in Fast Response

3.3.1 To the government

Digital technology helps improve the quality and efficiency of the government's decision-making in response to the public health emergencies. Governments need to make specific decisions and implement effective measures within a very short period of time when facing various adverse circumstances, uncertainties, and other factors during public health emergencies. The information platform, using advanced technologies including artificial intelligence, data middle platform, big data analysis, geographic information system, and location technology, is an upgrade from traditional manual data collection, analysis, monitoring, and

tracking methods. This upgrade to advanced information platforms can improve the efficiency of data analysis, and can provide more reliable information support to the government for decision-making.

3.4

Limitations and Challenges

3.4.1 Fragmented and disconnected systems, resulting in ineffective flow of data

Currently, the medical system and the public health system are not integrated with each other, thus the respective clinical data and the public health information collected cannot be promptly integrated and analyzed. There are inconsistencies in the format and reporting mechanism of data between medical institutions and Centers for Disease Control (CDCs), as well as between different medical institutions. Clinical institutes also require a better mechanism in uploading and sharing their data. Furthermore, with poorly integrated data from multiple channels, it is very difficult to effectively compare and match. In the face of emergencies that require fast response, these issues create magnified difficulties in data analysis and tracing, making it even more difficult for digital technology to engage seamlessly and provide a rapid and panoptic view of the outbreak.

Fast Response

3.4.2 Strict information security thresholds set requirements on private sector participation

As information collected encompassed personal data such as location information, companies need to take strict and comprehensive safeguards on information security. This greatly increased the threshold for companies to participate in fast response. We observed that in China's fight against Covid-19, most of the companies that participated in the fast response are state-owned. Each company has its own strategy for information security, and thus it is difficult to achieve uniformity in information protection. How to allow more companies to participate in fast response to emergencies with unified information protection mechanism must still be further explored.

EPIDEMIOLOGICAL STUDIES

Epidemiological Study

Understanding the characteristics of a virus is essential for infection prevention and epidemic control. SARS-CoV-2, the virus that causes Covid-19, is a novel virus that requires comprehensive and in-depth investigations and research, such as testing, diagnosis, treatment, virus tracing, mutation prediction, as well as their mode and scale of transmission. Therefore, it is of great significance to carry out epidemiological studies on SARS-CoV-2 as soon as possible for better outbreak prevention and control.

4.1

Digital Technology in Epidemiological Study

4.1.1 SARS-CoV-2 genetic sequencing and protein structural research

Genetic sequencing and protein structure research of the SARS-CoV-2 are the first steps in understanding this novel virus. Using artificial intelligence and supercomputing capabilities can codify these two complexed research areas and convert a biological enquiry into a mathematical one that can be rapidly analyzed and computed in terabytes and even petabytes worth of stored data. On one hand, the highly efficient computing power significantly reduces the time needed for the genetic sequencing of SARS-CoV-2 retrospectively by comparing the sequencing results with other viruses. On the other hand, computing models offer direct visualization of the SARS-CoV-2 protein structure, and thus help us understand its pathogenesis and transmission mechanisms. At the same time, the use of big data computing can predict the mutation of viral proteins and can grasp the possible future mutation trends of the virus.

For instance, Shenzhen MGI Tech (MGI) provided the first batch of high throughput sequencer to assist professionals and researchers around the world to conduct genetic sequencing and assembly of the SARS-CoV-2 at a faster pace. It also provided the basis for the rapid development of subsequent fluorescent PCR kits.

4.1.2 Projections of the scale and prevalence of the outbreak

It is believed that the Covid-19 outbreak in China originated at a seafood wholesale market near a transportation hub in Wuhan. The outbreak coincided with the Chinese New Year, also the largest human migration annually, bringing significant challenges to the epidemiological study. The study of epidemiological history is, in turn, directly related to the prediction of the scale of transmission and epidemiological trends of the virus. In epidemiological history tracing, extensive analysis of data from transportation, payments, and travel can play an important role in the development and analysis of infection models. At the same time, based on epidemiological history research models, the use of big data and artificial analysis can further make more

accurate predictions and simulations of the existing scale of transmission and future epidemic trends, unleashing the potential value of the data.

For instance, with its enhanced SEIR model and AI capabilities, Nanjing Innovative Data Technologies set up Covid-19 outbreak simulations and prediction models and helped Prof. Zhong Nanshan consolidated the research results on the progress of the outbreak, and subsequently served as an important reference for national level epidemic prevention and control strategy.

4.1.3 Drugs and vaccine development for SARS-CoV-2

To strengthen the control of the Covid-19 outbreak, it is important to invest into research and development of drugs and vaccines for the highly transmissible virus. In addition, extensive data analysis and literature reviews are necessary to support the research and development of new drugs and vaccines. Whether it is screening molecular databases to find potential candidates for treating SARS-CoV-2, or formulating new medications based on its genetic information, the massive amount of data and myriad of possibilities under the complex viral structures are important factors hindering the efficiency of research and development. Therefore, the combination of big data, AI and computing power has vital importance in the research and development of medication and vaccine for SARS-CoV-2. The application of these technologies allows rapid molecular

screening from literatures and laboratory data, simulates the ligand-receptor binding effects, and provides data analysis in a stable and efficient data computing support for research and development.

For instance, technology companies such as Sugon, Sense Time and Tencent, in collaboration with the National Supercomputing Center in Shenzhen, released a platform for research and development of drugs and vaccines for SARS-CoV-2. Relying on the super-computing power, the platform supported researchers to conduct full-scale research and screening of therapeutic agents. Baidu and the China Center for Disease Control (CDC) also established a "China CDC Emergency Technology Center - Baidu Gene Sequencing Workstation" to accelerate the genetic analysis and vaccine research for SARS-CoV-2.

Note

In this report, the research team focused on three aspects of the epidemiological study, namely gene sequencing and protein structure research, predictions on the spread of outbreak and epidemiological trends, and research and development of drugs and vaccines for SARS-CoV-2.

No specific case was selected in this part for the in-depth study. The two main reasons are:

Epidemiological Study

1) The participation of companies in epidemiological study remained relatively simple, with a focus on providing technology support directly to relevant research institutions, such as supercomputing, artificial intelligence, and big data analytics. These cases shared many similarities;

2) The difficulties and challenges in the use of the technology are mostly problems of the technology itself, such as optimization and enhancement of algorithms, models, and computation power, which are beyond the scope of this case study report.

4.2

Value of Digital technology in Epidemiological Study

4.2.1 To the government

The use of digital technology in epidemiological study has accelerated the understanding of viruses, and in this case, SARS-CoV-2. It has allowed more timely interventions and regulations from the government to control the viral transmission and to manage the spread, delineating the relationship between SARS-CoV-2 and other viruses. This has helped develop more specific prevention and control strategies and policies. In addition, through more accurate predictions on the virus mutation, trends, and scale of transmission, the government can proactively prepare strategic plans and policies to mitigate the foreseeable risks in the future, and to minimize the potential devastation caused by the outbreak.

4.2.2 To the healthcare system

For the healthcare system, the use of digital technology in epidemiological study has improved the capacity of diagnosis and treatment. On one hand, the rapid sequencing of virus and the optimization of sequencing capabilities can improve the efficiency and quality of virus detection in health care and disease control. On the other hand, the use of digital technology in viral proteins can provide a structural understanding of the viral pathogens, and screen for potentially effective drugs from already developed drugs. This allowed medical institutions to experiment with different targeted treatments using tools available, thus optimizing treatment plans and improving outcomes. Ultimately increasing efficacy and efficiency in the healthcare system.

4.2.3 To the industry

Pharmaceutical companies have been using digital technology for drug research and development for many years. Due to the nature of the Covid-19 outbreak, the value of digital technology in drugs and vaccines development and research for SARS-CoV-2 is amplified. The rapid screening of literature and experimental data to identify potential viral targets and chemical compounds has set directions for developing specialty drugs and vaccines. The use of digital technology has significantly accelerated the drugs

Epidemiological Study

and vaccines research and development processes, enabling pharmaceutical companies to complete the development process in the shortest possible time and at a lower cost.

4.3

Limitations and Challenges

4.3.1 Predictive models have more academic research significance than their practical value

As computer models use available data and algorithms to make predictions of viral mutations and epidemic trends, they can only produce the most likely similar results based on model calculations and are not representative of actual developments. In reality, human interventions and non-human contingencies can lead to many variables that make it more difficult for predictive models to accurately reflect future epidemic progression. Although references can be made from these predictive models in policy making, actual policy decisions require comprehensive consideration of social, environmental, and economic factors. Therefore, such predictive models carry more academic research value than actual practical bearings.

4.3.2 Computing power resources require further optimization

During the outbreak, in order to improve efficiency of epidemiological study,

computing power has become an important and widely used research resource. Many technology companies had proactively provided technology and technical support in sharing computing capabilities with relevant research institutes to empower the research of SARS-CoV-2. Under such circumstances, government and relevant departments should better mobilize and distribute the existing available computing resources according to the computational difficulties and level of urgency, in order to enhance the utilization of the computing resources. In the future, computing resources will become increasingly important. Therefore, government should establish a more holistic computing resource coordination system in preparation for future public health emergencies.

4.3.3 Nominal business value

Aside from drugs and vaccine research and development, other dimensions of epidemiological study do not have a mature business model and commercial value. Technology, such as big data, artificial intelligence and supercomputing, require large investments. Yet, these do not guarantee to generate revenue, especially during a pandemic outbreak. It is also difficult to rely solely on technology companies to fully devote support on epidemiological study in the long run. Therefore, the government and other social enterprises should recognize the value and necessity of the technological companies' input in epidemiological study and should provide appropriate support.

Epidemiological Study

By promoting and fostering a mutually beneficial relationship between technology companies and research institutes, the quality and efficiency in epidemiological study can be sustained.

DIAGNOSIS & TREATMENT

5

Diagnosis and Treatment

Diagnosis and treatment involve the contact between medical personnel and patients, which is an important part of outbreak prevention and control. In order to improve the utilization efficiency of medical resources, avoid cross-infection, and meet the needs of medical services, the application of data networks, the Internet, artificial intelligence, 5G, and other technologies in this field is worth studying.

5.1

Digital Technology in Diagnosis and Treatment

5.1.1 Set up remote diagnosis and treatment

During the Covid-19 outbreak, a large number of patients emerged in high-risk areas, but the number of medical institutions and doctors could not meet the rapidly growing demand for medical services. Furthermore, during the examination process, close contact was extremely likely to cause cross-infection. In other areas, the medical resources for non-communicable diseases have been squeezed. Meanwhile, to avoid cross-infection, medical institutions set limitations on the number and manner of face-to-face diagnosis and treatment, which makes it difficult to meet public needs on medical services. Advanced technologies such as data networks, the Internet, artificial intelligence, and 5G helped gather doctor resources across the country. Through online consultation, remote diagnosis, and intelligent identification, the diagnosis and treatment capabilities and efficiency of frontline medical institutions were improved, contributing to meeting various medical needs of the public.

For instance, United Imaging provided digital imaging equipment to Wuhan modular hospitals in the early stage of the outbreak to help realize the remote diagnosis and scans, and thus reduce the risk of disease transmission between doctors and patients. Taking the advantages of 5G for being high-bandwidth and low-latency, China Telecom and other Internet service operators built a Covid-19 Teleconsultation Platform with tertiary hospitals as the core, radiating to other medical institutions around the region. WeDoctor, an Internet hospital, provided patients with Covid-19 diagnosis and treatment services through online consultations, under-took the medical needs of patients with common chronic diseases, and established a psychological assistance section to provide free psychological consultation and professional counseling services.

5.1.2 Assist the management of home care

The guidelines issued by the World Health Organization indicated that when hospitalization conditions were not allowed or unsafe, and medical resources were insufficient, home quarantine should be considered for suspected patients with mild symptoms. The Internet and artificial

Diagnosis and Treatment

intelligence connected multiple health service providers such as knowledge publishers, Internet hospitals, and offline tertiary hospitals to provide patients with convenient, scientific, and comprehensive home care knowledge and supporting services.

For instance, MedLinker, Zuo Shou Yi Sheng, and other intelligent medical platforms launched service programs for home quarantine, including intelligent screening and pre-diagnosis, intelligent check-in, and medicine delivery. In addition, the intelligent medical platform also provided knowledge to the public.

5.2

Case Study II: United Imaging

ABOUT United Imaging

United Imaging Healthcare Co., Ltd. (United Imaging) is a professional advanced medical imaging company covering imaging diagnosis and treatment and offers innovative medi-cal information technology solutions. United Imaging is an exceptional company that develops and produces a full portfolio of advanced medical imaging and radiotherapy equipment. Its portfolio encompasses several advanced imaging specialties, including modular imaging (MI), positron emission magnetic resonance (PET/MR), computer tomography (CT), magnetic resonance imaging (MRI), X-Ray, radiotherapy (RT), medical software (HSW).

[1] BACKGROUND: Imaging Diagnosis Served a Crucial Role in The Management of Covid-19

Bounded by the limitations of Covid-19 nucleic acid tests, including the insufficient supplies and limited number of laboratories, as well as false positives caused by inappropriate handling of the nucleic acid test kits and varied qualities of test kits, many suspected Covid-19 patients failed to receive timely and accurate diagnosis.

As Covid-19 is an acute respiratory infectious disease, thoracic imaging played a crucial role in the diagnosis of suspected cases and the disease progression monitoring in severe cases. The National Health Commission (NHC) has highlighted the importance of thoracic imaging in the diagnosis of Covid-19 in the Diagnosis and Treatment Protocol for Novel Coronavirus Pneumonia (Fifth Edition). The protocol stressed that thoracic imaging would be the standard diagnostic tool for Covid-19, rather than relying on nucleic acid test results only.

In the Diagnosis and Treatment Protocol for Severe and Critical Cases of Novel Coronavirus Pneumonia (Second Edition), the NHC also emphasized that thoracic imaging allowed early identification of severe Covid-19 cases. CT became a commonly used imaging method and was widely used in the diagnosis and disease monitoring of Covid-19 patients. A research study led by Prof. Zhong Nanshan, a prominent epidemiologist and pulmonologist and lead medical advisor

Diagnosis and Treatment

for China during Covid-19, had a sample size of 2866 cases of Covid-19 patients. Among the 2866 Covid-19 cases, 2528 (88.2%) detected abnormalities from CT scans, including bilateral or unilateral ground-glass appearance and opacities. Majority of the cases with pulmonary abnormalities detected by CT scans was subsequently confirmed as Covid-19 cases.

[2] CHALLENGES: Rapidly Increasing CT Scan Demands During the Outbreak

The role of CT scans to detect Covid-19 is irreplaceable. However, it is demanding in terms of technology and professional personnel. As Covid-19 cases rose exponentially across the country, so did the demand for the CT scans. The capacity across the country during this period was unable to meet the needs. The challenge manifested in three facets:

[2.1] Lack of CT scan capacities in modular hospitals

During the critical period of the Covid-19 outbreak in China, in response to the National government's call for "Admitting all where and when possible to avoid missing even a single patient", a series of modular hospitals were constructed. The modular hospitals not only alleviated the shortage of medical resources, especially in Wuhan City, but also provided a refuge for the mild Covid-19 cases who were unable to seek treatment in other hospitals. 16 modular hospitals were built in Wuhan City. 15 were used since the first modular hospital began operations on February 5, 2020. On March 10, 2020 the last modular hospital was finally put to rest. A total of

13,400 hospital beds were available for admission of 12,000 mild Covid-19 cases. Because of its temporality and short construction period (the shortest duration to construct a modular hospital took only 20 hours), modular hospitals were not designed to equip with high quality hardware facilities and professional clinical teams, comparing to regular hospitals. However, as CT scan was proven and assigned to be a critical method to support clinical diagnosis and managements of Covid-19 cases, there was an urgent need for rapid establishment of radiological departments in the modular hospitals.

[2.2] Risk of transmission during CT scans

In standard CT scan sessions, medical professionals need to be in the same room as the patients in order to aid the positioning of the patient to ensure adequate and acceptable imaging quality. The space in the CT scan rooms are restricted and enclosed, forcing the patient and the medical professionals to be in close contact with each other. With Covid-19 highly human to human transmittable, this greatly increased the risk of spread. Despite the efforts in many hospitals to minimize the risk of transmission by implementing infection control protocols in radiological departments, transmission was inevitable.

[2.3] Limited radiologist capacities to interpret CT images

Shortage in radiologists has been a persistent issue in China. Studies showed that the radiological demand increased at

Diagnosis and Treatment

an annual rate of 30%, while the annual growth rate of the number of radiologists was only at 4.1%. In addition to the number of radiologists, the levels of their expertise also varied, which further affected the efficiency and accuracy of diagnosis. Reading the images and reports are time consuming as well. Statistically, a senior radiologist spends on average 7 to 8 minutes to read a CT report. In other words, it would take over 12 hours to read a total of 100 reports. At the peak of the outbreak in Wuhan City, these aforementioned limitations exacerbated the existing challenges for the epicenter. As a result, it was vital to explore means to better mobilize the limited resources, and to better utilize artificial intelligence to improve the efficacy and accuracy of radiological diagnosis of Covid-19 cases.

[3] SOLUTION: The Remote Diagnostics Platform by United Imaging

In order to tackle the three challenges described earlier, United Imaging offered a software-enabled, end-to-end remote diagnostics solution to improve the CT image diagnosis processes. This solution empowered Wuhan City's imaging examination in three aspects: the design and construction of a modular CT "Emergency Radiology Department" for the modular hospitals, remote Covid-19 diagnosis platform, and artificial intelligence-enabled image diagnostic systems. The holistic end-to-end solution leveraged medical big data, cloud platforms, artificial intelligence, and 5Gnetworks to provide high quality and fast imaging diagnosis for patients.

[3.1] Emergency radiology department in modular hospitals

United Imaging designed a fast, agile, mobile and smart radiology solution called United Imaging Modular CT "Emergency Radiology Department", hereafter known as Emergency Radiology Department (ERD). The ERD piloted at the Wuhan City Jianghan Modular Hospital. It accomplished close to two hundred CT scans for Covid-19 patients on the first day of its operation. The ERD comprised of a set of essential technologies including individual CT suits, operation rooms, and ultraviolet disinfection devices. Architecturally, the ERD is a box-like structure independent from the modular and regular hospitals. It is designed to be easily assembled and transported, occupying a small area of merely 20 square meters and requires only electricity to operate. Furthermore, it is waterproof, heat-isolated, and isothermal, which allows smooth operation even under extreme weather conditions. The ERD was designed to be a great frontline solution in times of crises.

United Imaging's first and foremost considerations when designing the ERD was radiation isolation and on-site assembly. United Imaging team needed to make sure the CT scanner chosen is compact, easy to transport and assemble, as opposed to the high-end CT scanners that are usually large and immobile. The team collaborated closely with Wuhan City's local government, engineers and designers to continuously refine the ERD. Together, they effectively shortened the assembly duration, from 3 days to 24

Diagnosis and Treatment

hours. By the end of March, United Imaging provided Wuhan City government with 61 CT scanners and 27 mobile DR devices during the outbreak, and drastically advanced the imaging diagnosis capacities in the city.

[3.2] Data networks and remote diagnostics platform for Covid-19 imaging screening

The ERD provided a foundational hardware for the modular hospitals. On this basis, United Imaging utilized cloud computing platforms to provide an all-inclusive workflow for close-loop remote diagnostics, including imaging scans, quality control, diagnostics, review, and data transfer. United Imaging collaborated with partners to use cloud platform technology, building upon Wuhan City's Medical Cloud Network, to support remote imaging diagnosis for Covid-19. At the same time, Wuhan City's local government assigned specific hospitals as the designated locations to use remote diagnostics for Covid-19 cases, further optimizing the allocation of the already limited radiology examination resources.

Secure and efficient data transfer is a prerequisite of remote diagnostics. As the majority of modular hospitals were converted from existing public facilities (i.e. sports stadiums and exhibition centers), the internet networks in these facilities were unable to meet the requirements of medical data transfer.

Hence, United Imaging collaborate with multiple Chinese telecommunication companies to use the latest 5G technologies to build medical data transfer systems for the modular hospitals. Leveraging the power and the efficiency of 5G technologies, the speed of data transfer was four times faster than the traditional networks, while still ensuring data security and data storage.

Wuhan Medical Cloud Network is mainly comprised of the city's Medical Private Network Platform and its Medical Imaging Cloud Platform. Raw clinical data first enters the Medical Private Network Platform, and then connects to the Medical Imaging Cloud Platform. Radiologists across different geographies have access to this Platform to read and perform remote diagnosis, and then transfer the data back to the patients' hospitals. Through the closed-loop process, the city's Medical Private Network Platform took responsibilities in data security and data transfers. The Medical Imaging Cloud Platform safeguarded the legitimacy and privacy on the cloud. The precise and effective online network was accredited to the existing digital medical system development in Wuhan City. The city has had a city-wide online medical data system infrastructure in place before 2019, interlinking most of the public hospitals through its online system. United Imaging's Remote Diagnostics Platform served as an extension to the city's Medical Private Network Platform and its Medical Imaging Cloud Platform (Figure 3). Wuhan Municipal Health Commission mobilized and coordinated hospitals to improve resource utilization. They arranged designated partnerships between the offering and receiving hospitals for

Diagnosis and Treatment

Medical Cloud Network

Wuhan Medical Private Platform

Wuhan Medical Imaging Cloud Platform

Helper Hospitals (Wuhan and National Tertiary Hospitals)

Recipient Hospital (eg. Modular Hospital, Primary care centres)
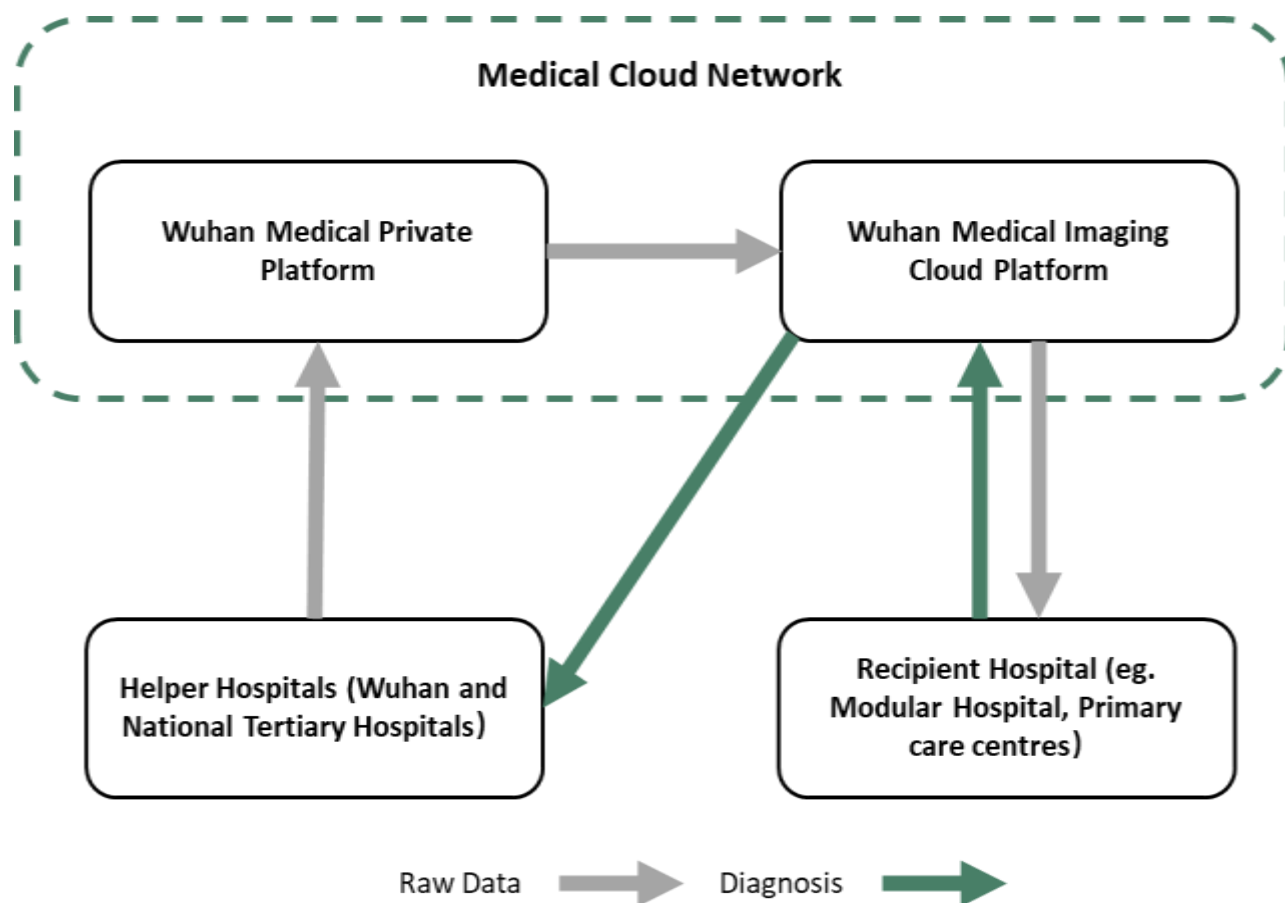
Raw Data → Diagnosis →

Figure 3. Components and operation of Wuhan Medical Cloud Network

remote diagnostics, switching from multi-directional partnerships to designated bi-directional partnerships, clarifying roles and task division. Such designated partnerships minimized the chance of repeating and neglecting tasks, and ensured the effective triage and diagnosis of patients. The designated partnerships were not limited to hospitals within Wuhan City, but opened to the rest of the country's tertiary hospitals. The supporting tertiary hospitals from other regions offered their support in remote diagnostics through connecting the hospitals' medical data systems with Wuhan City's Medical Cloud Network. Taking Donghu district in Wuhan City as an example, United Imaging bridged nine community hospitals with Wuhan's Third People's Hospital (Guanggu Hospital), and helped conduct over 14,000 remote diagnosis. Remote diagnostics played an instrumental role in outbreak control by offering timely and accurate diagnosis to support efficient decision-making.

[3.3] uAI Smart System by the United Imaging

Artificial intelligence offered powerful support in the remote diagnosis of Covid-19 cases, especially in the area of radiology, quality control, and diagnostics. United Imaging's uAI Smart System for remote diagnostics is comprised of two components, the Sky Eye Smart Platform and the Smart Assistance Analytics System.

Diagnosis and Treatment

When using the ERD and operating its AI function, the Sky Eye Smart Platform will conduct facial and body recognition on the patients without removing their masks to ensure they are properly situated for the CT Scan. The radiologists can also perform the CT Scan remotely in an isolated operation room without entering the ERD. This greatly reduced not only the operation time, but also the risk of transmission. The enhanced workflow facilitated smooth operations, and hence allowed a larger quantity of scans. It is worth mentioning that the Sky Eye Smart Platform was not created specifically for the Covid-19 outbreak. It was originally designed for China construction of a tiered diagnosis and treatment system, as part of the remote patient CT Scans guidance to reduce the number of doctors required at the primary hospitals. The timely implementation of Sky Eye Smart Platform during Covid-19 outbreak has provided additional advantages in reducing the risk of disease transmission, as well as containing the outbreak.

During imaging diagnosis of Covid-19, how to diagnose with more accuracy, at the same time to assess disease severity while facing various images with atypical lesion features was a pressing issue. As a result, United Imaging designed and built the Smart Assistance Analytics System and **embedded in the Wuhan City's Medical Cloud Network, to increase doctor's** diagnosis efficiency. The Smart Assistance Analytics System was also developed to be compatible with various brands and models of CT Scanners. Using highly sensitive detection algorithms, subtle and minute lesions can be detected and automatically labelled to assist doctors in screening, diagnosing, and prioritizing suspected positive cases. In addition, for confirmed cases, the System can evaluate and provide gradings according to the Covid-19 Severity Index. During the outbreak, combining clinical features, the System categorized the Covid-19 cases into mild and severe categories to triage and formulate treatment plans. On each image, the System would display the automated labelling of pulmonary radiological abnormalities, anatomical location, estimated area of pathology, and comparisons with scans in the database. The information provided valuable references to doctors in diagnosing and evaluating each Covid-19 case. In the long run, the accumulation of medical big data on the platform can provide valuable basis for developing radiology guidelines and protocol for Covid-19.

[4] DISCUSSION

United Imaging's Remote Diagnostics Platform was a cornerstone in combating the Covid-19 outbreak in Wuhan City. United Imaging was faced with many challenges and difficulties in the execution and implementation of the platform, such as supply chains, logistics, and access resources. To overcome these challenges, United Imaging negotiated and liaised with partners in the gaming industry and the government to enable steady and speedy implementations. To date, United Imaging continues to improve the Remote Diagnostics Platform to combat the Covid-19 pandemic worldwide.

Diagnosis and Treatment

[4.1] United Imaging's key success factors

[4.1.1] Technical resource capacity

United Imaging's Remote Diagnostics Platform employed many advanced technologies in advanced imaging, artificial intelligence, and telecommunications. The rapid adjustments and coordination were enabled by the huge capacity of technical resources and expertise United Imaging already possesses. In advanced imaging, United Imaging housed a wide variety of CT imaging facilities, which allowed swift selection of the best set of hardware equipment suitable for the ERD. In artificial intelligence, United Imaging gained competencies in the uAI intelligence system. They finetuned the system for rapid diagnosis of Covid-19 cases. In telecommunications, major Chinese telecommunication companies are in mature stage of development of 5G technologies. When processing the large amount of data in medical imaging, the key characteristics of 5G technologies, including high speed, broad bandwidth, and high securities, allowed efficient and secured medical data transfer.

[4.1.2] An established medical informatics infrastructure

Wuhan City has one of the most ideal medical informatics systems in China. In accordance to the national direction to digitalize medical data, Wuhan City has had a basic online medical informatics system in place since 2019, which later became a major component in the Wuhan Medical Cloud Network. Therefore, United Imaging's Remote Diagnostics Platform can merge with the existing online medical informatics network with minor modifications, without the effort to build one from scratch. Building the infrastructure for a regional medical informatics system is complex, time-consuming, and technically challenging. Without the existing medical informatics system of the city, United Imaging could not have established the Remote Diagnostics Platform for Covid-19 within such limited time.

[4.1.3] Rapid decision-making and response

With rapid development in Covid-19 outbreak, United Imaging executed rapid decision-making and response process beyond commercial logic. At the early onset of the outbreak, United Imaging immediately mobilized its entire resources to fight against Covid-19, hastened the decision-making process with the top-down approach for quick execution. The selflessness and bravery of the employees of United Imaging, and the generosity of the company to donate an array of medical resources reflected the determination of United Imaging to prioritize public well-being before the company's commercial benefits.

[4.1.4] Collaborate and government partnership

The construction and implementation of United Imaging's ERD for modular hospitals and its Remote Diagnostics Platform for Covid-19 involved several

Diagnosis and Treatment

government departments, including the **Wuhan City's Municipal Health** Commission, Civil Affairs Bureau, Municipal Development and Reform Commission, and other local governments. Close collaborations between these departments and United Imaging was the key to accomplish such complex undertaking. Prior to the Covid-19 outbreak, the collaboration between United Imaging **and Wuhan City's government on the** Wuhan Medical Cloud Network had already fostered trust between the two institutions. During the lockdown of the city, without any air and rail transportations, United Imaging faced an unprecedented challenge in importing the construction materials, equipment, engineers, operators, and suppliers into Wuhan City to build the ERD for the modular hospitals, as well as the Remote Diagnostics Network. During this critical period, United Imaging proactively engaged the local government at different levels to negotiate logistic plans to facilitate transportations. The relevant government departments offered invaluable support and coordination and opened a green channel for United Imaging to effectively resolve any abrupt changes during the transportations, and to ensure the smooth passage of resources and manpower to enter Wuhan City.

[4.1.5] Collaborations between various government departments to mobilize medical resources

As the outbreak progressed rapidly, there was overwhelming workload across different governmental departments and hospitals to react urgently to the crisis.

Effective collaboration with United Imaging and different government departments was paramount in implementing the Remote Diagnostics Platform for Covid-19. The construction of the ERD and the Remote Diagnostics Platform required various government departments to collaborate and coordinate medical resources, construction, and logistics support. Relevant government departments also needed to efficiently mobilize medical resources through designated locations and provided administrative level guidance for hospitals to accept and adopt the Remote Diagnostics Platform, eliminating any potential obstacles for implementation.

[4.1.6] Supply chain security

During the outbreak, most of the manufactures were closed, the supply chain for both medical imaging equipment and ERD construction was in great uncertainty. Any hurdles in the supply chain can greatly impact the efficiency of the construction of the ERD and the Remote Diagnostics Platform. To tackle this challenge, United Imaging negotiated with suppliers genuinely, and with its existing reputation, United Imaging was able to influence and empower the suppliers to join its mission and fight against Covid-19.

[4.2] Necessary conditions to replicate United Imaging's solutions

United Imaging's efforts in Wuhan City was successfully implemented because of the aforementioned key success factors.

Diagnosis and Treatment

However, in order to replicate United Imaging's efforts in other regions, three factors will be indispensable: 1) telecommunication and informatics capacities; 2) professional medical equipment and personnel; 3) financial sustainability.

[4.2.1] Telecommunication and informatics capacities

United Imaging's work demanded high telecommunication and informatics capacities. Telecommunication capacities were used in the validations in medical data transfer between offline medical data and online Medical Cloud Networks. Information technologies were used in data processing and data management in the remote diagnostics. By building informatics systems and platforms, medical data were able to be further analyzed.

[4.2.2] Professional medical equipment and personnel

Remote Diagnostics Platform requires professional medical equipment and personnel. Imaging facilities and equipment determined whether a patient can receive timely radiological diagnosis and contribute towards medical data source. At present, AI technology is still an auxiliary tool, therefore it cannot completely replace radiologists' diagnosis. Therefore, radiologists needed to be remotely operating the Remote Diagnostics Platform. The lack of professional medical equipment and personnel will directly hinder the implementation of Remote Diagnostics Platform.

[4.2.3] Financial sustainability

The implementation of United Imaging's efforts required resources, equipment, technical expertise, and a sizeable amount of financial reserve. Regardless of forms of financial support, whether it is collaborative donations or government purchases, the demand for financial capacity from United Imaging was still high. As a result, any spending needed to be monitored stringently to avoid any possible hiccups caused by funding gaps.

[4.2.4] Overall planning

The hardware construction, software configuration, and resources coordination involved in United Imaging's Remote Diagnostics Platform required close collaboration and communication among all stakeholders. This requires one party to undertake the overall coordination, to monitor and to push forward the implementation. In this case, the party was Wuhan City's local government. Therefore, in order to replicate United Imaging's work, the coordinator needs to have strong execution and supervision capabilities, to guide the orderly participations of stakeholders. At the same time, this role needs to have enough authority to assemble and reallocate medical resources.

[4.3] United Imaging remote diagnostics platform and current stage of development

During the Covid-19 outbreak, United Imaging provided hardware and software support in medical imaging for Wuhan City

Diagnosis and Treatment

and the rest of the country, accumulating much experience in tacking pandemic crisis. Combining with its rich technical reserve and the determination of the entire team to fight against the pandemic, United Imaging developed comprehensive end-to-end solutions specifically for the imaging diagnosis of Covid-19. Currently, the outbreak in China has somewhat stabilized, United Imaging is proactively sharing its solutions with countries still fighting against Covid-19 to empower them with imaging diagnosis capacities. For instance, United Imaging visited Iraq with the National team in March 2020 to share their experiences, and donated its ERD and digital mobile DR. On April 7, 2020, United Imaging sent the mobile digital CT Scanner to the epicenter of New York City. It served as the first 24-hour mobile digital CT Scanner for Covid-19 in the United States, and operated in Maimonides Medical Center, the largest hospital in Brooklyn, New York.

5.3

Case Study III: WeDoctor

ABOUT WeDoctor

WeDoctor is a healthcare technology platform of Guahao (Hangzhou) Technology Co., Ltd. that provides users with new "online + offline, general + specialized" healthcare services. In 2015, WeDoctor established Wuzhen Internet Hospital, the first Internet hospital in China, and has launched branches in 19 cities and provinces. It has also forged medical

treatment partnerships with over 100 domestic hospitals, and established 19,000 healthcare service outlets including WeDoctor general practice centers, community healthcare centers and pharmacies. With its hardware and software terminals, WeDoctor provides hundreds of millions of families with quick access to 24/7 complete healthcare services. By May 2018, WeDoctor had built up an "online + offline, general + specialized" medical supply system involving more than 2,700 key hospitals and 240,000 doctors in 30 Chinese cities and provinces. The number of real-name registered users had exceeded 160 million, with a total of over 580 million people benefiting from its services.

[1] BACKGROUND: The Medical Demands of Various Population Groups During Covid-19 Have Been Met by Internet Healthcare

The epidemic disrupted the normal order of medical services, leading to discontinuation of many existing medical services (including inquiries for common diseases, revisits and maintenance medication for chronic diseases, etc.), and increasing demands for new medical services (such as medical demands of people in home quarantine, diagnosis demands of suspected Covid-19 patients, and psychological counseling demands of the public). Internet hospitals and medical platforms provide services such as free virtual consultation, online self-examination, teleconsultation and family healthcare guidance through remote technologies. These have alleviated the

Diagnosis and Treatment

shortage of offline medical resources, helped satisfy the medical demands of various patients, and allayed the panic among the public.

[2] CHALLENGE: During the Epidemic, Medical Resources Couldn't Satisfy Various Medical Demands of Different Patients

Since January 2020, the rising onset of Covid-19 was accompanied with travel restrictions, medical resources shortage, and increasing medical demands of patients and general public. Specifically, the medical demands of various population groups during the epidemic include:

[2.1] Basic medical demands of the public could not be met because they were scared to seek treatments in medical institutions, for fear of cross infection

During the peak of the epidemic, people could hardly go out because of strict local travel restrictions, and medical institutions were crowded with Covid-19 patients. If there were any basic medical needs, such as common colds, inflammation, or minor cuts, people stayed home and purchased over the counter products online. This affected the living quality of local residents, and might have exacerbated potential health issues.

[2.2] Medical resources became scarce for patients with noninfectious chronic diseases, leaving their demands unmet

With medical resources prioritized for diagnostics, treatment, prevention and control of Covid-19, the supply of medical services for patients with non-communicable chronic diseases became secondary. With nationwide practicing home quarantine, reduced outpatient services at non-designated Covid-19 hospitals, and fear of transmissions at hospitals, many patients with chronic diseases were not able to receive proper care. Moreover, with traffic control during Covid-19, logistics supply became unstable, making the situation more miserable for these patients. Patients with cancers, diabetes and other diseases gradually became desperate for their medications and treatments.

[2.3] While hospitals were over-capacity, the medical demands of patients with mild or suspected Covid-19 symptoms could not be fulfilled

The clustered outbreaks of Covid-19 caused a shortage in medical resources. Medical institutions in the affected areas quickly became overwhelmed. While institutions in non-affected areas, for fear of hospital infection, strictly prevented clustering of patients. In these situations, medical demands of patients with mild or suspected Covid-19 symptoms could not be met. Some people with Covid-19 like symptoms could not seek treatments due to hospital restrictions or limited medical resources, while some would not go due to fear of transmission.

[2.4] Public demands for mental health emerged

New public demands emerged from the

Diagnosis and Treatment

epidemic, such as mental health related services. Many people had not expected the epidemic to be so over-whelming. Negativity permeated, causing heavy mental and emotional stress on the public. With the lockdown of Wuhan, and unprecedented subsequent measures taken by the rest of the country, such as the regional containment, people panicked. There were fear and anxiety for themselves or their families and friends over the risk of being infected. There were also feelings of loneliness due to home quarantine, and helplessness due to insufficient medical resources.

[3] SOLUTION: WeDoctor's Internet Medical Service System

[3.1] Supplementary to primary hospitals, mobile hospitals provided basic medical services and Covid-19 screening

To meet the general public's basic medical needs and potential Covid-19 patient's diagnostic needs, WeDoctor provided a unique solution: mobile hospitals. As a special service of WeDoctor, the mobile hospital is a medical treatment vehicle equipped with smart examination and testing system. It also has a cloud-based HIS and health maintenance system, as well as a drug and medical supply system. The mobile hospital covers seven major examination and testing items and 53 minor ones, as well as standard diagnosis and treatment services for 100 diseases. The vehicle functions are similar to the ones in a small secondary hospital, offering blood oxygen, blood routine, urine routine, type-B ultra-sound, ECG, and

other tests. There are also various built-in functions for the doctors, such as AI-based smart auxiliary diagnosis system. This system provides guidance to primary hospital doctors, assisting them to collect medical records, conduct preliminary examinations, basic diagnosis, and simple treatments. For more complex cases, doctors in the mobile hospital can access the built-in laptop in the workstation and send requests to doctors at higher level hospitals for teleconsultation support. If the mobile hospital is an older model or if the local network is unstable, the grass root doctors can log in to the WeDoctor Global Consultation and Prevention Center (GCPC) by scanning the QR code via WeChat to connect with superior doctors. During the Covid-19 outbreak, WeDoctor's mobile hospitals arrived in cities and provinces such as Tianjin, Hubei, Henan, Gansu, Xinjiang and Tibet. The mobile hospitals provided basic medical services for local residents, thereby reduced the flow of patients, and lowered the risks of transmission.

Mobile hospitals also participated in Covid-19 screening. In addition to preliminary screening of residents in the neighborhood, mobile hospitals also took care of the testing on travelers at traffic nodes, and helped disease control authorities with Covid-19 surveillance. To be specific, WeDoctor mobile hospitals became local Covid-19 checkpoints. All drivers, passengers and residents who wanted to pass and enter different jurisdictions had to be tested at the checkpoint locations by the mobile hospitals. The travelers would only be

Diagnosis and Treatment

permitted to move on if results came out normal. If there were suspected patients with high fever and other Covid-19 related symptoms, the information would be submitted to the information system of the mobile hospital, using its AI analytics to assess the situation. For suspicious cases, the doctors would advise the individuals and report to the local disease control authority. To report suspected cases, the **mobile hospitals have a "one-click report"** function in the system. Once the suspected cases are uploaded in the system, the back-end employees will contact local CDCs based on the reported locations. At the same time, doctors working in the mobile hospitals would give self-protection instructions and send potential carriers to designated hospitals assigned by local government, for quarantine and further examination.

Over 80 WeDoctor mobile hospitals were deployed in Gansu, Henan, Ningxia, Hubei and other areas for Covid-19 prevention and control. They were incorporated into the public health and primary medical service systems, as part of the government efforts in epidemic prevention and control. It is worth noting that WeDoctor mobile hospitals, originally served primary medical services, and unable to help with Covid-19 nucleic acid testing as they were not designed with the function of infectious disease testing. However, as epidemic situation stabilizes in China, WeDoctor plans to add this to its mobile hospitals as a key basic function in future. This mainly requires applicable testing consumables to be used in mobile hospitals.
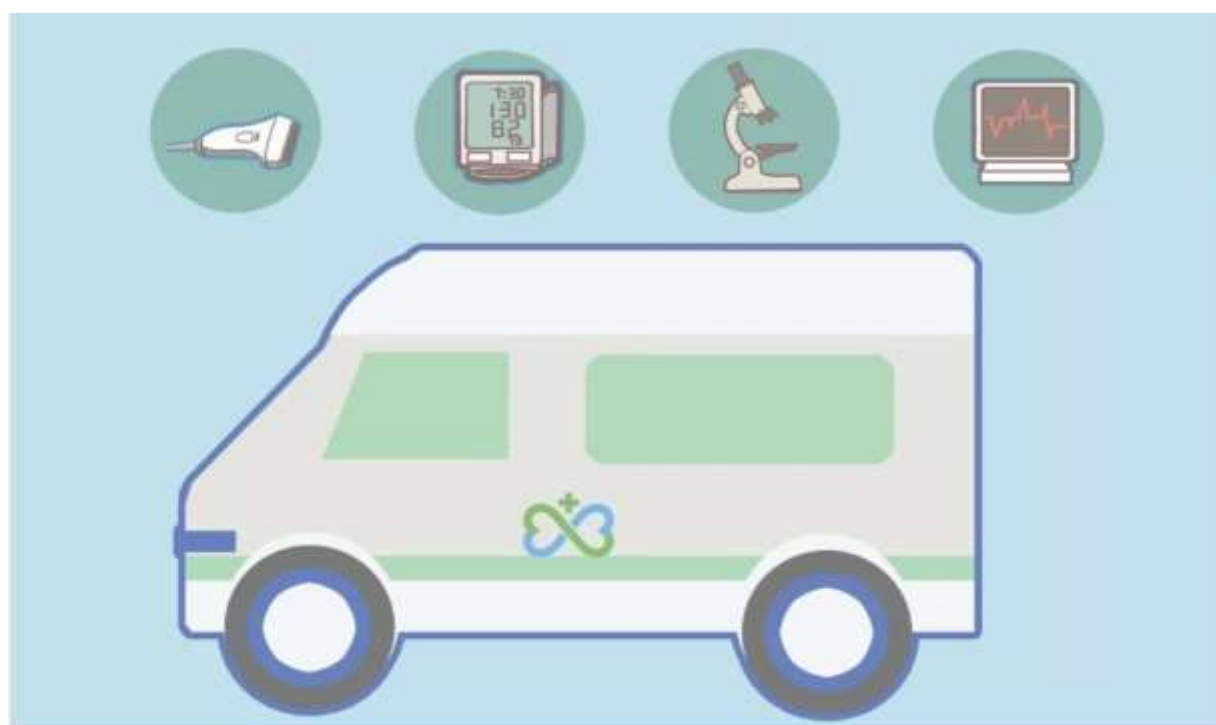
Source: Image the Internet, Available at https://www.sohu.com/a/277506559_685386

Figure 4. WeDoctor Mobile Hospital

Diagnosis and Treatment

[3.2] As the only nationwide online clinic, WeDoctor served the medical demands of a considerable number of patients with noninfectious chronic diseases

To combat the epidemic that swept the country, many tertiary hospitals and infectious disease hospitals have been selected as the first batch of designated Covid-19 hospitals. Before Covid-19, these hospitals provided a wide range of medical services. During Covid-19, they closed general clinics, yet the medical demands of patients did not decrease. To resolve this problem, WeDoctor's online clinic offered specialized treatments, chronic diseases management and drug delivery, providing the much-needed medical support for these patients.

By the end of January, there had been more than 400,000 patients with severe chronic diseases in Wuhan, the first epicenter of Covid-19. However, these patients had to wait for over a month to receive offline prescriptions. Upon the launch of the WeDoctor Smart Clinic, the Wuhan municipal headquarters for the Novel Coronavirus Disease (Covid-19) Epidemic Prevention and Control sent announcements to the entire city via China's top three telecommunication networks. It announced that patients with severe chronic diseases can conduct tele-consultations and apply for medical insurance reimbursement. Merely on January 26, the day WeDoctor Smart Clinic was launched, there were more than 13,000 inquiries, with the total number of inquiries exceeding 26,000 within 24 hours. In comparison, the average number of daily outpatients in Tongji Hospital of Huazhong University of Science and Technology, a Wuhan-based AAA tertiary hospital, is 15,600. It was evident, the medical demands of chronic disease patients in Wuhan during the epidemic were substantial.

Since February 6, the WeDoctor Smart Clinic of WeDoctor Internet hospitals has been successively launched in cities such as Guangzhou in Guangdong Province, Tianjin Municipal City, and Jinan and Tai'an in Shandong Province, providing services such as treatments for common diseases, treatment for revisiting patients with chronic diseases, and drug delivery to more than 100,000 patients.

The purpose of the WeDoctor Smart Clinic is to satisfy the urgent medication needs of chronic disease patients. However, during the epidemic, one of the major challenges for WeDoctor was drug delivery, especially in Wuhan, as the city was in complete lockdown. The outbreak during the Chinese New Year prevented many delivery service workers from returning to Wuhan, reducing delivery efficiency. Meanwhile, the local logistics companies were overloaded with delivery tasks for urgent medical supplies and were unable to help. Facing such challenges, WeDoctor chose to work with local leading courier companies, bypassing retail pharmacies, and deliver drugs directly to patients from its central warehouse. To adjust for this service, WeDoctor allocated a large group of employees in Hubei Province to help with logistics and delivery coordination.

Diagnosis and Treatment

Another major challenge was to identity authentication. It is necessary to authenticate patient's medical insurance identity during inquiry and prescription to mitigate potential insurance fraud. During the epidemic, with support from the National Healthcare Security Administration (NHSA), WeDoctor worked **directly** with Wuhan City's HSA to link their system with **WeDoctor's** medical insurance system. The medical insurance e-certificate enables facial or real name **authentication for the patient's insured** status. This process was aimed to ensure and protect both the patients and the security of medical insurance funds. On the newly-launched Shandong Healthcare Security platform, the historical medication information of a patient in the past 3 months can be obtained within 0.02 second. The whole process, from **authenticating the patient's identity, to** completing all the settlements with the **individual's outpatient pooling account** and personal account, takes less than 3 minutes.

[3.3] Internet healthcare has helped create a closed medical treatment loop, triaging patients to alleviate the stress on hospitals

To tackle the epidemic, WeDoctor Internet **General Hospital urgently launched "Real-**Time Aid Platform for Covid-**19"** (hereinafter referred to as Real-Time Aid Platform or Platform) on January 23, 2020. The key function of the Real-Time Aid Platform is to help triage patients, identify mild symptoms, offering rapid responses to inquiries within 3 minutes. Qualified

doctors were invited to give medical advice on the Platform in their off hours. On one hand, the Real-Time Aid Platform promoted the creation of a complete closed medical service loop that connects Internet hospitals with offline ones. This service enabled patients with common or chronic diseases to access regular medical services without leaving home, thereby reduced unnecessary population flow, and minimized cross infection possibilities. On the other hand, by providing Covid-19-related online consultation or free clinic services to the whole society, the Platform educated the public on self-protection and timely identified patients with mild symptoms.

During the peak of the outbreak, the biggest challenge for WeDoctor was exploring ways to face the soaring inquiry demands and to mobilize medical personnel. Shortly after the Platform was launched, WeDoctor began inviting specialists, such as respiratory, infection, general internal medicine, and intensive care unit, to provide free unlimited teleconsultation services for local residents. 1,500 specialists were selected, out of a pool of 300,000 WeDoctor contracted doctors. Within the first three days of launch, tele-consultation averaged about 10 million times per day. It was clear that the demands were over-whelming and very difficult to meet. Facing this challenge, WeDoctor quickly expanded its doctor base through the following three methods: 1) Widening the selection scope of doctors to any doctor who had experienced rotations in the infectious disease department. WeDoctor rapidly

Diagnosis and Treatment

announced doctor recruitment via its portal to invite more qualified doctors to the Platform, and arranged them to work online immediately; 2) Call out for more doctor participation in tele-consultation in specific communities, such as doctor communities; 3) Recruit through official channels such as local health com-missions of areas with Covid-19 prevention and control needs, including Heilongjiang Province, Shandong Province, Tianjin Municipal City, and Longyan City in Fujian Province. The local Health Commissions of these locations collaborated with WeDoctor, releasing policies to request doctors from local secondary hospitals or above to join the Platform. Some industry associations also offered support. Many local associations such as the Chinese Medical Doctor Association and the China International Exchange and Promotion Association for Medical and Healthcare, helped mobilize more doctors to participate and provide teleconsultation on the Platform.

Based on statistics collected at 11:00 pm on February 5, 2020, the Real-Time Aid Platform operated by WeDoctor Internet General Hospital, had provided medical consultation services to a total of 1.002 million visitors, with the daily treatment capacity reaching 100,000. In comparison, at the end of January, the daily number of outpatients at hospitals with fever clinics in Wuhan was at 10,000. Evidently, the demand for tele-consultation during Covid-19 was much too overwhelming to be handled by local hospitals alone. By the morning of April 12, 2020, visits to the Platform had exceeded 135 million times,

with over 54,000 doctors providing tele-consultation to a total of 1.73 million visitors. During this outbreak, all consultations were free of charge, with the cost equally assumed by WeDoctor and the Minsheng Public Foundation. Though the Covid-19 outbreak has somewhat normalized in China, this Platform is still in service. On June 17, based on the statistics collected, total visits to the Platform had exceeded 144 million times. Over 61,000 doctors provided tele-consultation to a total of 1.968 million visitors.

Source: Image the Internet, Available at https://www.sohu.com/a/277506559_685386

Figure 5. WeDoctor's Internet Medical Services

[3.4] Mental health assistance zone

On the early morning of January 27, 2020, WeDoctor Internet General Hospital launched a mental health assistance zone, in collaboration with the Wenzhou Kangning Hospital Group, the Zhejiang Psychological Health Promotion Association, and the Mindful Heart Power psychologist volunteer team. The services included self-assessment and prognosis, expert consultation, psychological support

services, and 24/7 psychological consultation. The 100-member psychologist team mainly consists of psychiatrists and psychological consultants, over 20% of which are clinicians, providing free consultation services to all users. There are now two services available in the mental health assistance zone: self-assessment and prognosis, and expert consultations. For post-traumatic stress disorder (PTSD), anxiety and depression, which are most commonly observed in the Covid-19 affected areas, users can answer 7 to 17 self-assessment questions as preliminary assessment. Once complete, based on the self-assessment survey, the system will suggest whether psychological consultation is recommended.

[4] DISCUSSION

[4.1] WeDoctor service system's key success factors

WeDoctor Internet hospitals provided a wide variety of services for different population groups throughout the epidemic outbreak. Its services effectively triaged population flow away from local medical institutions and provided services for the non-critical Covid-19 population. The key success factors mainly include:

[4.1.1] High-level policy and funding supports from the government for Internet hospitals, as well as multi-party collaboration

As a link in the healthcare system, Internet hospitals have consistently played an important role in basic healthcare and

telemedicine. With the onset of a major public health emergency like Covid-19, the innovative value of Internet hospitals has truly been realized for the first time. Recognizing the significant role of Internet hospitals during epidemic crises, government departments, such as the National Health Commission (NHC) and the NHSA, issued a series of policies to support the use of telemedicine and Internet hospitals, with WeDoctor leading the fight against Covid-19. The policy support from the top level has expedited local health authorities to work with WeDoctor, and accelerated project implementation. For example, as mentioned above, the local Health Commissions in Heilongjiang, Shandong and Tianjin have released policies to call for participation of local doctors and medical institutions to integrate their online and offline services.

In addition to supportive policies, local governments offered financial and insurance assistance to WeDoctor. During the outbreak, many local governments purchased WeDoctor's mobile hospitals to provide primary medical services to local residents. In Wuhan, medical services of the WeDoctor Smart Clinic were incorporated into the medical insurance coverage, which lessened the financial concerns of patients. In additional to official organizations, some industry associations have also supported WeDoctor with various resources. The Minsheng Public Foundation provided 50% subsidies to the doctors participated in free teleconsultation. Some financial institutions, including the five largest

Diagnosis and Treatment

state-owned banks, Shanghai Pudong Development Bank, China Guangfa Bank, and American International Assurance, added **WeDoctor's** free tele-consultation services page to their official App, extending **WeDoctor's** services to a wider range of population. Many media outlets, such as China Daily, China Economic Net, **People's Daily,** Sina Weibo and Tencent, also participated and voluntarily recommended **WeDoctor's** free tele-consultation services to users, to help WeDoctor widen its coverage. With all these assistances to free tele-consultation services, the WeDoctor Platform has helped more populations in need, which to some degree mitigated much of the epidemic-induced public panic and fear.

[4.1.2] Unique value of platform-based Internet hospitals

In terms of resource mobilization and matching, digital health platforms have realized large-scaled consultation and screening capacity, and contributed to the **improvement of China's public health** emergency system. Generally speaking, due to travel restriction during the outbreak, more and more patients chose to seek treatment and medication services via Internet hospitals, largely increased the relative value of Internet. Moreover, when collabo-rating with local partners, platform-based Internet hospitals can use the same technical and operation system and apply to the local diagnosis and treatment systems. Furthermore, all systems are controlled by the same backend, so that the operation of the local systems can be monitored across various

regions. During the epidemic outbreak, this feature helped WeDoctor understand better the trends of disease prevention and control across different areas, and stay informed of the local demands.

[4.1.3] WeDoctor's solid achievements in building industry infrastructure

WeDoctor leveraged its mature digital platform to create a digital closed loop that links medical services, examination, testing and medical insurance payment services together. Each service is coordinated and connected to ensure the **platform's continuous service capabilities** and to deepen its linkage with industry resources. Therefore, in the face of the unexpected crisis, WeDoctor was able to quickly and sufficiently utilize its digital platform to achieve efficient collaboration with local Health Commissions, healthcare security administrations and medical institutions, making its services synergistic, professional, and easily accessible.

[4.2] Necessary conditions to replicate WeDoctor's model

WeDoctor's success in extending a wide variety of services to different populations in the epidemic lies on the following conditions:

[4.2.1] Digital-enabled telemedicine platform

WeDoctor's various service solutions are based on its existing sophisticated telemedicine platform. The Platform has a solid and powerful foundation. Even with the large-scale usage across the country,

Diagnosis and Treatment

with visits reached the upper limit of the Platform, it can still operate steadily. In addition, communication and information technologies are indispensable for the operation of the telemedicine platform, ensuring effective data transmission and interaction, and smart management.

[4.2.2] Sufficient doctor resources

By signing contracts with doctors, the WeDoctor platform maintains a stable employment relationship with a large number of doctor groups. When a public health emergency arises, such a sizeable reserve can be quickly mobilized. However, it was also due to WeDoctor's industry reputation, the company was able to attract much attention from other non-contracted local doctors, as well as other public and private stakeholders. Through support and collaboration, WeDoctor was empowered to tackle the challenges brought on by the crisis.

[4.2.3] Financial guarantee

Among the services offered by WeDoctor, mobile hospitals are the most expensive and require a high level of financial support. The operation and human costs of the inquiry platform are also two of the key factors for implementation. More importantly, WeDoctor manages to link its services with social insurance in different regions to help support patients with chronic diseases financially. This is a precondition for the success of the WeDoctor Smart Clinic.

[4.3] Social responsibilities and development of WeDoctor Internet hospitals services

In the battle against Covid-19, due to lack of relevant knowledge and insufficient information available, unfounded and unscientific information was propagated via Internet and other channels. In an effort to stop the spread of rumors and provide the public with scientific disease prevention and control information, the Chinese version of the Handbook of Prevention and Treatment of the Pneumonia Caused by the Novel Coronavirus (2019-nCoV) was released on the anti-Covid-19 public benefit inquiry platform of WeDoctor Internet General Hospital on January 27, 2020. In the following week of its release, the handbook was downloaded 342,000 times. On January 29, 2020, WeDoctor published the Handbook of Prevention and Treatment of the Pneumonia Caused by the Novel Coronavirus (2019-nCoV), the world's first public-cation on Covid-19 prevention and control that is written in both Chinese and English. The Handbook can be downloaded for free. By providing foreigners in China and the overseas Chinese with professional, scientific, and informed guidance on Covid-19 prevention and control, this handbook helped the public strengthen self-protection and reduced the risk of disease transmission.

Since March 2020, although Covid-19 outbreak has gradually stabilized in China, there have been multiple outbreaks in the rest of the world. To help the 60 million overseas Chinese and the international

Diagnosis and Treatment

society combat the epidemic, on March 14, 2020, WeDoctor Internet General Hospital, joined hands with China International Exchange and Promotion Association for Medical and Healthcare and China Alliance of Renowned Doctors, launched the Chinese and English versions of the WeDoctor Global Consultation and Prevention Center (WeDoctor GCPC). Together, they also launched a psychological consultation zone. Medical experts at home and abroad are gathered on this platform to provide services targeted at the pandemic crisis, including online consultation in multiple languages to equip the overseas Chinese and other visitors with necessary healthcare information. By June 15, 2020 the WeDoctor GCPC had gathered 10,816 experts, including attending doctors or higher in position from Covid-19 related disciplines, such as respiratory medicine, ENT, internal medicine and general practice, and professional psychological consultants. Over 3.47 million visitors from more than 220 countries and regions had benefited from the free teleconsultation services, accumulating over 14 million visits.

WeDoctor's various attempts to fight Covid-19 leveraging its digital platform throughout the pandemic have been highly praised by the government. The Ministry of Foreign Affairs and over 170 Chinese embassies and consulates overseas have recommended the WeDoctor GCPC via their official websites and social media accounts. They have also placed the information on the top of the service platform list on the overseas

assistance platform sponsored by the NHC.

Since its launch, apart from diligently serving the public at home and abroad, the WeDoctor GCPC has been invited to **vigorously promote and share China's** experience in fighting against Covid-19 with medical professionals across the globe. To date, it has organized 12 online webinars to share experiences in Covid-19 prevention and treatment with medical professionals from countries and regions such as Italy, North America, Germany, Thailand, India, Kenya, Portugal, Uganda and Mexico. Each webinar was viewed for over 10,000 times, on average, and have aided more than 30 countries and regions with their fight against Covid-19.

5.4

Case Study IV: Zuo Shou Yi Sheng

ABOUT Zuo Shou Yi Sheng

Zuo Shou Yi Sheng (ZSYS, or Left-Hand Doctor) is a product developed by Beijing ZhuYi Technology Co., Ltd. It integrates deep learning, big data analytics, natural-language understanding, and medical interactive dialogues to bring smart medical technologies to the healthcare industry. Zuo Shou Yi Sheng (ZSYS) is an open platform which currently covers more than 35 disciplines and consists 6000 common diseases. The platform offers five main services: smart self-diagnosis, smart consultation, smart pre-diagnosis, smart pharmaceutical Q&A, and smart Q&A. Apart from its smart

Diagnosis and Treatment

services, ZSYS also provides its solutions to public hospitals, pharmacies, family doctors, smart technology hardware companies, and information technology firms. An example is its rapid medical treatment solution, which helps patients receive timely treatment before, during, and after the diagnoses. This also helps hospitals accurately receive appropriate patients. Other examples include ZSYS's smart follow-up, rehabilitation guidance, reminders, and health knowledge related services, which help hospitals manage outpatients more effectively.

[1] BACKGROUND: Internet Hospitals Help Reduce and Mitigate Hospital-Acquired Cross-Infections During the Covid-19 Outbreak, Leaving More Medical Resources and Services for The Patients in Need

Patients' demands for medical services increased exponentially during Covid-19. With increased patients and suspected ones crowding hospitals, hospitals and healthcare personnel became overwhelmed, leading to insufficient services and treatments. Internet hospitals, using Artificial Intelligence (AI) technology, offer patients with Covid-19-like symptoms general medical knowledge and self-quarantine instructions. This service not only reduces the risk of Covid-19 patients infecting others, but also breaks geographical boundaries on medical resources, allowing more effective distributions of those resources, thereby eases the stress on the hospitals.

[2] CHALLENGE: Insufficient Medical Supplies Verses Increasing Medical Demands

Panic-induced hospital visits, rising demand for medical services, and finite supply of medical resources were unavoidable challenges during an epidemic outbreak. Facing these problems, the already chaotic hospitals and overwhelmed medical personnel were even more unprepared to properly respond to and manage the flood of suspected patients, discharged patients, and quarantined population. Specifically, there were two main problems:

[2.1] Panic-induced hospital visits cause cross infection

Since the outbreak of Covid-19, panic and fear prevailed in public sentiment. Overwhelmed by the amount of mixed public information and insufficient medical knowledge, the general public was prone to rush to hospitals to consult with experts as soon as they observed any cold-like symptoms. Panic and fear drove crowds to hospitals and increases the risk of cross infection, which further hindered efforts to prevent and control the epidemic.

[2.2] Lack of medical resources to follow-up and effectively manage quarantined and discharged patients

Those who have been in close contact with Covid-19 patients are required to self-quarantine for fourteen days. Those who were under quarantine, however, were unable to receive their medical needs

Diagnosis and Treatment

during this period. Similarly, discharged patients might also require medical follow-ups, yet they were also unable to receive the treatments and care they need. During the early onset and the peak of Covid-19 outbreak, hospitals were over-burdened and found it hard to respond to the medical needs given their strained medical resources, majority of which were prioritized for the Covid-19 patients.

[3] SOLUTION: AI-based "Covid-19 Smart Screening System" and "Covid-19 Smart Follow-up System"

Given the challenges above, ZSYS built upon its existing AI self-diagnosis and guided treatment solutions and developed multiple remote medical services.

[3.1] Covid-19 smart screening system

For suspected Covid-19 patients, ZSYS developed a Covid-19 Smart Screening System that can be accessed and used via WeChat. When patients observed fever, cough, fatigue, nasal congestion and other suspected symptoms of Covid-19, they could use the System to determine their next best steps. The System simulates doctor consultations and generates a final conclusion, including medical and quarantine advices. This prevented people from blindly rushing to hospitals and reduced the risk of cross infection at hospitals.

The system was launched on January 21, 2020. By the end of February, the Covid-19 Smart Screening System has covered over 150 hospitals across 20 provinces in China, with user volume exceeding one million.

[3.2] Smart pre-diagnosis system

Based on the hospitals' requests, ZSYS upgraded and adapted its Covid-19 Smart Screening System as Smart Pre-diagnosis System for the hospitals. The System reduced human resources involved in Covid-19 diagnosis consider-ably, and increased doctor consultation productivity.

In the Smart Pre-diagnosis System, ZSYS added personalized questions to the Smart Screening System for fever clinics, becoming the new upgraded tool. The new upgraded System asks questions based on Covid-19 clinical observations, the virus' development, epidemiological history, and patients' basic disease history. In helping doctors collect key relevant information from their patients prior to the actual consultations, the System drastically saved time and energy for the doctors.

The patients still need to make appointments with the hospitals. However, once a patient books one, he or she can get access to the Smart Pre-diagnosis System. The System is accessible through the hospital's official WeChat account or by scanning the WeChat QR code at the hospital. Patients can then inform the System the reasons behind their hospital visits, and based on that information, the System generates personalized questions about the patient's main symptoms, medical history, allergies, and family medical history. The System then creates an Electronic Medical Record (EMR) for the individual patient, based on the hospital's recording formats.

Diagnosis and Treatment

ZSYS's Smart Pre-diagnosis System utilizes deep learning and other machine learning strategies on large volume of medical literatures and records, creating a reliable network of medical knowledge. This further allows the System to simulate **doctors' logic during medical** consultations and reproduce the consultation process for the patients. At the end of the consultation, the system generates a medical record for each patient. Using the Smart Pre-diagnosis **System increases patient's participation in** the process of diagnosis and allows patients to have some understanding of their own medical status before communicating with their doctors. The System also saves doctors from spending time on writing medical records, thereby improving medical efficiency.

During the Covid-**19 epidemic, ZSYS's** Smart Pre-Diagnosis System helped produce over ten thousand medical records on a daily basis, with less than 10% of the records require corrections. The most basic functions of the system also supported medical photo uploads and past examination records. With the upgrade, the System was programmed to analyze key patient information with these records and prompt new questions based on that information. For the patients, the process saved them from repeatedly entering personal information and medical history. For the doctors, the system helped collect as much outpatient information as possible to support medical decisions and research.

[3.3] Covid-19 smart follow-up system

On February 19, 2020, the National Health Commission (NHC) added a new recommendation to the sixth Covid-19 Diagnosis and Treatment Protocol. The NHC recommended that discharged Covid-19 patients must continue to monitor their own health status for 14 days after their discharge, and the patients must be followed up at the end of the second week and fourth week after their discharge. In response to these new recommendations, ZSYS promptly launched a Covid-19 Smart Follow-up System which helped the hospitals to conduct online follow-up consultations for the discharged patients, offering services such as smart follow-up consultations, disease management and monitoring. The System greatly reduced contacts between patients and doctors, and in turn reduced the workload of hospitals.

The Covid-19 Smart Follow-up System has two components: a patient-facing component and a hospital-facing component. The System can be accessed via either a mobile device or a desktop computer. It is also accessible through the **hospital's public WeChat account. When logging into the hospital's WeChat** account, the user is connected directly to the Hospital Information System (HIS), which then allows hospitals to send follow-up reminders directly to the discharged **patient's personal WeChat account.** AI-powered doctor assistants also regularly **collect patient's information after** discharge, such as symptom changes, contact history, medications, and

examination appointments, and send them **to the patient's doctors, allowing their** doctors to receive up-to-date information and monitor their patients accordingly.

Patients can also sign up and participate in the Covid-19 Smart Follow-up System via short message service (SMS) or scan QR code via WeChat. By signing up, the discharged patients can receive information from hospitals such as their own medical follow-up schedules and recovery progress. On the medical follow-up and management page, patients can **access the hospital's fever clinic internet** consultation services and help doctors better understand their health situation.

[4] DISCUSSION

[4.1] ZSYS's key success factors

During the Covid-19 outbreak, ZSYS developed various solutions catered to different population segments and served over one million users, covering over 150 hospitals across 20 provinces. The main reasons behind its success are as follows:

[4.1.1] Classification of solutions based on different needs

During the epidemic, patients and hospitals have different needs, and ZSYS was able to respond to these needs by separating its solutions into two categories, based on their demand **urgency, impact level, and partners'** expectations. These two categories of solutions are then managed by different product managers: 1) ZSYS updated and developed new solutions based on **patients' and hospitals' feedbacks. For**

instance, after learning about the fact that people flooding to hospitals putting more pressure on medical personnel, ZSYS updated its Covid-19 Smart Screening System to a Smart Pre-diagnosis System to help triage and divert hospital flow. 2) ZSYS also developed new functions for **their solutions based on specific hospitals'** needs and circumstances. For example, when working with Wuhan Tongji Hospital, ZSYS developed the Covid-19 Smart Follow-**up System in response to the NHC's** Covid-19 Diagnosis and Treatment Protocol updates.

[4.1.2] Close collaboration with hospitals in updating its solutions

ZSYS's well-established work relation-ship with multiple hospitals across China became important during the Covid-19 crisis. As hospitals needed to modify its work scope based on the disease development and any government policy changes, ZSYS was able to quickly and accurately understand the changes in demand and develop corresponding solutions for the hospitals. For instance, after the NHC published its sixth Covid-19 Diagnosis and Treatment Protocol, hospitals had to institute follow-up visits for discharged patients and were in need of support from AI and internet technologies to meet those protocols.

[4.2] Necessary conditions to replicate ZSYS's solutions

In order to implement a similar project in other countries or regions, certain conditions need to be considered:

Diagnosis and Treatment

[4.2.1] AI technology as a foundation

During the outbreak, AI and big data technologies helped replace repetitive labor by analyzing past data and quickly finding solutions and predictive measures. In the future, other countries and regions can also incorporate AI technology as needed to improve the efficiency of existing human resources and replace repetitive menial tasks.

[4.2.2] A social media or information platform with high market penetration

One of the reasons that ZSYS was able to reach more than one million users was that it chose WeChat as its launching platform. WeChat has a high market penetration and user volume within China, and is also very user friendly. Users were able to enter the system by simply scanning a QR code via WeChat. Other countries trying to execute similar projects should consider whether such a platform exists within the community. If not, they could consider building a platform for targeted population segments during the outbreak.

[4.2.3] Hospitals need to be equipped with HIS systems

ZSYS was able to link its system to the HIS of the hospitals, which made it easier for the doctors to use as they are already familiar with HIS. Countries or regions without HIS should carefully consider the feasibility of internet hospitals or build temporary data systems in hospitals.

5.5

Value of Digital technology in Diagnosis and Treatment

5.5.1 To the healthcare system

The application of digital technology in diagnosis and treatment effectively eased the imbalance of medical resources during the epidemic, and promoted the development of normalized telemedicine. In the short term, the use of digital technology enabled remote diagnosis and treatment, and thus effectively improved the capacity and efficiency of frontline medical institutions while guaranteeing the safety of frontline medical employees. In the long term, the participation of digital technology also accelerated the pace of normalizing telemedicine. Under the urgent situation of the epidemic, the healthcare system accelerated the sinking of high-quality medical resources to areas through remote consultation and other means, so that critically-ill patients in remote areas can also receive timely and effective treatment. This laid the foundation for the normalization of telemedicine after the epidemic.

5.5.2 To the public

For suspected patients and mild patients who needed home quarantine, the participation of digital technology can provide them with timely, convenient, and reliable home care knowledge and services, reducing both panic and the possibility of transmission to family

Diagnosis and Treatment

members. For non-Coronavirus patients with common diseases and chronic diseases, the participation of digital technology can provide continuous online monitoring, diagnosis and treatment services to help patients avoid being exposed in the crowd and reduce the risk of cross-infection.

technology are not fully available, being able to quickly build a network is currently an urgent problem that needs to be solved. Especially in remote areas where medical resources are scarce and medical experts are in need, the conditions for the rapid establishment of communication and information technology are also lacking.

5.6

Limitations and Challenges

5.6.1 Limitations of online consultation

Due to its own limitations, online consultation can only play a limited preliminary role on screening and pre-diagnosis. Even for offline fever clinics, it will take a long time for doctors to ask patient's previous experiences and medical histories when doing the screening. Although online consultation can help relieve the pressure of offline hospitals and reduce the risk of cluster infection, there may be treatment delay for patients with the Coronavirus due to unclear descriptions of unclear symptoms, and limited time and means for the consultation. Therefore, the areas and modalities of the participation in online consultation need to be further explored.

5.6.2 High technology requirements

The participation of digital technology in diagnosis and treatment relies on high requirements of communication and information technology, such as the teleconsultation based on 5G. In areas where communication and information

SUPPORTIVE
ACTIVITIES

6

Supportive Activities

During the outbreak prevention and control period, timely disclosure and dissemination of information, professional knowledge training, sufficient resources supply, and management of special population groups and other supportive activities are of vital to all sectors of society. In this chapter, the study focuses on how digital technology participates in the following six supportive activity areas during the Covid-19 pandemic: population flow information, information communication, medical personnel training, hospital information, resource supply, social mobilization, and elderly population group management.

6.1

Digital Technology in Supportive Activities

6.1.1 Provide the public with intuitive personnel movement and distribution

Due to the highest contagious nature of Covid-19, avoiding human interactions and crowd gatherings are important measures to prevent large-scale outbreaks. Therefore, information such as the quantity, the direction, and the aggregation degree of population flow is the crucial reference for the public when traveling during the outbreak. Artificial intelligence and big data analysis technology help visualize the flow and distribution of the population, helping the public intuitively understand the relevant information required for travel considerations.

For instance, Baidu Map, Tencent Map, and Amap all launched their own "Travel History of the Covid-19 Cases" thematic maps, "Migration Maps", "Heat Map" layers, "Epidemic Community Map" and other functions.

6.1.2 Provide the public with timely, accurate, detailed, and objective information

Timely and accurate information communication is an important means to ensure the public's emotional stability and social order during a major public health event. It is also a necessary basis for the government to promote unified disease prevention and epidemic control measures. Outbreak news published by new media platforms, such as social media platforms, and news media, can reach a large-scale audience, providing real-time epidemic updates in a timely manner, and deliver official information explanations. This offers public demand for trustworthy and transparent information, while also mitigates misunderstandings and mis-interpretations.

For instance, DXY launched a "Covid-19 Real-time Information Platform", which included modules of "Rumor Dispelling and Self-protection" and "Covid-19 Knowledge"; The "For Truth" channel of Tencent News launched the "Real-time

Supportive Activities

Covid-19 Rumor Dispelling"; **Yidian's "Combat Covid**-19" successively launched **topics including "Real**-time Broadcast for Covid-19 for the Country and Provinces", "Covid-19 Prevention and Treatment & In-depth Analysis", "Covid-19 Rumor Crusher". Tencent Health, Baidu Maps, and Amap develop-ed and launched the "Fever Clinic Map" and provided the public with timely official hospital information. The maps, later in the outbreak, achieved synchronized population flow information.

6.1.3 Provide professional training for medical personnel and disseminates professional public health knowledge to the general public

Covid-19 came without much warning. The medical personnel, especially those on the grassroots level, lacked the relevant knowledge of the virus let alone the capability to manage it. Thus, they urgently needed to supplement professional knowledge, skills, and experience to ensure their own safety, and enhance the effectiveness of prevention and control measures. In addition, as the public generally lacked sufficient public health knowledge, they were easy misinformed by unverified misinformation. Therefore, officials and professional public health experts desperately needed to provide their inputs in order to stabilize public sentiment. The remote communication technology enabled doctors, infectious disease experts, and public health experts in the tertiary hospitals in urban cities to provide online training lectures for a large number of

grassroots medical personnel, and in turn further promote professional public health knowledge to the public.

For instance, DXY launched free public online courses for Covid-19 diagnosis and treatment, providing professional training for medical personnel, conveying public health knowledge to the public; JuniperMD teamed up with China Primary Health Care Foundation and ASK Health to jointly launch charitable live broadcasts on heated topics and public concerns around Covid-19.

6.1.4 Set up the reliable resource supplement and donation platform

The outbreak of the Covid-19 pandemic in China coincided with the Chinese New Year holiday. With supply chains closed for the holiday, the supply of medical supplies was challenged to a great extent. In addition, due to short-age of manpower, resource donations and supplies needed more support for audit and supervision to ensure the quality of the donations. Leveraging the Internet platform, the collection, integration, distribution, and matching of donation information can be completed online, enhancing greatly the efficiency of resource matching for those in need.

For instance, Tencent Charitable, Sina Micro Charitable, Easy Fundraising, Gongyibao, Shuidi Charitable, and many other charitable platforms joined many foundations to launch fundraising for Covid-19. Viewhigh Technology and Yonyou built an efficient emergency

Supportive Activities

materials management platform to achieve efficient docking between hospitals and donors.

6.1.5 Provide assurance for the elderly during this critical period

The elderly population accounts for a high proportion of deaths from Covid-19, therefore, the care management and services of the elderly were crucial during the pandemic outbreak. With measures such as isolation and travel restrictions, routine care services for the elderly were greatly affected. Using ICT technologies such as the Internet of Things and artificial intelligence, remote care, and health management can be carried out to avoid contacts between caregivers and the elderly, while ensuring the quality of care.

For instance, IZhaohu provided remote care for the elderly through smart sensors, movement recognition, data prediction. They also provided online training and support through remote communication technology to enable the family members to take care of the elderlies at home.

6.2

Case Study V: DXY

ABOUT DXY

DXY, founded in 2000, is originally a medical knowledge sharing platform. Its initial goal was to establish a medical professional search website, via which to popularize search experience and knowledge sharing to a wide range of

medical students and medical personnel. At present, DXY has developed into one of the major professional Internet healthcare platforms in China, with high credibility and influence in the field of public health. According to the latest data provided by DXY, its platform has more than 5.5 million professional users, of which more than 1.47 million are certified physicians, covering 70% of physicians across China. The services DXY provides can be roughly divided into four areas: for doctors, for general public and patients, for medical institutions, and for commercial services. Its services include Medicine Assistants, DXY Forum, DXY Public Courses, DXY Podcast, DXY Doctor, DXY Mother, DXY Family, DXY Clinic, DXY Talents, DXY Business Platform, DXY Hospital Library, and Insight Database.

[1] BACKGROUND: Timely and Accurate Communication of Epidemic Information Contributes to Emotion Stability of the Public, While Rapid and Authoritative Training of Medical Personnel Improves the Efficiency of Outbreak Control

The Covid-19 epidemic spread quickly and widely. In the face of an unexpected outbreak, a plethora of information and claims erupted across many platforms and media. Without timely supervision and adequate explanation, the information would be easily exaggerated and misinterpreted. Meanwhile, due to inconsistency in the information and communication platforms used across different regions, the accessibility of information and the frequency of update varied. This made obtaining and following

Supportive Activities

the information on the epidemic situation even more difficult for the public. Consequently, the outbreak information received by the public was markedly divergent, some of which were highly unreliable and distorted, exacerbating public panic and fear. Information communication is an important means to ensure the public emotion stability, especially when a public health emergency arise. It is also a necessary foundation for the government to implement a unified and centrally coordinated response to the outbreak. Therefore, there was an urgent need for the government to timely, accurately and appropriately communicate the outbreak information at the onset of Covid-19.

[2] CHALLENGE: Outbreak Information Was Not Communicated in a Timely and Accurate Manner, and Routine Training of Medical Personnel Was Difficult to Implement

[2.1] Outbreak information was not communicated in a timely and accurate manner

The Covid-19 outbreak affected the entire country. The methods and technology used for communicating information varied significantly across different regions, made it difficult to achieve timely and unified information dissemination right from the beginning. Insufficient and inaccurate information communication also increased the possibility of miscommunication and misinterpretation of information. There were three main problems with information communication during the Covid-19 outbreak:

[2.1.1] There were inconsistencies in the caliber and standard of data reporting, coupled with low levels of information visualization at the beginning of the outbreak

at the onset of the epidemic, the data and information on the outbreak provided by the provinces and municipalities were not standardized and were both complex and diverse. When the public searched for contents on the outbreak, the information was often scattered and complicated, leading to misunderstandings, causing distress and confusions among the public. This was not conducive to the active and effective prevention and control of the epidemic.

[2.1.2] Various false and misleading information appeared during the outbreak

In the early stage of the epidemic, there were many technical terms in the official statements released to the public. Consequently, the statements released were difficult to understand, and sometimes inadequately explained by the officials, with nominal supervision in place. As a result, much information and data were fabricated, replaced, exaggerated, and misinterpreted, some of which were widely posted and forwarded on the Internet and media platforms. This misled the public, especially those who were eager to search for information, resulting in misinformation and misunderstanding, further aggravating the already panicked public. Ultimately, this negatively impacted disease prevention and epidemic control. Even though there were

Supportive Activities

experts available to dispel the misleading information, they usually focused on information that had high social impact. Further, the dispelled information were scattered and more often delayed, leading to inefficient communication to the public.

[2.2] Medical personnel training was in great need, but difficult to carry out during the epidemic

To control the epidemic, rapid and professional medical personnel training could greatly increase the efficiency with which patients are treated. However, due to the urgency of the outbreak and the highly contagious nature of Covid-19, routine face-to-face medical personnel training was difficult to carry out in a timely manner. The Covid-19 epidemic first broke out in Wuhan City and then spread to the entire Hubei province. Many provinces across the country sent medical teams to support Wuhan City and Hubei province. In addition to assisting the treatment of patients and controlling the outbreak from spreading further, these medical personnel also accumulated some experience in diagnosis and treatment. In the midst of a concentrated outbreak, the demand for Covid-19 diagnosis and treatment protocols for medical personnel across the country increased rapidly. Nevertheless, due to high demand and risk of transmission, the medical team in Wuhan City and Hubei Province had to stay put for a long time, it was impossible for them to return to their original hospitals to conduct medical training immediately. As a result, medical personnel outside of Hubei Province were

generally unfamiliar with the diagnosis and the treatment of Covid-19, leading to a certain degree of delay in diagnosis and or misdiagnosis.

[3] SOLUTION: DXY's Covid-19 Real-time Information Platform and Online Special Courses

[3.1] DXY Covid-19 real-time information platform

To resolve the issue of lack of timely and easy to understand communication of outbreak information, DXY established a Covid-19 Real-time Information Platform on January 21, 2020. The platform consisted of four modules: Epidemic Map, Real-time Broadcast, Rumor Dispelling and Self-Protection, and Covid-19 Knowledge. All of the contents were updated and posted concurrently on a designated website for the platform, DXY App, the official public WeChat account of DXY, official Weibo account of DXY, and other major social media platforms. DXY Covid-19 Real-time Information Platform was the first professional platform to collect and integrate Covid-19 data, visualize the data results, and set up a rumor dispelling and knowledge module during the Covid-19 epidemic.

[3.1.1] Epidemic map and real-time broadcast modules

In order to effectively integrate the information on the Covid-19 epidemic from various locations, DXY Covid-19 Real-time Information Platform offered Epidemic Map and Real-time Broadcast modules.

Supportive Activities

The Real-time Broadcast module covered various information on domestic and foreign case notification, travel regulations and restrictions, clinical breakthrough cases and other epidemic related information. Information was updated in real-time, each marked with release time and source. Information was broadcasted in a unified format, with bold headlines and a brief summary below. A link to the source was also provided, allowing readers to grasp the latest information on the epidemic and have the option to view the quick updates or read in depth. Based on the collective information available, readers were able to, and continued to make informed travel or work and life decisions.

The Epidemic Map module was divided into two parts: China and the rest of the world. The outbreak information and data on China came from the official channels of Chinese National Health Commission, provincial and municipal Health Commission, as well as local government

channels. The global epidemic data came from the WHO, authoritative media platforms in China, such as CCTV News and People's Daily, and official websites of health departments around the world. These sources guaranteed the authority and the reliability of the data.

The Epidemic Map provided information on domestic outbreak based on the actual situation of the disease prevention and epidemic control information. There were six key information categories covered. These included cases from existing confirmed, cumulative confirmed, imported, to existing asymptomatic, cumulative deaths, and cumulative cured. Each case was noted clearly with the amount of increase or decrease compared with the day before, as well as the cumulative amounts based on regions. The statistical classification and display of these data could essentially meet the public's need for different aspects on the epidemic. Based on the above six categories of data, there was a map of the
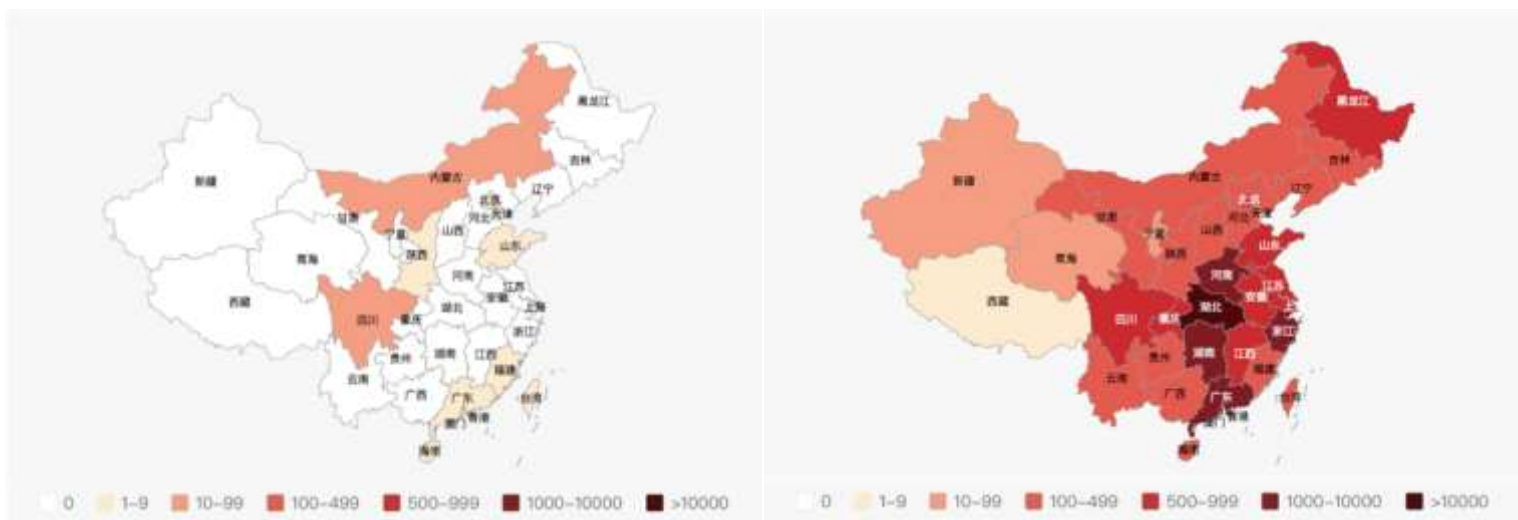

Figure 6. Map of the epidemic in China on June 8, 2020 at 3pm

Supportive Activities

domestic existing confirmed diagnoses (excluding deaths and cures) and cumulative confirmed diagnosed (including deaths and cures), with different colors indicating different severity levels to facilitate the inter-provincial comparison and highlight the key areas for prevention and control in the current and cumulative period.

In addition, the Epidemic Map also produced a domestic epidemic trend map based on the six categories of data and newly confirmed diagnoses. The Epidemic Map compared the various data since the onset of the outbreak, in a longitudinal and time dimensional manner, clearly and visually displaying the progress of the epidemic as well as new issues arise. The visualization of these data not only allowed the public to understand the implication behind the epidemic data more accurately, but also laid a solid foundation for the public to better understand and accept the prevention and control measures, policies, and regulations released by the government, based on these data.

For the epidemic data of key countries around the world, the platform set up tracking four categories of data: current confirmed diagnosis, cumulative confirmed diagnosis, cumulative deaths and cumulative cured cases. Each noted with the amount of increase or decrease compared with the day before. The platform ranked the epidemic situations of key countries in descending order based on their cumulative confirmed diagnosis, and demonstrated their cumulative confirmed diagnosis, cumulative deaths, and fatality rates. Corresponding trend figures of newly confirmed diagnosis were provided for the top eight key countries to intuitively present the epidemic development in those areas. Further, in order to help the users better visualize the outbreak development, comparing prevention and control of the epidemic local and abroad, the platform produced a graph that compared the two. The graph included newly confirmed diagnosis, cumulative confirmed diagnosis, and cumulative deaths on the global scale. Each graph presented two curves, one for
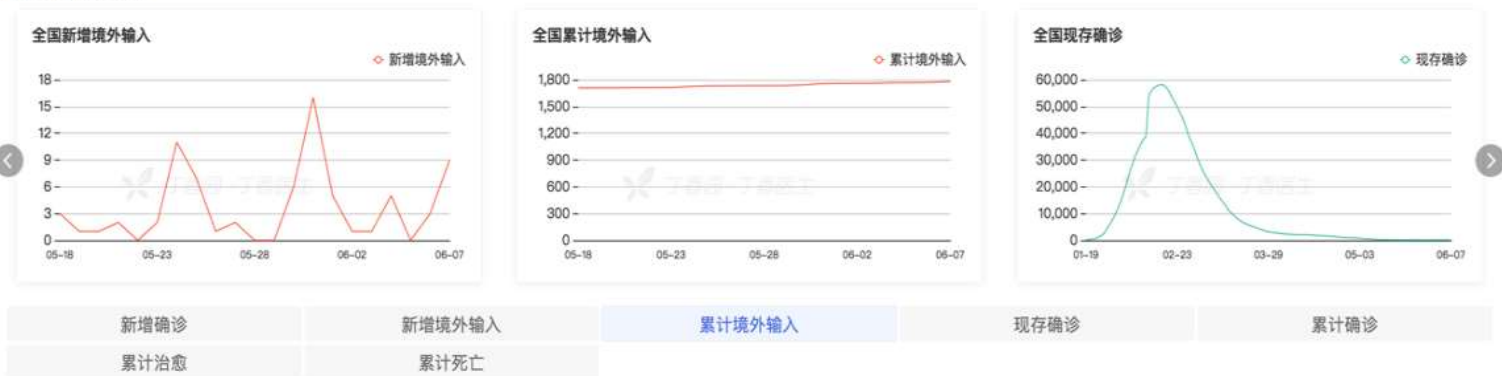
Figure 7. Domestic outbreak trends on June 8, 2020, at 3pm (National new imported cases, National cumulative imported cases, National diagnosed cases)
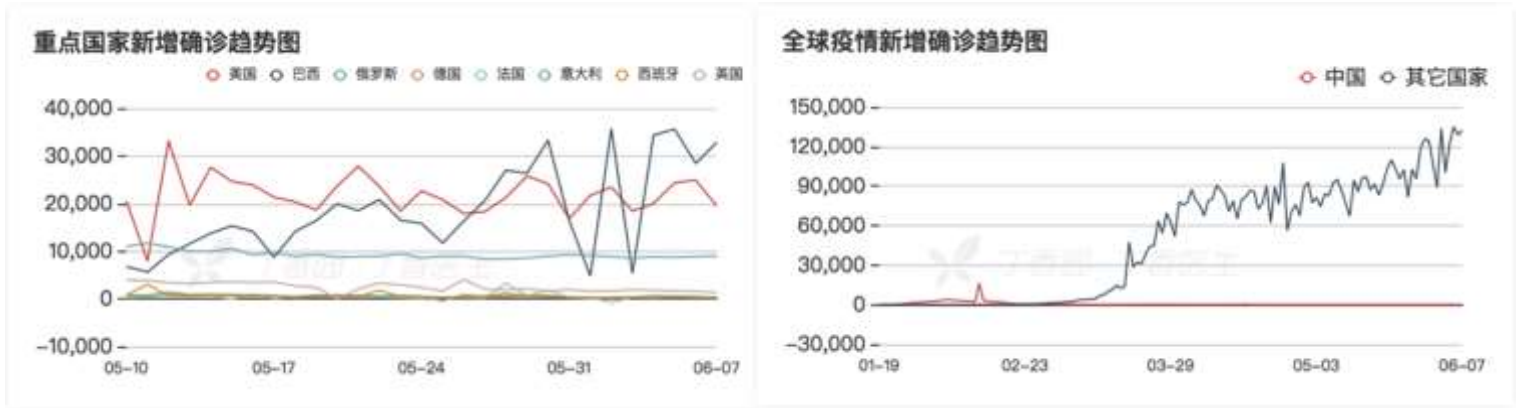
Supportive Activities

Figure 8. Trends in new diagnosis in priority countries and trends in new diagnosis in global outbreaks on June 8, 2020 at 3pm

China and one for the rest of the world for easy comparative analysis.

[3.1.2] Rumor dispelling and self-protection, and Covid-19 knowledge modules

In order to effectively curb rumors related to Covid-19 epidemic and disseminate scientifically correct knowledge on disease prevention and control to the public, DXY Covid-19 Real-time Information Platform set up modules of Rumor Dispelling and Protection, and Common Knowledge of Disease. Rumors Dispelling and Protection module invalidated rumors one by one. Each invalidation was noted with the party responsible and the source of proof to ensure credibility. The content of invalidations was published in a concise, direct and easy to understand manner. There were also images available for rumor dispelling that can be easily forwarded to major social media platforms, such as WeChat and Weibo, covering more people who can be informed. In addition, users could use the "I want to Expose Rumors" function to participate in rumor

dispelling, effectively expanding the scope of rumor collection. Users could also view and search "Rumors Ranking" to verify the authenticity of the information they need.

Rumor Dispelling and Self-protection module organized the individual protection knowledge with strong timeliness and operability, under the categories of "I want to Travel", "I am staying at Home" and "Family with Children". Different categories were marked with different colors, and the content was presented in bold headlines with links for in-depth reading, which was convenient for users to quickly search and read. The Covid-19 Knowledge module was mainly designed for Covid-19. Though its content was not meant to be for timely updates comparing to the Self-protection module, the Covid-19 Knowledge module offered more theoretical and comprehensive content. The Covid-19 Knowledge module provided authoritative integrated information on Covid-19, covering information such as Covid-19 causes, pathology, self-examination, prevention, and treatment. The

establishment of these two modules was intended to popularize the knowledge of the Covid-19, dispel and eliminate rumors by providing informative and credible information for the general public, and ultimately strengthen disease prevention and epidemic control.

[3.2] DXY free public online course for Covid-19 diagnosis and treatment

In order to strengthen the hospital treatment capacity of Covid-19 at all levels across the country and meet the rapidly increasing demand for trained medical personnel, DXY quickly communicated with the medical treatment team of the Shanghai Disease Prevention and Control at the onset of the outbreak, offering training course. On February 8, 2020, utilizing its mature online course platform, DXY launched the free online public courses for Covid-19 Diagnosis and Treatment.

The DXY Free Public Online Course for Covid-19 Diagnosis and Treatment focused on four areas: diagnosis and treatment plan, frontline expert experience sharing, in-hospital protection, and latest research progress. Prof. Zhang Wenhong from Department of Infection of Huashan Hospital, Prof. Hu Bijie from Zhongshan Hospital, Prof. Huang Yan from Department of Infec-tion of Xiangya Hospital, Dr. Xiong Zeng, Deputy Chief Physician from Department of Imagining of Xiangya Hospital, Dr. Miao Xiaohui, Chief Medical Officer of Shanghai Yuanhe Medical Group, and 27 other reputable experts and doctors with frontline clinical

experiences offered lectures. The lectures were played and shared on the DXY official website or DXY app. The course consist-ed of a series of 30 lectures, which were divided into seven chapters: Analysis of imaging characteristics, diagnosis and treatment plan for patients with severe conditions, diagnosis and treatment plan for patients with mild conditions, interpretation of guidelines for Covid-19, diagnosis and treatment plan for infected population groups, clinical care focused and self-protection against Covid-19, and research and progress. As of March 19, 2020, a total of 72,440 medical personnel participated in the DXY Free Online Public Course for Coronavirus Diagnosis and Treatment.

[4] DISUCSSION

[4.1] DXY's key success factors

During the Covid-19 epidemic, DXY's Real-time Broadcast module assisted the government in helping the public face the epidemic with emotional stability, rationality, and caution. Moreover, through timely and authoritative information communication as well as tailored lectures, DXY helped effectively addressed the challenges of high demand for medical personnel remote training in a short time. The key success factors are as follows:

[4.1.1] High reputation as a professional medical platform

DXY is a professional and well-respected Internet medical platform in China. It possesses professional methods, experience, technology and manpower to

Supportive Activities

gather medical and health-related information and conduct data processing. The strong abilities allow DXY to quickly build an information integration platform and achieve efficient and accurate information updates on a regularly basis to **meet the public's demand for information.** Also, due to its high reputation as a professional medical platform, compared with other social media platforms, more professional medical personnel and the public would choose DXY as a channel for information release and acquisition.

[4.1.2] Visual presentation of data and information

Visual presentation of the Epidemic Map integrated complex and diverse data and information in a continuous spatial and temporal dimension, which highlighted the implication of data and allowed the data to be more comparable, which helped the public to further reflect problems and trends. Through these visual images, users were able to clearly and intuitively draw scientific conclusions on epidemic development and effects of prevention and control through various horizontal and vertical analysis comparisons. With more accurate and in-depth understanding of the epidemic, users were less blindly optimistic or panic, which was conducive to maintaining public emotional stability. Users can also better understand and accept the relevant prevention and control measures implemented by the government. In this sense, visualization helped the implementation of unified prevention and control measures.

[4.1.3] "Single platform + multi-module" information communication method

DXY Covid-19 Real-time Information Platform was a highly integrated platform. After fully considering the information needs of the public, the platform integrated epidemic data, information, rumors, protection knowledge and other relevant contents, and arranged them based on priority. The intuitive and friendly interface design allowed users to quickly, accurately and conveniently obtain the information they needed on a single platform, which greatly simplified the tedious acquisition of information on the user side and provided a good user experience.

[4.1.4] New media matrix for information communication

In addition to the "single platform + multi-module", another significant characteristic of the DXY Covid-19 Real-time Information Platform is its integrated use of four new media channels, WeChat, Weibo, App and web pages. These four channels formed an effective information communication matrix. First, the four channels achieved a wide coverage, which can basically cover most of the public and ensure that users can obtain information through the channel they are most familiar with. Since the launch of the Real-time Information Platform, the official website has accumulated more than 4 billion views, with daily views up to 200 million, covering a considerable range of users. Second, the four channels have their own advantages. Instead of simply positioning

Supportive Activities

them as four different communicating ways with the same function, DXY utilized their respective strengths and allowed them to serve different purposes. While the most basic and most important information was ensured to be correctly communicated, the main modules of each channel were differentiated. This way, the effectiveness and efficiency of information communication can be effectively improved while its accessibility, timeliness, accuracy, and interactivity were guaranteed.

[4.1.5] Mature online education system

As a multi-functional integrated Platform, DXY itself has a mature online education system, consisting of a website and App for public classes. When new online lectures needed to be posted, DXY did not require additional manpower, material resources, and time to build a platform or contract for cooperation. Instead, DXY can directly embed the lectures into its online education system. In terms of communicating with the government, DXY's mature online education system was a guarantee for its efficient and effective operation. In terms of medical personnel who were already users of DXY, they did not need to refamiliarized with new interface or functions, and thus saving time and effort.

[4.2] Necessary conditions to replicate DXY's solutions

DXY performed well in the two major tasks of information communication and personnel training for the prevention and control of the Covid-19 epidemic. We can explore the following necessary conditions for replication:

[4.2.1] Mature and professional platform

As one of the largest Internet health platforms in the industry, DXY has professional platform operation technologies and personnel, a mature functional system, a considerable number of professional medical users, and a good reputation. Therefore, DXY has significant advantages in data sharing and course publication and publicity when collaborating with the government. Also, it has credibility and authority in conveying information and content to users, which in turn can attract more users, increase the influence of the platform, and forming a virtuous circle.

[4.2.2] Wide coverage and high usage rate of new media

Whether it is the Covid-19 Real-time Information Platform that covers four media channels of information communication, or the free online public courses for Covid-19 diagnosis and treatment, the wide coverage and high utilization rate of new social media platforms were the predominant reasons the system succeeded. At present, new social media sector is developing rapidly in China, and the number, age, occupation, and social class of user groups are increasing day by day. It can be reasonably and optimistically predicted that while the Covid-19 prevention and control will be a normalized measure, using new social media platform to complete various information communication and personnel

Supportive Activities

training in the medical field is highly feasible. Meanwhile, however, it should also be cautioned that the acceptance of new social media platforms still varies across different regions and across age and occupation. Therefore, this tool requires further improvement to ensure more timely and convenient access to new social media platforms like Weibo and WeChat, so that the information can effectively reach wider people groups.

[4.2.3] Good collaboration between public and private sectors

DXY fully utilized its own advantages in technology and platform maturity to **support the government's effort in wider** information communication and medical personnel training. The premise of achieving this goal was mutual trust and openness for collaboration. For example, in the case of the Covid-19 Real-time Information Platform, the government provided much data and information, while DXY visualized the data and publicized them to the most extent. This way, the credibility of the government and the data processing technology and communication technology of DXY were perfectly integrated. Another example, in the case of the free public online course, the government communicated with medical experts to record the lectures, and DXY gathered the targeted audience and launched the lectures on its online education Platform. In this sense, the cohesion and overall coordination ability of the government and the user management and business functions of DXY were well combined. Good

collaboration between the government and the enterprises can strengthen and enhance solutions to support social and public needs.

6.1

Case Study VI: Baidu Map

ABOUT Baidu Map

Baidu is the largest Chinese search engine in the world. In 2005, Baidu launched its travel service platform Baidu Map, which aims to provide users with various services including intelligent route planning, intelligent precise navigation, real-time road conditions, etc. Baidu Map is available on mainstream operating platforms such as the Web, PC, Android, and iOS. As a representative of the most advanced artificial intelligence map services, Baidu Map works with pioneering traffic data collecting teams and equipment, enabling it to cover 209 countries and regions around the world.

[1] BACKGROUND: Timely and Accurate Population Flow Data Can Help the Public Make Safe and Informed Travel Decisions

Covid-19 is highly transmissible and spreads at an accelerating speed. Therefore, avoiding human interactions as much as possible is the predominant measure to prevent large-scale spread of the epidemic. As a result, in addition to the number of confirmed cases and the growing infection rate, the population flow data of a place,

Supportive Activities

such as flow direction, flow rate, and aggregation level, are also important references for the public to make safe travel decisions. In terms of disease prevention and control, avoiding gathering and a large-scale influx of people into high-risk areas are important measures to cut off the infection chain. Since it is impossible for the government to provide precise travel guidance for every individual, it is particularly important to ensure that individuals can make the safest and the most informed travel decision on their own. This is also one of the key points for sustainably carrying out disease prevention and control in an epidemic outbreak. Offering population flow data and travel suggestions to the public is an indispensable assurance method to achieve the above goals. Timely and accurate population flow data can effectively help the public combat the epidemic wisely while still maintaining a relatively normal lifestyle. This information can also facilitate the public to effectively understand and use the information on the epidemic released by the government to dampen the panic and fear.

[2] CHALLENGE: Lack of Objective and Accurate Population Flow Data

Upon confirming that Covid-19 is highly transmissible, the government fully publicized, via various communications channels, the importance of avoiding crowd gatherings and travelling to high risk areas. However, the detailed information on which specific locations had crowd gatherings or where were high risk areas was not objective, clear, and concise enough. With misleading and **confusing information, general public's** risk of infection increased. This remained a problem from the provincial level, down to town and local village level. Information misalignment increased the difficulty in implementing effective disease prevention and control measures. There were two main problems:

[2.1] Text announcements of "Travel History of Confirmed Covid-19 Cases" lacked visual presentation

The official post of the Covid-19 cases usually contained information such as the origin of the case, the nature of the case, and travel history. However, the posts are presented in texts format, without any visual information of any key landmarks or environment information to help people easily locate and mentally capture the information. Yet during the outbreak, it is especially important for announcements to grab attention as the amount of public information is already overwhelming and confusing. If the public wanted to avoid high-risk locations when traveling, they would need to conduct much research and pre-travel planning. For those who are travelling to unfamiliar regions, following guidance in a text format proved neither timely nor effective.

[2.2] Insufficient information on locations with high population density

Besides the high-risk locations visited by confirmed cases, commercial districts, hospitals, transportation hubs, and other places were also high in population density,

Supportive Activities

and therefore were potential locations for large-scale transmission. However, the real-time population tracing in such areas can change radically. As a result, without an authoritative platform supported by a huge data system to collect, filter, process, and post relevant information, it was difficult for the public to obtain timely and accurate population distribution and gathering information to mitigate the spread.

[3] SOLUTION: Baidu Map Visualized Population Flow and Distribution

In response to the two major challenges mentioned above, Baidu Map develop-ed maps and layers specifically for Covid-19. Utilizing its own leading artificial intelligence technology, Baidu Map provided the public with timely, accurate, and easily comprehensible population flow information through visualization methods such as color separation and layering. It mainly offered the "Travel History of Confirmed Covid-19 Cases Map", the "Baidu Migration Map", and the "Heat Map" layer for all maps. According to statistics, by the end of March 5, 2020, Baidu's epidemic travel aggregation page had accumulated a total of 50 million inquiries, the epidemic community information provided had covered 261 cities and tens of thousands of specific epidemic sites across the country, and users have conduced searches via the platform over 100 million times .

[3.1] "Travel History of Confirmed Covid-19 Cases Thematic Map"

On February 6, 2020, Beijing Disease

Control and Prevention Center released information on previous locations of confirmed Covid-19 cases for the first time. That night, Baidu Map launched the "Travel History of Confirmed Covid-19 Cases Map" (hereinafter referred to as "Covid-19 Activity Map") for 49 cities across the

Figure 9. Covid-19 activity map, with labelled locations with Covid-19 cases

country, including Beijing, Zhongshan, Foshan, and Guangzhou. The high-risk locations were marked on the map with a red virus-like logos. Within a week, Baidu

Supportive Activities

Figure 10. Covid-19 activity map search result sample

Map completed labelling all locations with traces of Covid-19 cases. The Covid-19 Activity Map can timely provide the public with updated case information and assist the communities to carry out precise disease prevention and control, helping to further reduce the pace and scale of spread.

The Covid-19 Activity Map can be accessed via web and Baidu Map app, both are easy to operate and maneuver. If there was a need to check whether there had been confirmed cases in the desired destination(s) or proximity, users can also directly enter the destination(s) in the search box. If there were cases in the location, the system would post a notice in red, stating "This place was visited by individuals confirmed with Covid-19". In addition, if an individual were to use the

Global Positioning System (GPS) function, Baidu Map would also have navigation prompts to remind user(s) whether that location was a high-risk area. The functions on Baidu Map provided timely and accurate information to help residents or travelers make informed travel decisions.

[3.2] "Baidu Migration Map" and the "Heat Map" layer

"Baidu Map Chinese New Year Population Migration Big Data" (hereinafter referred to as "Baidu Migration Map") is the first big data visualization project for "population migration" launched by Baidu. It conducts migration analysis through massive Baidu Map navigation big data, which is also an important function of the Baidu Map Intelligence Project. The outbreak of the Covid-19 coincided with the 2020 Chinese

Supportive Activities

Figure 11. Baidu migration map page view sample

New Year, the biggest human migration period each year. To facilitate the targeted and comprehensive disease prevention and control by providing the referential cross-provincial population flow data, Baidu launched "Baidu Migration Map", on January 10, 2020, and later extended its access timeline. On May 8, 2020, Baidu Migration Map officially stopped its data updates.

"Baidu Migration Map" visually displayed popular immigration (emigration) regions nationwide using red (blue) circular markings. The color's depth and size of circle's radius represented the concentration level of people at the provincial/municipal level. The Map also directly provided rankings of the cities, based on their immigration (emigration) flow. In addition, the Map provided a migration scale index that did not distinguish between immigration and emigration. This was used to infer the degrees of population flow across different road sections. Users can also select specific provinces or cities to view the rankings and the travel intensity within the selected region. The information helped users make rational decisions on their destinations, routes selection, and travel methods.

Similar to the "Baidu Migration Map", the "Heat Map" layer of Baidu Map provided users visual information on population gatherings at the city/district level. The "Heat Map" layer used different colors and coverage sizes to reflect the degree and scale of population gathering: when the color has more yellow and orange tones, the higher the Heat and the higher the degree of population gathering; when the color has more blue and purple tones, the

lower the Heat and the lower the degree of population gathering. The "Heat Map" layer was updated with real-time data, which provided users with timely information and enabled them to avoid high heat and high transmission risk areas.

[4] DISUCSSION

[4.1] Baidu Map's key success factors

The maps and layers provided by Baidu Map, presenting population flow information, offering objective, accurate and timely population flow data, with effective visual presentation. The Map provided the public with ways to make informed travel decisions, avoiding high risk locations and crowds. The high public usage and inquiry rate also proved the practicality and effectiveness of these maps and layers. Baidu Map's key success factors are as follow:

[4.1.1] Superior artificial intelligence and big data technology

Baidu Map is a leader in the map service industry, and its core strength is the artificial intelligence and big data technology used for data collection and processing. Presently, 80% of Baidu map data collection is realized by artificial intelligence. During the Covid-19 outbreak, when on-site data collection was largely restricted, artificial intelligence showed its incomparable value. In the case of the "Baidu Migration Map" and the "Heat Map" layer, it was Baidu Map's high precision artificial intelligence technology that made it possible to collect both cross-provincial population flow information and real-time
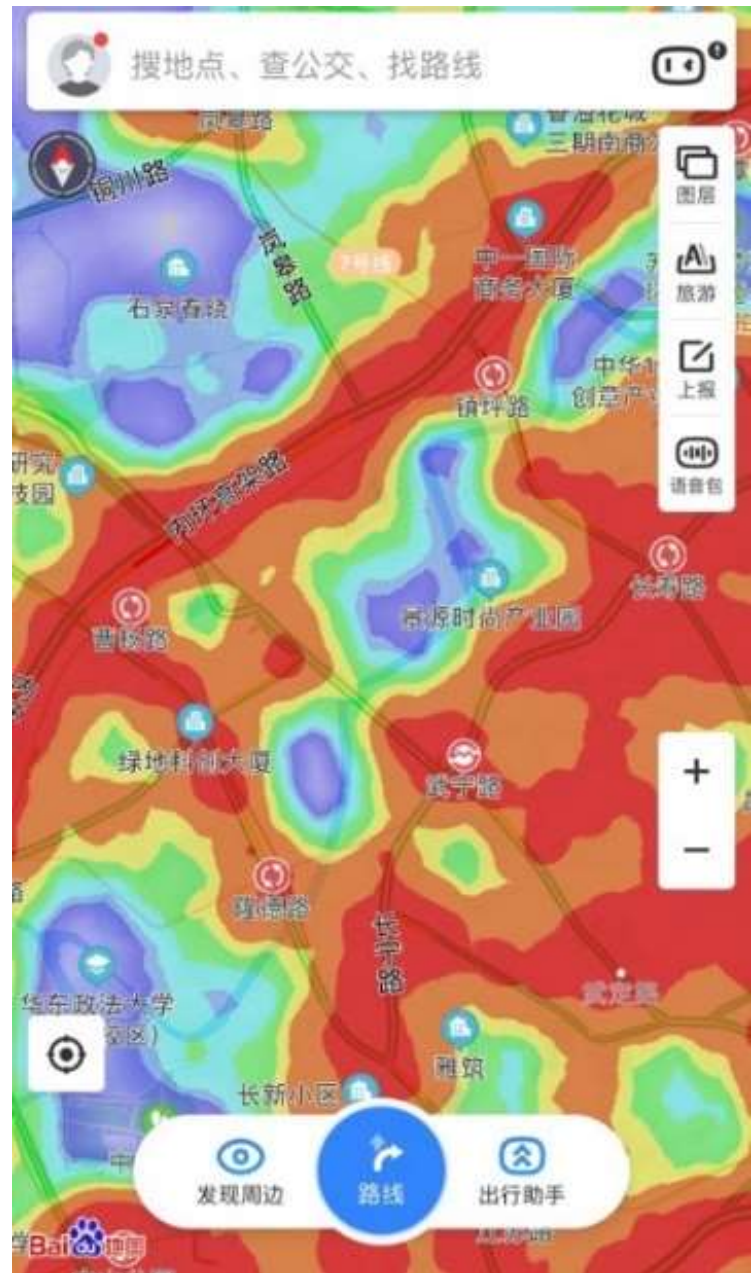

Figure 12. Baidu "Heat Map" layer effect sample

crowd aggregation, with precision down to a street level. The advanced technology makes it difficult for other platforms to imitate, leading to Baidu Map's success in leading the population migration map market.

[4.1.2] Great integration of existing services and modules

Supportive Activities

On the day Beijing released the locations and travel paths of the confirmed Covid-19 cases, Baidu Map responded rapidly and launched the Covid-19 Activity Map for 49 cities same day evening. The rapid response successfully channeled many people who were concerned about the case information to use Baidu Map's service. The ability to integrate existing services and modules was a major reason Baidu Map was able to provide several services within a short period of time. Although the Covid-19 Activity Map was a map service newly set up for the epidemic, solutions like location labelling and information insertion were modules Baidu Map had already been utilizing. Thus, Baidu Map was able to quickly add relevant information to the map. Similarly, although the "Heat Map" layer was a brand-new service content, based on the previous experience of layer design, it didn't require many technical innovations to add the "Heat Map" layer to the existing map. The users were able to use this function easily.

"Baidu Migration Map" is a service that is normally launched during the Chinese New Year Festival each year. This year, Baidu Map extended its availability to support disease prevention and control, offering a big data service that the public was in dire need. Great integration of existing services and modules not only successfully channeled many Baidu Map users to its new functions, but also rapidly and sustainably provided users with the services at nominal cost to the company.

[4.1.3] Baidu Map has many users and has gained public trust

As one of the most used map services in China, Baidu Map is widely used and highly trusted because it is accurate, fast, and has a wide coverage. The number of users of its intelligent voice navigation function alone has exceeded 300 million in 2015. Its number of monthly active users steadily ranks as top two in the country. As of 2020, the mobile user penetration rate of Baidu Map has exceeded 70%, and the number is still increasing. The massive user volume provides abundant flow of data for Baidu Map, which became the basis for the development of the "Baidu Migration Map" and the "Heat Map" layer. At the same time, the user volume ensured the high usage rate after the launch of new services, forming a reinforcing and positive cycle.

[4.2] Necessary conditions to replicate Baidu Map's solutions

The success of Baidu Map's population flow mapping service is mainly due to the above factors. If other countries and regions would like to launch a similar project, the following two necessary conditions are required:

[4.2.1] Mature application of artificial intelligence and big data technology

Artificial intelligence and big data technology are not just the key to Baidu Map's successful population flow mapping service, but rather the decisive factor of its pioneering position in the domestic mapping industry. Artificial intelligence and big data technology is at the forefront of the development of the digital technology industry, and this technology became indispensable during the Covid-19

epidemic. Without the support and empowerment of artificial intelligence and big data technology, such a large-scale, timely, and accurate population flow map would be difficult to achieve. However, the development and maturity of the artificial intelligence and big data technology takes time. Therefore, companies should prioritize the research and development of the technology and build its capability, so that when there are unexpected situations or crisis, the technology can be a strong support.

[4.2.2] Significant amount of user data

Baidu Map is one of the most used service platforms in the Chinese smart mapping service industry. Massive user data volume makes it possible for artificial intelligence to analyze and develop the flow map. A large number of Baidu map users provide abundant mobility data, which is then used by Baidu Map to process and produce an intuitive and understandable population flow map to help users make travel decisions. The more users are using the Map, the more data collected. To replicate the Baidu Map solution, companies would need to occupy a large enough market share in order to accumulate a significant amount of user data.

6.4

Case Study VII: Tencent

ABOUT Tencent

Shenzhen Tencent Computer System Co.,

Ltd. (Hereinafter referred to as "Tencent"), founded in 1998, is one of China's largest internet services providers. Tencent offers a wide variety of services, ranging from social and communication services, social networking platforms, games, and website development, to news media, online video services, and healthcare related solutions.

[1] BACKGROUND: The Importance of Timely Medical Information and Non-profit Organization (NPO) Management During the Outbreak

During the Covid-19 outbreak, it was important for suspected or probable Covid-19 patients to receive timely updates on medical institutions-related information, such as locations of fever clinics or the capacity of nearby hospitals. Many suspected or probably patients would panic as Covid-19 like symptoms arise and rushed to nearby hospitals, which overwhelmed the institutions or clinics and further increased the risk of transmission and the spread of the virus. There was thus an urgent need for a centralized platform to publish timely updates with medical institution related information for the public.

It was also critical for hospitals to receive donations during the pandemic as resources were depleting at an accelerating rate, as the Covid-19 outbreak unraveled very rapidly in China. Hospitals quickly ran out of medical supplies and resources, and many hospitals began to seek donations from the public. Companies and individuals across the country began to fundraise and call for supply donations via social media and

Supportive Activities

crowdfunding platforms. In China, only qualified public funds are legally allowed to raise money from the public in China. However, many organizations fundraised with insufficient qualifications, which greatly affected the efficiency of donations and resources allocation. Under these circumstances, a centralized platform that integrated philanthropic information and facilitated donations management became an important component in bringing hospitals, donors, and NPOs together.

[2] CHALLENGE: Hospital Information was Difficult to Synchronize and NPOs Lacked Management

[2.1] Hospital information was difficult to synchronize

[2.1.1] Suspected Covid-19 patients lacked information on which hospital to visit

During the Covid-19 outbreak, China's National Health Commission (NHC) designated specific fever clinics and hospitals to receive Covid-19 patients in order to reduce risk of cross infection in the hospitals. When suspected patients observed symptoms, they would ideally visit specified Covid-19 hospitals and clinics instead of rushing to any hospitals nearby. However, the information on which hospitals were available for Covid-19 diagnosis and treatment, as well as the institutes' capacity, was very limited. This led suspected patients to visit hospitals randomly, which further reduced the efficiency of disease control and prevention efforts.

[2.1.2] Long waiting lines in hospitals risks cross infection

As a respiratory infectious disease, Covid-19 can be transmitted via respiratory droplets. During the outbreak, an overwhelming amount of patients with various diseases, including suspected Covid-19 patients gathered in designated clinics and hospitals. Close contacts in hospital crowds and long waiting lines created more opportunities for infection transmissions.

[2.2] Fundraising organizations lacked management and supervision

[2.2.1] Varying quality of fundraising organizations and lacking in reliable donations channel

In the early stages of the Covid-19 outbreak, many hospitals' Personal Protective Equipment (PPE) and other medical equipment quickly became limited, and they turned to the public to ask for donations. Many fundraising organizations emerged during this time, but most of them were on social media platforms, and many were unverified organizations. The extend of the fund-raising information that these organizations created often misled potential donors, with some, unfortunately, deemed fraudulent. In addition, the fundraising information available were scattered across different social media platforms, which made it difficult for the public to acquire sufficient and trustworthy information. Donors thus lacked a reliable channel to support front line medical personnel.

Supportive Activities

[2.2.2] Unsupervised fundraising organizations fail to publish financial information

As most fundraising organizations emerged during this period were mostly unsupervised and lacked proper internal management, many failed to publish financial information after they raised funds. Important information such as whether the funds raised were used as promised, how the funds were used, and how individual and organizational donors could file feedback were often unavailable. Many times, donors even had to personally call these organizations to inquire about the funds. There was a strong demand and need for a reliable channel to supervise the management of funds raised and the resources collected.

[3] SOLUTION: Tencent Health Platform and Tencent Charity

[3.1] Covid-19 map on the Tencent health platform

Tencent Health is a digital health platform based on Tencent's Artificial Intelligence (AI), cloud computing, security, and digital payment technologies. In order to address the need for a centralized hospital relevant information, Tencent Health developed a mini program on WeChat, Tencent's multi-purpose messaging, social media and mobile payment app platform with the largest user-base and provided users' information on where to find the designated hospitals and fever clinics. The mini program allowed users to look up hospital traffic. Further, Tencent Health also provided other applications, mini

programs, and public accounts detailed manuals on how to embed or connect Tencent Health's WeChat mini program on their respective platforms.

[3.1.1] Application gathers official hospital information and automatically matches patients to the nearest fever clinics

On January 27, Tencent Health launched the "Covid-19 Designated Hospital and Fever Clinic Guidance Platform" (Hereinafter referred to as "The Platform") in partnership with China's NHC. The Platform is a mini program within WeChat that allowed users to look up designated Covid-19 fever clinics and hospitals, either in a list view or in a map view. With the list view, the application generates a list of designated Covid-19 hospitals and fever clinics, ranked by distance to the user. With the map view, users are able to view hospitals around them with visual reference to the locations. Users can access the application by simply searching "Covid-19 hospital" or "fever clinic" on WeChat. By February 4, 2020, The Platform covered 357 cities across China, with over 12,000 hospitals, of which 11,637 were fever clinics and 1,960 were hospitals.

[3.1.2] Real-time hospital traffic data reduces hospital crowds

Knowing that waiting time at fever clinics and hospitals was long and can increase the risk of cross infection, Tencent Health upgraded The Platform one week after its launching to include a hospital traffic function. Users were then able to schedule their own hospital and clinic appointments

Supportive Activities

Figure 14. Guangdong Maternal and Child Health Hospital's Real-Time Traffic Announcement and Consultation Guidance Page

based on the real-time hospital traffic. Hospital traffic data were updated by hospitals them-selves and categorized into three metrics: normal, more crowded than normal, and less crowded than normal. Take the Guangdong Maternal and Child Health Hospital for example, users were **able to access the "Hospital Details" page** from the map interface and view the **hospital's newest traffic information** (Figure 14). Hospitals also published information such as which departments were open, as well as other guidelines for patients.

[3.2] Tencent charity managed fund-raising organizations

Tencent Charity is an open platform where

individuals, private organizations, and public fundraising organizations can use to start fundraisers. Projects initiated by individuals and private organizations needed to be adopted by public fundraising organizations. Once Tencent Charity reviewed and approved the public organizations, they could begin fundraising on The Platform. During the Covid-19 outbreak, Tencent Charity also initiated a fund-raising project where users were randomly selected to send encouraging messages to frontline medical personnel. Until February 22, 2020, around 6.5 million people had participated in this initiative.

Supportive Activities

[3.2.1] The platform conducted quality control, project management and publishing for fundraisers

In face of the rising number of fund-raising organizations emerged during the Covid-19 outbreak, Tencent Charity conducted stringent reviews on these organizations before allowing them to fundraise on Tencent's platform. The review process included asking the organizations to register with real names, uploading their qualification certificates, submitting project introductions, budget, execution plan, as well as other proof of the organization's capability. Only after the review and approval process, public organizations were able to begin fundraising directly on the platform. Individuals and private organizations had to apply their projects to the approved public organizations and ask for their adoption. Tencent Charity allowed fundraising organizations to reach more donors and provided the donors an easily accessible and reliable donation channel.

[3.2.2] The platform allowed for public supervision

Tencent Charity, by requiring organizations to publish project execution details, allowed the donors and the public to supervise the progress of their projects. The donors and the public can easily monitor whether the funds were properly used and report feedback to Tencent Charity's customer service if they become suspicious of the usage. One month after Covid-19 broke out in China, Tencent Charity supported more than 90 charities and 126 projects fund-raise online. More than 11.5 million people donated via Tencent Charity, with donations exceeding RMB56.7 million.

[4] DICSUSSION

[4.1] Tencent's key success factors

[4.1.1] Disseminate information through WeChat

WeChat, Tencent's social media product, is one of the most widely used social media platforms in China, with over 1.1 billion users recorded at the end of 2019. WeChat's large user volume allows information on the platform to easily reach most citizens. Tencent also added a "Medical Health" function to its user interface during the outbreak so that users can easily access health information and services.

[4.1.2] Collaboration with the government to incorporate official information

When providing information on designated hospitals and fever clinics, Tencent collaborated with the NHC to publish the government's latest update on which hospitals were designated for Covid-19 patients on The Platform. This ensured that suspected patients were receiving the latest and most reliable information on how to seek treatment and diagnosis.

[4.1.3] A reliable and renowned philanthropic platform

Tencent Charity was established in 2007 and had garnered sufficient public

Supportive Activities

recognition and trust by the time Covid-19 broke out. Tencent Charity was able to establish public trust by hiring certified third-party auditor every year to review its accounts, which were then published on **Tencent's official website for the public to** review. Tencent Charity also regularly monitors and follows up with fundraisers on its platform, maintaining close communications with its members.

[4.2] Necessary conditions to replicate Tencent's solutions

[4.2.1] A communications platform easily accessible to the public

Both Tencent's hospital information and philanthropic projects relied on a countrywide social media platform to reach their audience. An application or platform similar in reach to WeChat will help maximize the audience reached and reduce the cost of launching projects. If such a platform is not available, one can also consider using phone calls or television broadcasting to communicate relevant information and services to the public.

[4.2.2] Reliable information sources

In terms of providing hospital information, Tencent launched its project at a time when most citizens were overwhelmed with the amount of mix of information related to Covid-19, much of which were inaccurate and misinterpreted. The developer of an information platform would thus need to obtain reliable information sources, similar to how Tencent collaborated with the government

to incorporate official data onto its Platform directly.

[4.2.3] A charity platform with high public trust

Public trust is a critical factor for fund-raising efforts to succeed. Therefore, a reliable and credible charity platform is needed to ensure that fundraising organizations are operating legally, at the same time, to maximize the amount received. During the outbreak, an existing charity platform with sufficient public credibility should step forward and shoulder the responsibility in pushing forward emergency fundraising projects.

6.5

Case Study VIII: Beijing Viewhigh Technology

ABOUT Beijing Viewhigh Technology

Viewhigh Technology (originally known as Dong Ruan Wang Hai) was founded in 2003 and has since then dedicated to optimize information technologies and digitalized operations. Viewhigh constantly explores and innovates in domains including Hospital Resources Planning (HRP), hospital costs unification, Diagnosis Related Group (DRG), auto payment and auditing, smart financing, smart logistics, holistic man-power, performance incentives, and healthcare resources management. Currently, Viewhigh has over 3,000 healthcare system partners, with 800 tertiary

Supportive Activities

hospital partners, over hundreds of contractual partnerships with municipal Health Commissions and Human Resources and Social Security Bureaus, and over 40,000 supply chain partners.

[1] BACKGROUND: Hospital Emergency Resources Management Platform Resolved the Hospital Resources Shortage Crisis

Supply chain management is a key element in hospital operations. Resource provision is one of the most important elements in medical institutions and health administration departments, especially in times of crises. These difficult times bring challenges to the sustainability of supply chain management and operations. Hospital emergency resource **management platform enhances hospitals'** operations. On one hand, the platform allows the hospitals to place urgent orders with suppliers or accept available donations via the platform. On the other hand, it offers a channel for the general public, including corporations and individuals, to donate to designated medical institutions via the platform. The platform then promptly reports back the relevant donations information to the medical institutions, allowing for more efficient supplies management.

[2] CHALLENGE: Information Mismatch Between the Shortage of Medical Resources and Abundant Donations Received from the Public

The Covid-19 outbreak coincided with the Chinese New Year, during which businesses were closed for holidays,

including manufacturing plants. As a result, during the outbreak, medical supplies became even more scarce as many hospitals were unable to secure more resources through their regular purchasing systems. Many frontline designated Covid-19 hospitals in Wuhan City had issued announcements to seek donations online. Though the announcement attracted massive amount of donations from factories and individuals, the hospitals lacked emergency resource management systems to handle the abrupt abundance of donations. Hospitals also lacked medical personnel to assess the suppliers and the supplies. Furthermore, many donors and suppliers were not on the existing approved list of suppliers for the hospitals. Therefore, even though there was abundance in donations from various sources, the hospitals lacked efficient management process to help properly receive and manage the supplies.

[3] SOLUTION: **Viewhigh's** Hospital Emergency Resources Management Platform

In the onset Covid-19 outbreak, Viewhigh leveraged its existing technology solutions and launched the Hospital Emergency Resources Management Platform (hereinafter referred to as the Platform) within four days of development. The Platform launched on February 3, 2020. The goal of the Platform was to establish a communication channel between suppliers and hospitals. The Platform addressed the needs of the hospitals, and provided a comprehensive resources management system via three aspects:

Supportive Activities

organized connection between suppliers and hospitals, efficient selection of resources and donations, and management of donated resources post arrival at the hospital.

The Platform connected suppliers and hospitals, and provided key support in two areas: online donations and emergency procurements. The platform published real-time donation requests and emergency procurements online to over 40,000 suppliers. Simultaneously, donors and suppliers could input donations and relevant information including qualification certificates, such as product registration certificate, business license, and production license, for hospital to assess whether to receive the supplies or donations. The platform also provided hospitals with single button enquires to the supplier to search for resources efficiently. Many hospitals on the frontline combating the outbreak, such as Wuhan Jing Yin Tan Hospital, registered on the Platform to issue requests for resources. Some hospitals were able to receive the resources they need via the Platform. As there was much data collected on this Platform, data from the hospitals, the donors and suppliers, Viewhigh's strong backend technology ensured to not only provide stable and secured operations, but most importantly, to ensure data security.

To reduce the time and effort spent by the hospitals in assessing the supplies from the suppliers or donors, View-High's operation team pre-screened the suppliers to ensure the quality of the donations meet the hospital procurement standards.

For the hospitals that still faced shortage in resources, Viewhigh broadcasted emergency resources requests to online medical supplier communities to help find **potential match based on the hospitals'** procurement standards. Once there is a match, Viewhigh would assess the quality of the suppliers for the hospitals before connecting the two sides. Once the supplies reached the hospitals, the Platform streamlined the existing hospital logistics workflow and established a new system, allowing procurement management, logistics coordination, inventory management, and real-time reporting. With real-time inventory management and tracing, such as real-time supplies monitoring of the ins and outs and real-time statistical data, the supplies were precisely and efficiently managed during the outbreak. During the time of Covid-19 crisis, this Platform solution not only helped hospitals and suppliers meet all the national audit requirements, but also drastically alleviated the workload for medical personnel, and met the demand for efficient medical supplies management.

Since its launch, in addition to Wuhan Jing Yin Tan Hospital, Wuhan Central Hospital, and Wuhan Leishenshan Modular Hospital, hundreds of hospitals and medical institutions registered on the Platform and sent out requests for resources. On March 25, 2020, Wuhan reopened its city, the Platform had over 170 hospitals registered, with over 25 charitable organizations and corporations offering support, realizing RMB 7.6 million in donations. It is also important to mention that the Platform

Supportive Activities

was established by Viewhigh specifically for the medical institutions to connect them with suppliers at no costs to the institutions.

[4] DISUCSSION

[4.1] Viewhigh's key success factors

Viewhigh's ability to rapidly design and launch the Hospital Emergency Resources Management Platform was based on its digitalization of information and resources. With its strong technological foundation, Viewhigh provided a strong channel and technical support to facilitate information exchange between both the supply and demand of emergency supplies. In addition, the Platform was able to conduct real time resources tracking for the hospitals to ensure efficient management. The key to Viewhigh's success is as follow:

[4.1.1] Viewhigh's rich resources and information reserve

The Hospital Emergency Resources Platform took merely four days to build, from design to launch. Within the few days, Viewhigh established a team, developed backend support, and conducted data cleaning. The highly efficient workflow was cultivated through its focus on hospital system management, especially in research and development, which provided in-depth understanding of the needs and challenges faced by hospitals. Therefore, Viewhigh was able to provide solutions specific to the hospitals' needs during the outbreak.

[4.1.2] Close relationships and trust between hospitals and Viewhigh

Viewhigh has established long term partnerships with many hospitals in China prior to the Covid-19 outbreak. As a result, when the Platform officially launched, close to 170 hospitals immediately registered on the Platform. This Platform served as a crucial means to secure medical resources to many frontline hospitals, including Wuhan Jing Yin Tan Hospital, Wuhan Leishenshan Modular Hospital, First Affiliated Hospital of Kunming Medical University, Qiannan People's Hospital, Xinhui People's Hospital in Guangdong Province, Chaoyang Central Hospital in Liaoning Province. The relationship and trust between Viewhigh and the hospitals was the catalytic factor for the Platform to build traction and become fully quickly utilized.

[4.1.3] Quality control and assurance of suppliers and the donated supplies

During the outbreak, frontline hospitals were overwhelmed with Covid-19 patients, with no medical personnel to spare to assess suppliers and the donated resources. Aware of this challenge, with the guidance from the National Medical Products Administration, Viewhigh decided to help. Utilizing its existing technology and channel partners, Viewhigh was able to support the hospitals by screening the suppliers to ensure their qualifications, assess the donations from various sources to ensure the donated goods were up to hospital standards. This greatly reduced the hospitals risks of

Supportive Activities

acquiring unsuitable resources, thereby increasing operational efficiency.

[4.2] Necessary conditions to replicate Viewhigh's solution

The aforementioned factors are conducive to Viewhigh's success in its resource management platform. However, in order to replicate Viewhigh's solution in other countries or regions, the following elements are essential to recreate the Platform:

[4.2.1] Cloud platform support

The Viewhigh Hospital Emergency Resources Platform was built based on its Viewhigh Cloud. During Covid-19 outbreak, the Cloud provided fundamental support to the overall Viewhigh's hospital management platform. It encompasses four major technologies as its framework, mainly mobility, cloud computing, internet of things, and big data. These technologies make the foundation for the hospital emergency resources management platform.

[4.2.2] Clear understand of collaborating parties' requirements

Viewhigh has built its reputation in hospital management industry and has established long term collaborative relationships with many hospitals. Further, during the outbreak, resources in hospitals were rapidly depleting, at a rate faster than they can be replaced. Upon learning this, Viewhigh was able to quickly develop a comprehensive and tailored resource management tool for its hospital partners to seek support for the public.

[4.2.3] Financial support

The Hospital Emergency Resources Platform was built by Viewhigh, committed its own resources to provide solutions for its partners. The price and agreements on the Platform were decided by the suppliers and hospitals. Without sufficient capital investment and personnel commitment, this Platform would not be in function for an extended period of time. Therefore, committed financial support and technical team support are important factors to continuously maintain the Platform.

6.6

Case Study IX: IZhaohu

ABOUT IZhaohu

Shanghai IZhaohu (IZhaohu), is the first platform in China that integrated knowledge, Internet of Thing (IoT), Big Data, and Artificial Intelligence (AI) to provide smart personalized eldercare services. IZhaohu was founded in 2007 and has since then invested significantly in research and development to enhance IoT technologies in ageing related industries. In order to provide targeted services for the different needs of the elderly in different life cycles, IZhaohu leveraged the power of AI and big data to digitalize and mobilize elderly services and healthcare related resources.

Supportive Activities

[1] BACKGROUND: Information and Communication Technology (ICT) Enabled Remote Health Management in the Elderly Population During the Covid-19 Outbreak

China's Center for Disease Control Covid-19 Emergency Response Group Epidemiological Team has published the "SARS-CoV-2 Pneumonia Epidemiological Analysis", detailing the characteristics of the mortality cases. The study specified that the related cases and mortalities of SARS-CoV-2, hereafter Covid-19, tended to occur in patients who were older in age, and was more common in the elderly population with majority of cases over 60 years old. It was also more prevalent in patients with chronic diseases. Therefore, the elderly health management was of utmost importance during the Covid-19 outbreak. Under these circumstances, leveraging ICT including internet and AI enabled remote health management through digital sensors, machine-assisted identifications, and data predictions, which can minimize the risk of contact trans-mission between caregivers and the elderlies while still maintaining quality care.

[2] CHALLENGE: The Three Main Challenges in Managing Infection Trans-mission Risks

Based on the characteristics of infectious diseases, the management of Covid-19 infection transmission risk among elderly population can be divided into three parts: eliminate routes of transmission, screen and monitor the source of infection, and protect susceptible population groups. This section analyses these three challenges in detail.

[2.1] Contacts between caregivers in eldercare facilities are unavoidable, and eliminating routes of transmission is difficult

Covid-19 has a relatively long incubation period, and thus it is needed to contain the source of infection and eradicate all possible routes of transmissions as soon as possible. During the outbreak, many eldercare institutions employed a closed management system and conducted contactless eldercare in order to minimize contacts between elderly in long-term care and people out of the institutions. However, actual implementations were difficult. For instance, during supplies or medications deliveries, elderlies in long-term care would still come into contacts with others.

[2.2] Difficulties in systematically monitor body temperatures for multiple groups of people, and inability to detect symptoms other than fever

During the Covid-19 epidemic, temperature and symptoms screening and monitoring are some of the most important measures. As many eldercare institutions have insufficient experience in outbreak response, they were unable to implement and monitor measures such as temperature screening for the elderlies and caregivers, symptoms screening, data auditing, and data storage. It was also difficult to obtain body temperature and movement records of the visitors.

Supportive Activities

[2.3] Insufficient support for the caregivers, the elderlies and their families

[2.3.1] Difficult to fulfil needs of elderlies, leading to increased anxiety

Due to the underlying chronic diseases and deterioration of health with age, elderlies face progressive decline in cognition and mobility, and thus they increasingly require support from caregivers. However, with travel restriction and strict disease prevention and control measures during the Covid-19 outbreak, relatives and caregivers were unable to visit elderlies at the eldercare institutions. For the elders living alone, they were unable to receive timely at-home care and living support. In addition, many caregivers were unable to return to eldercare institutions in time because of travel restriction and social distancing measures, leaving many elderlies having insufficient care during the onset of the outbreak. At the same time, due to travel restrictions and the need to minimize the risk of trans-missions, many elderlies living at the institutions were unable to see their families for an extended period of time. This has brought on stronger burdening emotions, such as anxiety and stress.

[2.3.2] Employee knowledge in disease prevention and control is insufficient, and traditional teaching and management methods need improvement

The educational background of the employees in eldercare institutions varies. Some employees had insufficient knowledge on infection control, dis-infection and other related topics. There was a need for professional training and management in these areas. However, conventional face-to-face teaching and management was undesirable for outbreak control and increased management costs.

[2.3.3] Family members' knowledge in eldercare is insufficient and profession-nal training is much needed

Since Covid-19 outbreak occurred during the Chinese New Year, many elderlies went home with their families to celebrate the New Year's holiday together prior to the spread. Subsequently, the elderlies were unable to return to the eldercare institutions as the outbreak worsened. Therefore, the family members became the elderlies' caregivers. However, family members often have insufficient knowledge and training to care for their elderlies, and therefore unable to provide the care the elderlies need.

[3] SOLUTION: IZhaohu's Digital Solution

IZhaohu is a care provider that highly leverages digital technologies, such as sensors and apps, to provide care for its residents. The company invented two digital management system: a remote monitoring system, called Cheetah, and a smart system, called Dolphin. The Cheetah is comprised of a client-facing and an employee-facing port, linking the families and the caregivers via their respective user-app. With a large number of sensors installed in its facilities, IZhaohu can pick up any activities inside the institutions and

Supportive Activities

notify the systems. The Dolphin is an internal management system within IZhaohu, mainly for employee management, client management, and risk management. During the Covid-19 outbreak, Cheetah's remote monitoring system and Dolphin's smart system were able to minimize transmission by eliminating contact, screen and monitor potential infection cases, protecting those with high risk of infection.

[3.1] Automated access control system will interrupt transmission chains

Automated access control system had already been in place in some of the IZhaohu's eldercare institutions prior to the Covid-19 outbreak. During the spread, in order to minimize risk of transmission, IZhaohu took stringent measures, expanded the usage of automated access control system, and opted for centralized management. Family members of the elderlies no longer had access to satellite care facilities. Everything was centrally monitored and managed. Automated smart surveillance was used to monitor care facilities, using face recognition to manage and track employees. The smart surveillance could also track whether the employees were wearing protective gears, whether the entrances were closed properly, and whether no-contact purchasing, and supplies collection were being conducted.

[3.2] Camera surveillance and cheetah remote monitoring system can cooperate in detecting the source of infection

IZhaohu mandated temperature and symptom screening for all the elderlies in its care facilities. To ensure the caregivers are following IZhaohu's Covid-19 guidelines, such as temperature taking, IZhaohu used smart cameras to monitor the caregivers' activities. After each temperature check, caregivers need to upload the data to the Dolphin system, the system would then produce graphs of body temperature and verify the authenticity of the temperature data collected. In addition, IZhaohu smart cameras were able to detect whether elderlies have cold-like symptoms, and create warnings based on the data received. IZhaohu also required its caregivers to monitor their own body temperatures and upload a photo to the employee app on a daily basis. Family members who wish to visit the elderlies would need to upload their temperature and photo daily for 14 consecutive days in advance of their intended visit and provide travel histories to IZhaohu's online survey.

[3.3] Providing protection and support for the caregivers, the elderlies and their families

[3.3.1] Cheetah remote monitoring system and smart devices helped protected the elderlies at home

For families with elderlies at home a-lone, IZhaohu offered home care services and technology solutions. IZhaohu utilized home sensors to collect data on elderlies' daily movements, such as getting out of bed, falls, and vital signs, and send timely updates to the family members. Sensors

Supportive Activities

and remote monitoring systems can be simultaneously used to help family members become actively aware of the **elderlies' daily needs. Other than sensors,** IZhaohu also provided the elderlies with smart beds. Smart beds utilize artificial intelligence (AI) technology and speech recognition technology, allowing the elderlies to control their beds using simple voice commands. This decreased the need for physical contacts between caregivers and the elderlies. In addition, IZhaohu created a single button alarm solution, which allows elderlies to call for help in emergency situations. If the button is pressed, the system not only sends the alert to the family members, but also to IZhaohu and emergency services.

In addition to the services and solutions described above for the elderlies at home, IZhaohu also provided non-emergency teleconsultations with doctors from top-tiered medical hospitals. This helped reduced hospital visits, hence reducing the risk of infection and transmission. Moreover, IZhaohu adopted contactless medication dispensing system by setting up a user app linked with individualized smart pill boxes. Family members can **scan the QR code on the elderlies' smart** pill box to order and deposit the proper medication into the box. Izhaohu employees would then disinfect the smart pill box and deliver the medication to the specific elderly. In addition, IZhaohu deployed robots with sensors and data collection functions to provide personalized care and rehabilitation support for the elderlies. Lastly, with travel restrictions during the outbreak, for the

elderlies at the eldercare institutions, IZhaohu caregivers scheduled regular WeChat video conference calls between the elderlies and their families, in the hope to help alleviate some anxiety and stress, as well as keeping the family feel connected with one another. If necessary, IZhaohu can also connect the elderlies with counsellors for emotional counselling.

[3.3.2] Dolphin smart system aided IZhaohu employees with disease prevention and control measures

IZhaohu employees and caregivers had minimal knowledge and training in disease prevention and control. With Covid-19 outbreak, IZhaohu needed to provide training and knowledge support for its employees remotely. **IZhaohu's** Dolphin smart system served as a Platform to provide training on disease prevention and control, as well as to regularly assess learning progress. IZhaohu also utilized its surveillance system to ensure the prevention and control measures were property implemented. In addition, to help **reduce caregivers' mobility, IZhaohu used** Dolphin smart system to arrange employee shift schedules efficiently.

[3.3.3] Video conferencing to educate family members

IZhaohu used remote eldercare robots with smart screens and speech recognition functions to educate family members at home on specific care techniques via video conferencing. IZhaohu also regularly scheduled WeChat video conferences with family members to provide professional support and eldercare training.

Supportive Activities

[4] DISUCSSION

[4.1] IZhaohu's key success factors

During the Covid-19 outbreak, IZhaohu used information and communication technologies to rapidly minimize and eliminate risks of transmission, through population group monitoring and screening, and provided remote eldercare services and training. These had crucial significance in reducing risks of infection and transmission, and ultimately helped protected the elderlies, their family members, and the caregivers. The keys to IZhaohu's success are listed below:

[4.1.1] Wealth of technology reserve

IZhaohu invests 15 to 20 million RMB on research and development annually and has extensive experiences in working with technologies such as IoT, AI, and big data. At the early onset of Covid-19, IZhaohu quickly finetuned and adjusted their existing systems to provide tailor-ed services for their elderlies.

[4.1.2] Fast response and forward-looking planning in leadership

IZhaohu set up a disease prevention and control task force to coordinate responses during the outbreak. Following government policies and appropriate protocols and issued prevention and control, the task force sent requirements through the employee-facing app and broadcasting across the entire company to ensure the information reached every single employee. IZhaohu leadership also had strong public health awareness and experience, and they developed a holistic management plan at the early stage of Covid-19. This provided guidance in the company's disease prevention and control at various levels and ensured zero infection within all the IZhaohu eldercare institutions.

[4.1.3] Multi-source income relieved cashflow shortage

During the Covid-19 crisis, many businesses were greatly affected. IZhaohu also faced serious cashflow liquidity challenges during the outbreak. In order to relieve the liquidity challenge and maintain in operations, as well as ensure their systems and remote ICT technologies are functioning normally, many IZhaohu employees voluntarily reduced their February salaries to Shanghai city's minimum wage level. This act was not only to ensure the company's survival, but also to ensure the elderlies at their institutions were taken care of. At the same time, Izhaohu leadership negotiated with the local government and obtained rental reliefs, tax reductions, social protection bene-fits, as well as financial support from local financial institutions.

[4.2] Necessary conditions to replicate IZhaohu's solutions

The key elements of IZhaohu's success are listed above. In order to replicate IZhaohu's success overseas, the following elements are indispensable:

[4.2.1] Professional information and communication technology (ICT)

Supportive Activities

In this case study, IZhaohu used internet technologies to collect data on elderlies' daily lives and provided contactless eldercare services. IZhaohu used AI technologies in cameras for automated access control to the facilities, which greatly reduced risks of transmission. IZhaohu used big data analytics to analyze body vital signs of the elderlies and to alert any issues. During the Covid-19 outbreak, caregiver manpower was limited, and family members of the elderlies were unable to provide the care they need. With ICT support, the caregivers were able to work more efficiently, and the family members were able to receive eldercare training remotely to ensure continuous care.

[4.2.2] Emergency response capacities in eldercare institutions

Aside from technology reserves, the implementation of IZhaohu's many measures demanded high emergency response capacities. By establishing a complete response plan for acute infectious diseases and other crises, conducting regular response exercises, and actively carrying out relevant training in public health, IZhaohu improved the ability of eldercare facilities in res-ponding to emergencies. These routine measures were also the basis of eldercare institutions to deploy timely outbreak prevention and control programs during the Covid-19 outbreak.

6.7

Value of Digital Technology in Supportive Activities

6.7.1 To the government

The use of digital technology in supportive activities has provided the government a platform to communicate with the public, helping the government to maintain effective communication and interactions with the public, in a timely and efficient manner during the pandemic crisis. In addition, in the absence of detailed standards for epidemic alerts, the information platform built by technology companies provided a reference for relevant government departments, incentivized the local governments to improve the quality and effectiveness of epidemic alerts, scientifically promoted disease prevention knowledge, and thus helped the government guide medical institutions to conduct diagnosis and treatment more accurately.

6.7.2 To the public

For the public, digital technology in supportive activities helped to ensure their needs, from information, to medical and daily living needs. First, the new media communication channels allowed for key information, such as outbreak situation and hospital information, to be promptly spread to a wider range of population. At the same time, ensured the quality of the information that are being delivered to the public, increasing public awareness, while

Supportive Activities

minimizing unnecessary panic. Second, the involvement of artificial intelligence and big data analytics can visualize complex and diverse information, provided the public with intuitive, understandable, and convenient pandemic-related information. Third, for special population groups who need long-term care, especially the elderlies, technologies such as the Internet of Things, big data, artificial intelligence, helped achieved remote care and health management during the outbreak, minimizing the infection rate, severe cases, and deaths among the special population groups.

6.7.3 To healthcare system

In the early stage of the outbreak, Internet platforms, new media Platforms and other channels shared immediately the first-line clinical experience with the entire country, and around the world timely. The platforms provided information for medical personnel with clear professional training and detailed specifications for healthcare workers. This improved the professional skills and response capabilities of the medical personnel, enhancing the efficiency of the medical system in prevention and control of Covid-19. In addition, the construction and the application of Internet platforms and cloud platforms helped medical material supply information to be effectively collected, verified, disclosed, and supervised, which is conducive to efficient communication between the supply and the demand side, enhancing the transparency of material supply and demand information, and expanding the mate-rial supply base. To a

certain extent, the platforms alleviated the shortage of supplies in the medical system.

6.8

Limitations and Challenges

6.8.1 The information posting platforms are highly homogenous

at the onset of the outbreak, numerous media platforms published information columns of high degree of homogeneity. The process of delivering messages across the platforms, due to insufficient explanations and insufficient supervision, was susceptible to mis-interpretation and inaccuracy.

In the future, the government can take the lead or provide guidance to relevant platforms in the early stages of the development of public emergency events and use advanced technologies such as artificial intelligence and big data analytics to collect, integrate, verify, and release the information.

6.8.2 The resource supply information platform failed to provide thorough, comprehensive, and complete process information

The resource supply information platform during the pandemic had only partial supply and demand information, thus unable to support centralized management and deployment. In the future, the information platform can extend the integrated data to both ends of the supply chain by joining suppliers,

Supportive Activities

logistics companies, government departments, and charitable organizations. Together, they can create an integrated data platform for the complete process, including resource production, supply, transportation, receiving, and quality control, strengthening effective management and deployment of resources.

6.8.3 Lack of linkage among fund-raising platforms

Similar to the information dissemination platform during the outbreak, the fundraising platforms were also highly homogenized, however, each was working alone. How to connect the various fundraising platforms to one another, sharing resources and leveraging on each **other's strengths, and provide** differentiated services for different donor groups needs to be further explored.
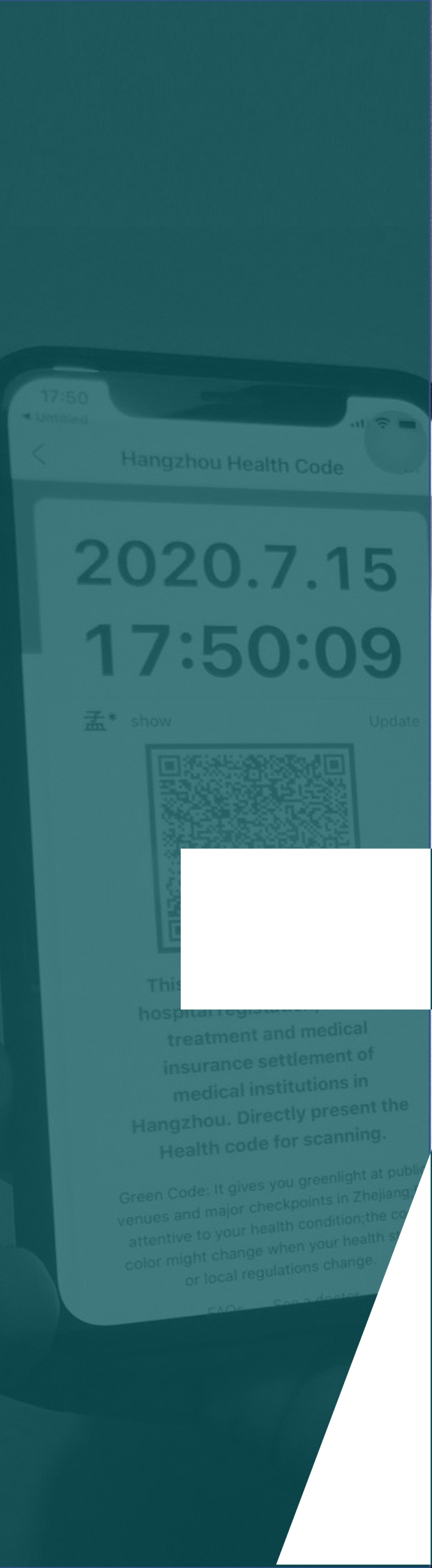
LONG-TERM
MANAGEMENT

Long-Term Management

Efficient long-term management is the key to driving socioeconomic recovery in the post-epidemic era. This chapter will sort out and discuss how digital technology can help companies safely resume work and help communities reduce risk of cluster infection.

7.1

Digital Technology in Long-Term Management

7.1.1 Support business continuity for companies and employees

As the Covid-19 epidemic gradually normalized, all sectors of society began to resume production and operations. Under such circumstances, the prevention of large-scale community transmission was, and still is, an important basis for ensuring the orderly resumption of work. The establishment of an integrated information system and the use of the data center can realize the information communication between employees, companies, and governments. This enables for timely monitoring of the risk of outbreak in a timely manner, ensuring a safe environment for work and production resumption.

For instance, Mininglamp Technology Group developed the "Mininglamp Intelligent Resumption Management System". By eliminating communication barriers between employees, companies, and government, the system can realize smart calculation of employee infection risk and the quick filing of employee return to work applications. The system helped companies carry out unified management and review employees' daily

health information, and helped the government timely grasp the status of local company work resumption. At the same time, the system provides a scientific basis for the governmental departments to control work resumption dynamically, promote normal disease prevention and epidemic control, while ensuring socio-economic recovery.

7.1.2 Assist communities with refined risk management

As the basis for joint prevention and control of the outbreak, communities need to strengthen the screening and management of suspected cases, timely grasp the health and mobility information of residents and track high-risk groups to reduce the risk of clustered infections in the community. Management platforms based on technologies such as the Internet, the Internet of Things, artificial intelligence, and big data analysis can complete information collection, intelligent classification, monitoring, and early warning through automated calls. The platform can help community workers carry out refined management of various population groups in the region, reducing the workload of community workers and improving management efficiency.

For instance, based on technologies such as cloud computing, big data, and artificial

Long-Term Management

intelligence, Internet Plus, JD Digital and Yidu Cloud implemented smart information collection in the community and provided in-depth analysis and data, effectively improving the efficiency and quality of community disease prevention and epidemic control. JD.com and Concox implemented smart temperature-sensor screening, entry and exit registration, non-contact elevator access and other information management and visual management based on artificial intelligence, the Internet of Things, and other technologies to prevent the spread of Covid-19 in the communities.

7.2

Case Study X: Mininglamp Technology

ABOUT Mininglamp Technology

Mininglamp Technology is a technology company that provides integrated artificial intelligence enabled products and services platform, dedicated to exploring the incorporating and utilizing a new generation of artificial intelligence in industries with high complexity of knowledge and management. Its core technology is a unique Human Intelligence, Artificial Intelligence and Organizational (HAO) Intelligence System. Mininglamp Technology offers services in the fields of smart industry, smart finance, smart city, smart analysis and decision-making, and data middle platform for companies.

[1] BACKGROUND: Integrated Management Facilitates Return to Work

Ensuring the orderly and stable re-operation of business, protecting the vast number of employees to return to work in a safe environment, and promoting the resumption of local economies are key focuses in the new normal of Covid-19 control. In order to reduce the risk of cluster outbreak, companies need to review and manage their employees' return, and local governments need to fully grasp and oversee the work resumption progress of each company. However, waves of groups of employees returning to work across various locations have brought on new challenges to information registration, risk identification, and epidemic control. The integrated work resumption management system can assist employees, companies and the local governments to efficiently remain in contact with one another, which is an important basis for the orderly work resumption across different industries.

[2] CHALLENGE: Lack of an Integrated Work Resumption Management System

At the onset of the Covid-19 outbreak, prevention and control measures were mainly focused on spread containment, population tracking, case reporting, contact tracing, and medical services provisions. As Covid-19 began to normalize, a work resumption management system, especially one that can highly integrate operations and functions required by the government, companies, and employees, became the next priority. In order to

Long-Term Management

ensure to provide safe environments for work resumption, the companies needed **to collect and manage their employees'** health status and understand their travel histories. However, due to the lack of professional guidance, the information collected and the standards for information review varied across companies. It was very likely for a company to mistakenly approve work resumption for an employee who was actually a suspected case, which further enhanced the risk of transmission. Moreover, due to inadequate or incomplete information collection even when a case was confirmed, it was hard to **investigate the patient's close contacts in** the company in a timely manner, bringing yet another challenge to epidemic prevention and control. For the government, work resumption meant an influx of a large number of populations, and thus the prevention and control measures were focused on within each company. With various information collection methods being used across different companies, the government needed to devote more manpower, resources and time to verify the information. This not only did not help increase work efficiencies, but also did not mitigate the risk of cluster infection for the companies.

[3] SOLUTION: MingAn Intelligent Work Resumption Management System

In response to the urgent need for work resumption, to help the government manage companies re-opening and employees returning to work, and provide

a safe working environment, Mininglamp Technology launched its MingAn Intelligent Work Resumption Management System (Hereinafter referred to as MingAn System) on February 13, 2020. The MingAn System established an "employee-company-government" information closed loop through data middle platform, artificial intelligence, cloud platform and other technologies. The MingAn System created three terminals for employees, companies and the government, respectively, and provided different functions of management or service for each. Services included information filling, information query, resuming application, resuming application review, statistical analysis, and online services.

[3.1] MingAn System collects data information from three terminals

The data of the MingAn System consists of three parts: employee personal information, company-related information, and public information. Before officially returning to work, employees are required to fill in their basic information, current residence, recent travel history, immediate family members, health status, and other information on the employee interface. For companies, they need to submit their management data, epidemic prevention and control strategy, resumption application information, from the company interface. For the government, it needs to upload public information such as confirmed cases data, and the visited sites of confirmed cases on the government interface. The MingAn System is a web-enabled system. Employees can use

Long-Term Management

WeChat, Alipay and other apps to access the employee interface by scanning the official access QR code, while government agents need to log in to the web service via PC or laptops or tablets. Managers of companies can access the company interface via both apps by scanning the QR code and PC or laptops or tablets.

[3.2] MingAn System realizes efficient communications among three terminals

Once employees, companies, and the government input and submitted their data, all the data and information will flow into the data middle platform for aggregation. Through efficient processing and artificial intelligence identification, the system will send each employee a risk level assessment and a public access permit, in the form of a health QR code. At the same time, the government can obtain data on the risk-identified population in

public areas through the MingAn System to keep track of the epidemic risk level across different regions. The government can also evaluate and approve work resumption applications submitted by the companies through the system. Companies can acquire risk identification data from the system after submitting relevant information and their applications for work resumption. Upon government evaluation and approval, MingAn System will send work resumption permissions to the companies who meet the requirements.

Once a company resumes work, its employees need to fill in their basic health information on a daily basis and enter their office with their health QR code generated by the MingAn System. Based on the information filled by employees, the system will generate "Today's Health Statistics and Analysis" for the company and report it to the government. In addition to multilevel approval and review
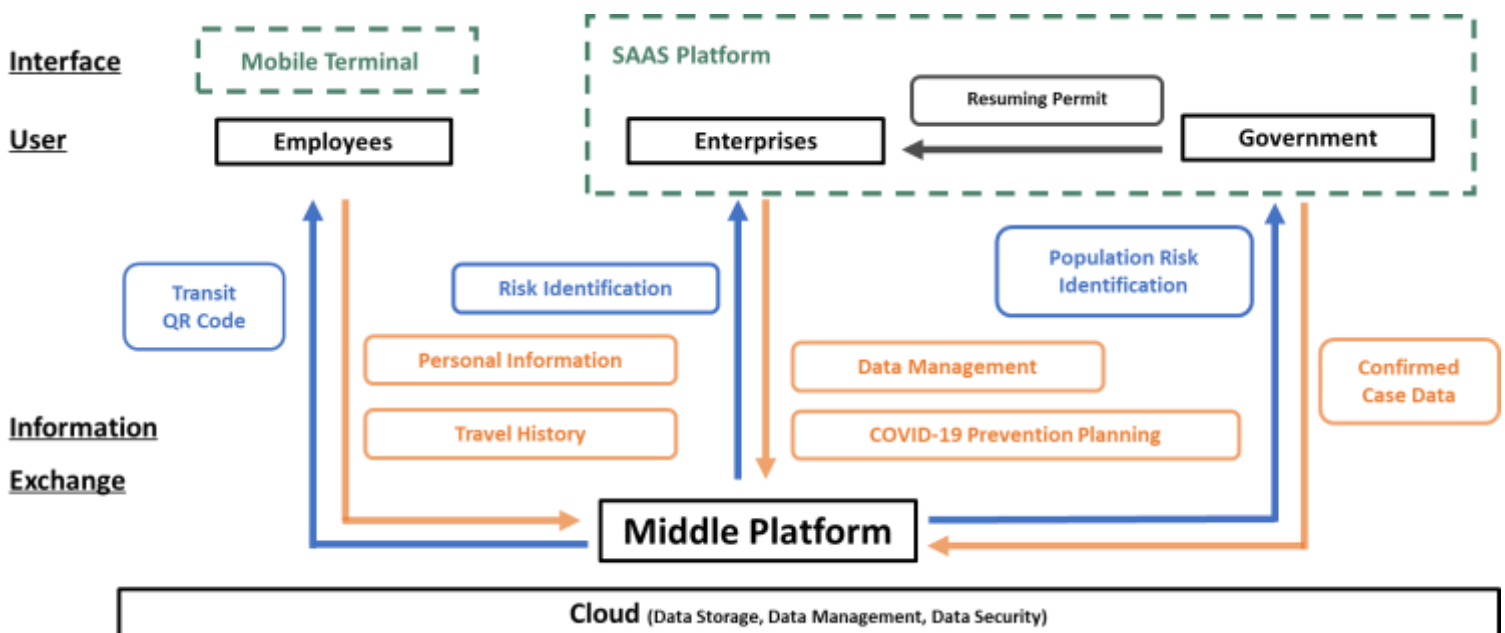

Figure 15. Components and information exchange flow of MingAn System

of the list of employees returning to work, the functions for the government also include data statistics and analysis, which quantitatively monitor the dynamics of region-al epidemic prevention and control. This helps the government accurately and effectively monitor the companies and employees returning to work, greatly dampening the risks of sudden clustered infections, enhancing the ability of quick investigation after the occurrence of cases, and ensuring the sustainability of work resumption.

[3.3] Mature and reliable partners ensure the safe and efficient operation of the MingAn System

In order to ensure the normal operation of the MingAn System and the efficient flow of data, Mininglamp Technology established a system server jointly with China Unicom, a Chinese state-owned telecommunications operator of China. In addition, in order to avoid data security issues such as information leakage, theft, and fabrication of employees and companies, Mininglamp Technology collaborated with mature service providers such as Huawei Cloud and Ten-cent Cloud. This collaboration allowed Mininiglamp Technology to launch its MingAn System in a very short time, providing employees, companies and the government with safe, reliable, and timely management services.

[4] DISCUSSION

[4.1] MingAn System's key success factors

MingAn System had a high utilization rate in areas with large numbers of migrant employees and local companies, in locations such as Zhejiang Province and Guizhou Province. Taking Beilun County, Zhejiang Province as an example, within 10 hours of the MingAn System's release, there were more than 1,000 applications from companies requesting return to work, and hundreds of thousands of employees registered and submitted their information. Further, the government also thought highly of the system. The key success factors for the MingAn System can be attributed to the following three aspects:

[4.1.1] Adjustment of the system construction plan in time according to progress of the epidemic

The most important feature of the MingAn System is that it takes into account the needs and the connections among employees, companies and the government in terms of work resumption. The intricate design allows functions for three different types of user to access for their respective needs, ensuring timeliness and the effectiveness of the two-way information communication. Further, due to the rapid changes of the Covid-19 epidemic, the requirements of employees, companies, and governments for work resumption management system changes as well. Therefore, the MingAn System is not static. Instead, it has been progressively updated and refined to ensure it follows the progress of the outbreak. The MingAn System began as a simple questionnaire system, with an updated version of the system released every day. After three weeks, the

requirements for work resumption management system were gradually stabilized, and the MingAn System that integrated employees, companies, and governments slowly finalized.

[4.1.2] Technology accumulation and manpower input guaranteed the system's rapid launch

MingAn System integrates many data systems and technologies, including data middle platform, artificial intelligence technology, and cloud services. In the case where the system needs to be quickly built and launched, the accumulation of experience in various technologies and applications is essential to the success of the system. In addition, a large amount of manpower input is also crucial in accelerating system construction. After receiving the requirements for work resumption management, Mininglamp Technology established a work team of more than 20 people instantly. Though the team worked remotely, they completed the design, built, and launched the system within just 4 days.

[4.2] Necessary conditions to replicate Mininglamp Technology's solution

Presently, the Covid-19 pandemic in many European and Asian regions have been effectively controlled. Reopening the economy and returning to work has become a priority. If there is need to replicate the success of the MingAn system in overseas countries or regions, the following 3 necessary conditions need to be met:

[4.2.1] Informatization infrastructure

MingAn System integrates all information of employees, companies and the government into one integrated system, effectively breaking the information barrier caused by the hierarchy, and thus facilitating the timely and accurate epidemic prevention and control. Data informatization is the basis for the successful establishment of the system. If there were no equipment for the Internet, servers, terminals, and infrastructures for information and communication technology, the MingAn System could not have been realized.

[4.2.2] Use of the data middle platform

The data middle platform collects, calculates, stores, processes and standardizes massive data, which is the basis of big data analysis. This is also the most important technology for the MingAn System to break the information barrier and build the "employee-company-government" information closed loop.

[4.2.3] Ensuring data security

MingAn System attaches great importance to the security of information, and therefore collaborates with many well-reputed companies in the digital technology industry to ensure that data can be transferred at high speed, while ensuring security and privacy. While the collection of information and data is a prerequisite for the operation of the MingAn system, being able to stably and reliably ensure data security is a necessary condition to gain the trust from all users,

and to develop and promote such system sustainably.

[4.3] The development of the MingAn System

The successful launch of the MingAn System helps the orderly process of work resumption. Standing on this basis, Mininglamp Technology continuously expands the source of data connection, and tailors its system for community management and school resumption management, to help communities and schools obtain multi-dimensional information of the different population groups. The system improves the efficiency for communities and schools to investigate and deal with potential infections and reduces the risks of transmission and contain the spread in a timely manner.

7.3

Case Study XI: JD Digits

ABOUT JD Digits

JD Digits, formerly known as JD Finance, is a technology company that provides digital services. JD Digits spun off from JD.com in October 2013 and rebranded as JD Digits. It is one of the three major independent subgroups of JD.com; JD Retail and JD Logistics are the other two. JD Digits leverages the latest and most cutting-edge technologies, including big data, artificial intelligence (AI), Internet of

Things (IoT), and blockchain, to help financial and real economy sectors reduce costs, improve efficiencies, optimize user experiences and advance business models. To date, JD Digits has established its positioning in areas including smart cities, fintech, and smart robots, serving different types of clients, from individual customers and corporates, to governments.

[1] BACKGROUND: The Importance of Community Screening during the Covid-19 Outbreak

Local communities take on a critical role in outbreak control. During the Covid-19 outbreak, there was a need to increase the capacity of disease detection and management of suspected cases in the communities. It was crucial to time capture the health status and mobility of the community residents, and to monitor contact tracing of high-risk individuals, in order to reduce the risk of developing community outbreaks. Therefore, a comprehensive community management was initiated to gather essential **information on the community residents'** health status, travel history, and close contacts to achieve community outbreak control. In addition, for citizens under home quarantine, the community screenings can help understand better the needs of the residents. The collection of **these key information on the residents'** health status and needs allowed community managers to promptly understand the spread at the community level and to act accordingly.

Long-Term Management

[2] CHALLENGE: Manual Implementation of Community Screening was Impractical

Albeit the importance of community screening as a means to understand the community health status, there were many difficulties during implementation. This operation requires for a wide area of coverage, which is demanding in both the number of employees and workload. It also increases the risk of transmission. Therefore, traditional manual implementation of community investigations was not feasible during the Covid-19 outbreak. The challenges were manifested in the following three aspects.

[2.1] Traditional door-to-door community screening method increases the risk of transmission

Traditionally, door-to-door community screening was conducted by community workers and volunteers. However, the risk of transmission was very high during the outbreak, which was adverse to outbreak control. Further, the employees may come into close contact with potential carriers when conducting community screening, hence all employees would be required to wear protective gears. This added additional pressure to the already scarce medical resources. Therefore, using remote telecommunication technologies to conduct community screening was the most ideal method during the outbreak.

[2.2] Manual community screening was inefficient, labor intensive, and time consuming

Manual implementation of community screening demanded massive manpower, inefficient, and time consuming. According to a population census, there are at least 3000 families in each district, in a city. Even by means of telephone survey, at an average of 10 minutes per teleconsultation, it would require up to 500 hours to complete a community screening for 3000 families. Evidently, door-to-door visit would take even longer. Moreover, for suspected cases and high-risk individuals, continuous follow-up surveys would be needed. Therefore, communities needed a solution to replace manual community screening to increase the efficiency and frequency of the surveys.

[2.3] Manual implementation of community screening cannot export data in a timely and efficient manner for data integration and analysis

Another drawback of the manual implementation of community screening is its inability to export survey data timely and efficiently for subsequent data integration and analysis. Traditional surveys required manual data entry and upload. This process is not only laborious, but also does not guarantee data quality. Therefore, how to properly for-mat, integrate, and analyze the collected data became the main challenge. If the data cannot be promptly collected and effectively utilized, then community outbreak would not be properly hand-led, losing the value in timely community screening.

Long-Term Management

[3] SOLUTION: JD Digits Digitalizing Community Screening

Targeting the three major limitations and demands described earlier, JD Digits provided digitalized community screening solutions, including two survey methods: JD Smart Outbound Robot and JD Queries Survey or JD Liangyan Survey. Based on JD software platform and WeChat platform, JD Digits employ-ed data analytics, AI capabilities, and speech engine technologies to execute highly effective contactless survey.

[3.1] JD smart outbound robot

Based on AI technology, JD Smart Outbound Robot conducts one-on-one telephone communications with the public, which can be used for community surveys, announcement broadcasts, and return visits of key population groups. JD Smart Outbound Robot facilitated large amount of data collection for the community and the disease prevention and control system,
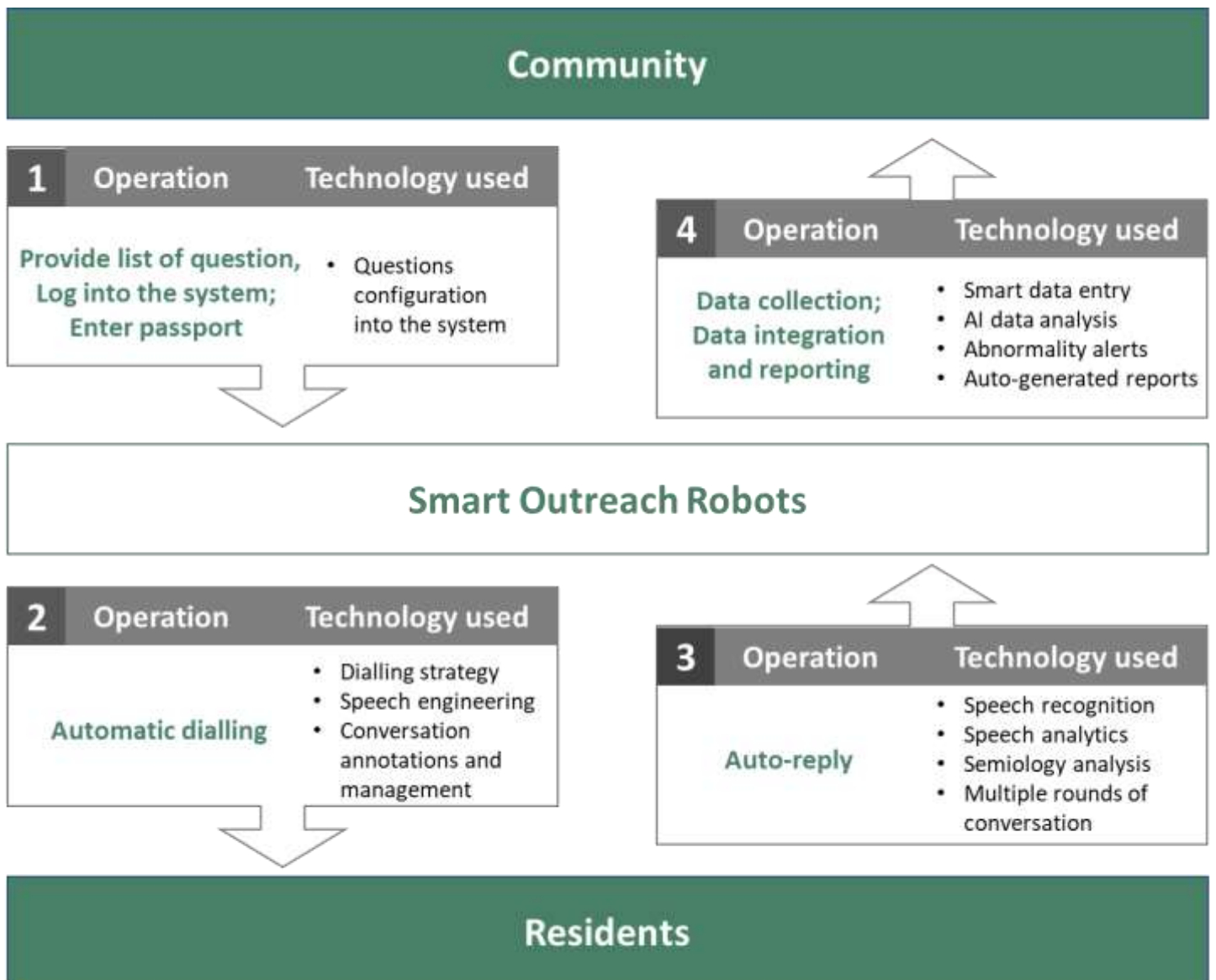

Figure 16. JD Smart Outbound Robot operation logistics

Long-Term Management

which significantly improved efficiency. For the workers returning to work, JD Smart Outbound Robot conducted automated telephone survey to record the details of their travel plans and health status information. For the residents within their respective jurisdictions, the Robot collected health status information and captured any difficulties in the daily livelihoods of persons under quarantine. For the key monitoring personnel and quarantined persons, the Robot conducted daily automated telephone surveys on their health status and alerted the community to take immediate intervention activities when any abnormalities are detected. If there were suspected cases newly detected, the Robot will notify the nearby neighborhoods to take the necessary measures for self-quarantine and protection.

Presently, community management employee only needs to provide the list of questions for JD Digits to configure the questions into the system. Once the community management employee logs onto the system and uploads the **community residents' telephone numbers,** the Robot will call each number automatically. The employee can revisit all call records on the system. The system will automatically generate data reporters of the call records, with simple AI analysis to alert any abnormalities for early warnings.

JD Smart Outbound Robot can conduct multiple simultaneous telephone surveys with speech recognition and semantics interpretation. This alleviated the need for data entry and upload by community management employee, which diminished the time required for data integration and analysis, hence drastically increased the overall efficiency and accuracy of the survey.

[3.2] JD Digits queries survey

JD Digits rolled out JD Digits Queries Survey mini-application to rapidly collect feedbacks. With a few simple steps, the data collector can easily create, edit, and disseminate the survey. Community workers can share the screening survey in two ways: share the link to the mini-application via WeChat platform, or create a survey QR code, print and post it on noticeboards in residential buildings for residents to scan and fill-in. JD Digits Queries Survey can be completed online and remotely, omitting the need for contacts with the interviewers and the risk of transmission.

As a professional analytical tool for research and analysis, JD Digits Queries Survey can generate data rapidly, and gained positive feedback and credibility internally within JD Digits. Therefore, JD Digits has made the online data collection system openly available to the public and the communities in need. For example, in Taolin, a town in Jiangsu province, JD **Digits's** survey system had optimized the 37 existing information registration stations to 22 enhanced stations, which did not only improve the information registration efficiency, but also alleviated the manpower shortage in their community disease prevention and control measures.

Long-Term Management

[4] DISCUSSION

JD Digits has digitalized the community screening and provided important support to the community disease prevention and control measures. The success in the promotion of the JD Digits' solutions relies on the following aspects: 1) JD Digits' technical resources; 2) The convenience in usage and replicability; 3) The construction of community disease prevention and control informatization is promoted by the national government. Aside from the solutions used during the outbreak period, these tools would also be applicable for long-term community management.

[4.1] JD Digits' key success factors

[4.1.1] JD Digits has vast technical resources

JD Smart Outbound Robot and JD Digits Queries Survey were both technical products available prior to the Covid-19 outbreak. These two solutions only required minor modifications to operate during the outbreak for disease prevention and control measures. The vast technical resource capacity housed by JD Digits had not only reduced the time needed for research and development in other products, but also reduced the potential errors during the use of the solutions as the solutions had already been used and refined prior to their applications for Covid-19.

[4.1.2] Solutions convenience and replicability

JD Smart Outbound Robot and JD Digits Queries Survey both are independent software systems. The solutions can be easily installed in the users' electronic devices. In addition, as the whole software process can be visualized for the users, making it easily operable. These advantages greatly increased the replicability of the applications, hence achieved the widespread and large-scaled nationwide usage.

[4.1.3] National promotion of the construction of community disease prevention and control informatization

Community screening was an important element in community disease prevention and control informatization construction. China's national government had promoted and regulated the application of community disease prevention and control informatization since the early onset of the outbreak. The guideline had set clear objectives and directions for the community disease prevention and control, including systems settings, security requirements, and privacy protections in accordance with the public welfare principles to foster a constructive ecosystem.

Internet technology companies, when collaborated with communities to develop information surveys, may involve sensitive matters including information handling, privacy details of the residents, and certain public private partnership issues, which contributes to many hurdles in its implementation. Under such circumstances, the national government

Long-Term Management

had offered unified guidance for corporations to facilitate community screening to achieve community disease prevention and control. The government provided model cooperation protocols in order to effectively leverage the proactiveness of corporations while reducing the worries among the residents when implementing in the community. This had drastically increased the overall speed of development and promotion to achieve widespread coverage.

[4.2] Necessary conditions to replicate JD Digits' solutions

[4.2.1] JD smart outbound robot implementation requirements

In terms of its hardware, JD Smart Out-bound Robot required prevalent use of telephones and mobile phones as a foundation to roll-out the survey. In terms of software, JD Smart Outbound Robot used an automated dial system with speech recognition and semantics interpretation, and AI enabled data **analysis. These are the "neural circuit" of** the system, enabling functions including smart dial, smart recognition, and smart analytics. In practice, JD Smart Outbound Robot also required a robust community information registration system. In the past few years, China had an extensive plan to collect population census, using districts and communities as units, to reach full coverage of community registration. This provided a great information system foundation for remote community screening.

[4.2.2] JD Digits queries survey implementation requirements

In terms of hardware, JD Digits Queries Survey required prevalent use of smartphones or devices as telecommunication method. It also required the users proactively fill in and upload the survey data on their own. In terms of software, JD Digits Queries Survey encompassed many software technologies including application development and data analytical software, which were already widely available.

Regarding in-app surveys such as JD Digits Queries Survey, the willingness and proactiveness for the public to adopt the app and complete the in-app survey with quality data were integral aspects to its success. In China, it is common for the government and community workers to mobilize and carry out publicity efforts. During the crisis, the teams even drafted relevant policies and regulations to mandate citizens to truthfully report their data for community disease prevention and control. This step has greatly ensured the timeliness and the accuracy of the data reported by the public.

[4.2.3] Governmental supervision and guidance

Regardless of using either JD Smart Outbound Robot for automated out-bound calls to collect information or mini-applications to disseminate electronic surveys, the security and efficiency of the information systems to protect the data and safeguard privacy were essential

Long-Term Management

considerations when designing the surveys. The government had set comprehensive laws and regulations specific to outbreak prevention and control measures. The regulations offered guidance in promoting the informatization of community screening, and promoted orderly collaborations between corporations, local governments and communities to achieve community disease prevention and control.

[4.3] Comparison between JD smart outbound robot and JD Digits queries survey

Both JD Smart Outbound Robot and JD Digits Queries Survey were jointly used in the community screening and community disease prevention and control measures.

JD Digits Queries Survey is less demanding in terms of software but required the use of smart devices and applications. Therefore, the Survey was more suitable for communities with higher level of technology usage, and more often with lower proportion of elderlies. JD Digits Queries Survey also relied on the users' willingness to provide information. However, due to the new regulations set forth by the government, residents returning from other location are mandated to complete the survey, increasing the efficiency of information registration for the newly returned citizens.

JD Smart Outbound Robot has advantages in the ability to make pre-selections within communities to assign designated regular return visits, which increased the frequency of survey among targeted population groups. Therefore, detailed survey information can be collected by advanced speech engineering technologies with speech recognition, automated response, and AI prompted conversations. Hence, JD Smart Outbound Robot is more suitable for designated population groups, such as newly returned citizens, suspected cases, and persons with daily livelihood difficulties, as these groups require continuous collection of information, allowing more accurate community screening and specific community disease prevention and control measures.

7.4

Value of Digital Technology in Long-Term Management

7.4.1 To companies

For companies, digital technology can help eliminate potential dangers of epidemic spread and reduce health risks during work resumption. Online information collection and data connection eliminate the need for companies to manually collect daily health status on employees. The application of the data center can quickly analyze employees' information and report the risk assessment back to the company to ensure the safety.

7.4.2 To the public

For residents who are isolated at home, digital community management can assist

Long-Term Management

them to report back to the community about their living difficulties and needs during the outbreak and receive necessary and timely support. For those who need to return to work and study, the Internet platform can help them achieve remote work and study, while avoiding the risk of reinfection. For people who need to return to work offline, information system such as the smart management system can enable personnel risk assessments and conduct return-to-work approvals online to ensure employee safety and reduce the risk of infection and transmission.

7.4.3 To the government

The application of digital technology in the long-term management can assist the government to promote socio-economic recovery, at the same time maintain outbreak control. In the process of outbreak control, societies may experience social and economic disruption. As the Covid-19 epidemic gradually stabilized in China, the government urgently needed to vigorously promote work resumption to restore the orderly operation of society and economy, while ensuring safety. The establishment of an integrated information system, coupled with the application of technology such as data center, artificial intelligence, can help the government timely capture work resumption status, epidemic prevention, and control situation in a timely manner. With the information, the government can take corresponding measures and guide the companies and communities to carry out precise outbreak management and services.

7.5

Limitations and Challenges

### 7.5.1 Government guidance and regulations need to be refined

Whether it is to upload of employees' personal information for work resumption or to collect residents' information for community management, privacy and security are matters of public concern. Presently, many companies and communities are jointly carrying out digital smart management solutions. The government should continue to improve corresponding regulations and strengthen supervision and management, to provide detailed and standardized guidance for community screening.

7.5.2 Public awareness and coordination with smart management need to be strengthened

The successful application of digital technology in long-term management cannot be achieved without public trust and cooperation. At present, many people, especially the elderly and the people with lower levels of education, have nominal knowledge of the Internet of Things, Internet, artificial intelligence, and other technologies, and thus they do not trust or find it difficult to cooperate with smart management system using technology. In the future, society still needs to strengthen public education and improve public awareness of and access to advanced technology solutions such as digital technology. This has become

Long-Term Management

especially critical during the fight against
Covid-19 epidemic and will be of same
importance in times of any future public
health emergencies.

COMPREHENSIVE
DISEASE
CONTROL SYSTEM

8
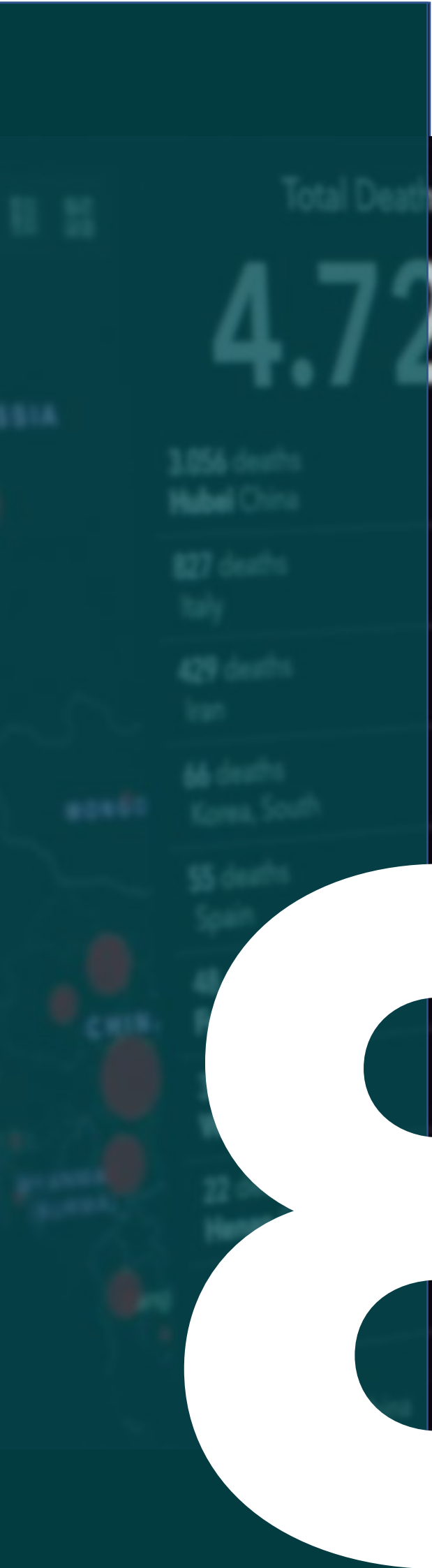
Comprehensive System

8.1

Digital Technology in Comprehensive Digital Prevention and Control System

During the Covid-19 epidemic, all stakeholders including governments, healthcare system, communities, enterprises, and the public, need the support of data and information to carry out prevention and control strategies. The comprehensive digital prevention and control system based on digital technologies such as Internet platforms, big data analysis, and artificial intelligence can realize the efficient information connection in the region. The system can strengthen and facilitate communications among all stakeholders, improving efficiency in coordination of various moving parts in the fight against the epidemic.

For instance, Alibaba collaborated with Zhejiang Provincial Government to launch "Zhejiang Covid-19 Prevention and Control Public Services Platform". With more than 20 functions, the Platform connected the information and communication among residents, com-munities, healthcare system, and local governments, forming a provincial-level comprehensive digital prevention and control system.

8.2

Case Study XII: Alibaba Group

ABOUT Alibaba Group

Alibaba Group (Alibaba) is an e-commerce conglomerate founded in 1999, headquartered in Hangzhou, Zhejiang Province. It offers services ranging from B2B commerce, online retail, and shopping search engine, to third party payment services and cloud computing services. The Group's subsidiaries include Alibaba B2B, Taobao, T-mall, Alibaba Cloud Computing, Alipay, Ant Financial, DingTalk, and more. It is currently one of the largest retailers in the world and has contributed to dozens of smart city and government digitalization projects since 2015.

[1] BACKGROUND: The Importance of a Digital Prevention and Control System

Comparing to SARS in 2003, Covid-19 outbreak unraveled at a much faster pace and a larger scale. China today is also drastically different from 2003, both economically and socially, the country now has a larger population participating in more economic activities. Given these socioeconomic changes to the country, China needed a more comprehensive disease prevention and control strategy during the Covid-19 outbreak than in the 2003 SARS outbreak. China has also been going through a digital reform. Therefore, Chinese government actively encouraged the use of digital technology to prevent and control Covid-19 outbreak. In an announcement released on February 3, 2020, the National Health Commission pressed local authorities to utilize digital health technology to assess the outbreak situation, to develop new diagnosis

Comprehensive System

systems, and to support relevant services during the epidemic.

[2] CHALLENGE: The Lack of an Integrated Platform for Governmental, Medical, and Community Services

During the Covid-19 outbreak, real-time data and information are very important elements in disease control and prevention efforts. However, the traditional information systems are not easily integrated. Further, most digital technology companies are only able to provide one service, or at most a handful of services, to support a specific aspect of the larger disease prevention and control strategy. There is thus a need for a centralized and integrated system to coordinate these different components contributing to disease prevention and control. An integrated information platform would allow data to be aggregated and then disseminated to different parties more efficiently. Medical, governmental, and community organizations would also be able to better share and communicate information on the outbreak with one another. In turn, an integrated platform would reduce each **organization's work**-load and raise its productivity, which is especially valuable given that human and material resources were limited during the Covid-19 crisis.

[2.1] Traditional information systems fail to meet information dissemination needs during an epidemic

Gathering timely and accurate information is critical to controlling the spread of a disease outbreak. This is even more significant during the early onset and peak of the spread. Three information systems are especially important in this process: the epidemiological and disease control system, medical service and management system, and the resident information statistics system. All three systems are highly demanding in data gathering and analysis during the epidemic. Traditional information systems are unable to meet both the needs to upload sizable volume of information and the need to rapidly analyze the collected data during a epidemic outbreak. It is thus necessary to design a data input system and a database catered specifically to Covid-19.

Meanwhile, the public also need to have access to updated information and news on Covid-19. As a result, making efficient and timely information dissemination became very critical. Further, during the outbreak, governments, communities, and medical institutions all need to disseminate Covid-19 related information, from epidemic updates, medical information, and epidemiology, to contact tracing, policy development and community management. However, how to ensure transparent, authoritative, and easy to understand information are being disseminated to the general public became a major challenge.

[2.2] Reduce burden and increase efficiency via prevention and control measures

The Covid-19 outbreak puts tremendous pressure on community and medical services. In terms of community services,

Comprehensive System

community volunteers and employees need to conduct a comprehensive health checks and key population group registration and tracing, enhancing risk of transmission. However, the work required is extremely labor intensive and runs risks of transmission. Similarly, in terms of medical services, increased number of patients over-whelmed local hospitals and depleted medical resources. Traditional modes of offering medical resources through physical hospitals can no longer satisfy medical needs during the epidemic. With digital technologies, conducting **residents' health status, population group** tracing, and medical consultation can all be done remotely, alleviating burden for not only the residents, but also the community employees, medical personnel and hospitals.

[2.3] Government lacked an integrated information platform to support its policy decisions

Due to the high infection rate of Covid-19, and the return to work travels after the Chinese New Year, the prevention and control measures became even more intense. In addition, with information on the Covid-19 coming from various sources, it was difficult for the government to obtain timely updates from various data systems. There were three types of system that were critical in informing government decisions: epidemiological monitoring system, hospital information system, and com-munity information system. Without simultaneous updates from these systems, the government could not make timely and informed policy decisions, and carry

out disease prevention and control measures. An integrated information platform became necessary.

[3] SOLUTION: Alibaba's "Zhejiang Covid-19 Prevention and Control Public Services Platform"

Alibaba, along with its subsidiaries, built an integrated public services platform for Zhejiang Province. The Group collaborated with the Zhejiang Health Com-mission in late January 2020, and mobilized its expertise from Alibaba Cloud, Alipay, DAMO Academy, Alibaba Health, DingTalk, and Yida. Together, they built an integrated epidemic-related services platform within just 24 hours. The Platform consists of four categories of services : Residents, Community, Medical institutes, and Administrative management and services. These four categories encompass around 20 services in total.

[3.1] For residents: self-declaration and communication

Alibaba's Public Services Platform provided Zhejiang residents with two types of services—reporting and receiving information. In reporting information, Zhejiang residents were able to self-declare their health status and report suspected Covid-19 cases via the Platform. Residents could access these functions by **simply looking up "Zhejiang Office" on** their Alipay application, where they could then report suspected cases near them. Once a resident reported a suspected case, they were contacted for follow-up questions. Residents could also input their daily health status on Alipay, and the

Comprehensive System

health status survey included question on **the residents' health conditions, past** contacts, travel histories, and more. The survey took less than five minutes to complete.

In terms of receiving information, the platform provided a number of services. One of them allowed residents to retrospectively look up whether anyone on the same public transport had been confirmed with Covid-19. Users could do so by logging onto their Alipay application and entering the date, train or bus number, and region in the search engine. The Platform launched in late January, by early February, the search function had already reached over 30 million in search volume.

The Platform also provided residents online medical services through the Zhejiang Province Internet-based Hospital. Services offered included online smart consultation, online psychological counselling, home-based medical

observation and management, centralized medical observation and management, and more. When the Platform launched, its system connected nearly 400 hospitals in Zhejiang, with over 40 thousand doctors ready to provide internet medical services. These doctors were able to prescribe medications online, and once a pharmacist verified the prescription, the prescribed medication would be delivered to the **patients' homes. This allowed patients to** receive professional medical services without leaving their doorsteps.

[3.2] For communities: information collection and population management

The Platform helped community managers **better understand the outbreak's situation** and record visitors entering the **communities. The "Covid-19 Reporting"** system, for instance, was a cloud-based call center, where intelligent robots made phone calls to residents and asked questions related to the outbreak situation.
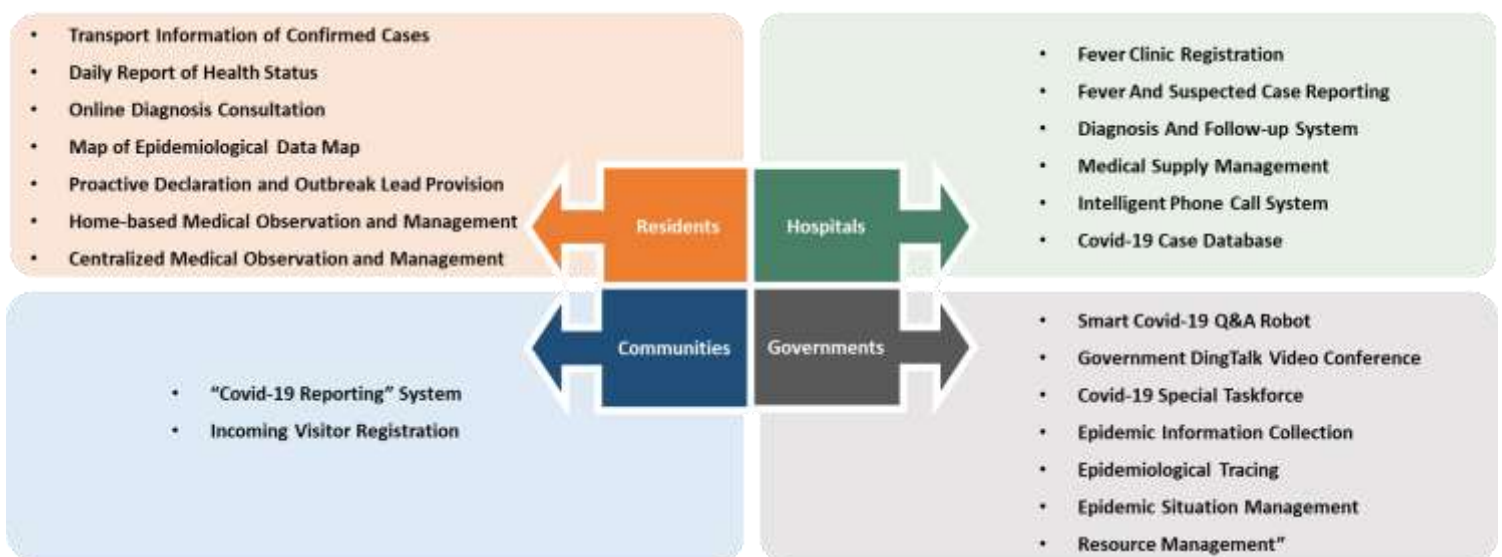

- Transport Information of Confirmed Cases
- Daily Report of Health Status
- Online Diagnosis Consultation
- Map of Epidemiological Data Map
- Proactive Declaration and Outbreak Lead Provision
- Home-based Medical Observation and Management
- Centralized Medical Observation and Management

Residents

Hospitals
- Fever Clinic Registration
- Fever And Suspected Case Reporting
- Diagnosis And Follow-up System
- Medical Supply Management
- Intelligent Phone Call System
- Covid-19 Case Database

Communities
- "Covid-19 Reporting" System
- Incoming Visitor Registration

Governments
- Smart Covid-19 Q&A Robot
- Government DingTalk Video Conference
- Covid-19 Special Taskforce
- Epidemic Information Collection
- Epidemiological Tracing
- Epidemic Situation Management
- Resource Management"

Figure 17. Services on the "Zhejiang Covid-19 Prevention and Control Public Services Platform"

Comprehensive System

The system could also answer calls from the public and engage in conversations with the callers about Covid-19. With its voice recognition technology, the system then turned these phone conversations and respondent answers into tables and statistical reports. Community managers could also design and set their own questions that would be asked in the phone calls. Comparing to traditional, manual phone calls, the intelligent robot system was able to make multiple phone calls at once—specifically, around 100 thousand calls per hour. The system drastically improved community managers' information collection capability, allowing community personnel to conduct check-ups on residents more efficiently.

Communities also had to register incoming visitors as part of population management. To meet this need, Alibaba, in collaboration with its subsidiaries DingTalk and Alipay, developed a sub-program within Alipay that allowed communities to collect visitor information. Once community managers applied to use the system via Alibaba Cloud, they would be able to download community-specific QR codes and paste them on community billboards or entrances. Visitors could then simply scan the QR code and enter their information into the system. This sped up the process of visitor registration and freed up additional human resource within communities to focus on other disease prevention and control measures.

[3.3] For hospitals: more efficient resource management

The Platform also helped medical institutions better manage their resources and work performance. Services provided include fever clinic registration, fever and suspected case reporting, diagnosis and follow-up system, medical supply management, intelligent phone call system, Covid-19 case database, and many more. Most notably, the Platform allowed hospitals to manage multiple administrative systems through one single, integrated platform. Specifically, the Platform allowed hospitals to manage up to 50 administrative systems, 40 kinds of information systems, and over 700 hardware systems on the Platform. This meant that when a new Covid-19 patient entered the hospital, the patient's registration, health status report, and the entire treatment and recovery process could be managed via a single platform. Alibaba also provided medical databases catered to Covid-19 data and helped doctors make informed clinical decisions.

To support the treatment of Covid-19 patients, Alibaba's DAMO Academy, the company's R&D arm, developed an Artificial Intelligence (AI) based CT Scan system. The system could read and analyze a suspected patient's CT image within just 20 seconds and assess the severity of the patient's condition.

During the Covid-19 outbreak, more than a thousand hospitals in Zhejiang needed to ensure that they were receiving sufficient medical supplies. In order for authorities to appropriately distribute medical resources, these hospitals had to regularly report their medical supplies to district,

county, city, and provincial-level authorities. The traditional method used excel sheets to summarize the level of medical supply made the reporting process tedious. Integrating the reported data was time consuming, data were often lost in the process, and feedback from **upper levels was slow. Alibaba's integrated** system allowed hospitals to quickly report their medical supply levels. The system then integrated these data to inform resource distribution decisions.

[3.4] For the government: policy decision support

In order to help the government to improve their productivity, the Platform offered work management and policy decision support. "Smart Covid-19 Q&A Robot", "Government DingTalk Video Conference", and "Covid-19 Special Taskforce" services helped government improve work capacity and efficiency during the outbreak. Other services like "Epidemic Information Collection", "Epidemiological Tracing", "Epidemic **Situation Management," and "Resource Management" provided data support for** policy decisions.

The system can support real-time import of data from multiple departments, and simultaneously conduct statistical analysis and produce reports. The system also generated analysis reports with information from the local Center for Disease and Control (CDC), hospitals, and other sources. This removed the time consuming and complicated administrative processes involved in

integrating information from different administrative levels. With its data visualization function, the system also helped government agencies better understand the epidemic situation and make informed decisions.

As the economy gradually reopens in Zhejiang Province, the government also **relies on Alibaba's big data analytics to** adjust its policy measures. Specifically, the government focused on a few key indicators to support their decisions. These indicators include the number of people under quarantine, people who have been in close contact with con-firmed cases, people who have been to high risk areas, people exhibiting symptoms, and **people who visited fever clinics. Alibaba's** system also allowed government agencies to monitor at-risk population, manage industrial areas, and other populations key to manufacturing. Government personnel are able to access information on a single platform and focus on maintaining one information system instead of multiple systems, drastically reducing government workload and pressure.

Notably, to address population management in hospitals, train stations, super-markets, and other administrative **offices, Alibaba also developed a "health code" function on its Alipay application. Users simply had to look up "health code"** on Alipay and enter their health status, current location, and contact history to **obtain their own "health code". Once user-**input data is verified against the **government's database, a color-**coded QR code is generated. This serves as a permit

that determines whether the permit-holder is allowed to enter or travel to certain areas. Color green indicates that the health code holder is allowed to travel and enter freely, whereas the yellow and red codes indicate that the code holder needs to be quarantined for 7 days and 14 days, respectively. Once the code holder serves the quarantine and updates their health status as requested, the code will automatically turn green. Likewise, the code color changes with the user, as the user's health condition and physical location change. A trial version of the "health code" program first launched in Yuhang District, Hangzhou City on February 4, 2020 and was officially launched in Hangzhou on February 11, 2020. Within three days after its launch, the Hangzhou city "health code" was used more than 35.3 million times. By February 17, the "health code" program covered 11 cities throughout Zhejiang Province. "Health code" removed the need for physical check points and allowed different organizations to reopen their services as the economy opens up. This also reduced government expenses, and by mid-March, more than 200 cities in China adopted "health codes".

[4] DISCUSSION

[4.1] Alibaba's key success factors

[4.1.1] Technological expertise across a variety of products

A key reason Alibaba was able to develop such a comprehensive digital disease prevention and control system and to be utilized at a provincial level was attributed to its extensive products and technology expertise accumulation. In engineering the Platform, Alibaba Group engaged multiple subsidiaries: Alibaba Cloud, China's leading cloud service developer, Alipay, one of highest market penetration in mobile payment industry, DAMO Academy, the Group's R&D arm in AI and 5G innovation, Ding-Talk, a highly applicable business communication application, and Alihealth, with presence in online pharmaceutical retail, internet-based hospital, consumer medicine, and smart medicine. The wide range of digital products that Alibaba Group had developed prior to the Covid-19 outbreak laid a solid foundation for its work during the epidemic.

In addition, Alibaba's own reserve technology also played a role in the outbreak. An example is Yida, a website builder that allows users to drag-and-drop elements to design their website. During the Covid-19 outbreak, Yida was used to build multiple medical platforms. This solution helped build the digital disease prevention and control system.

[4.1.2] Experience in smart city and digital urban planning projects

Zhejiang Province is known for its digital technology industry and has always been leading in China's digital trans-formation. In particular, Alibaba, being headquartered in Hangzhou City, has been deeply involved in the development of internet and digital technology application in the Zhejiang Province for many years. In particular, Alibaba Cloud has played a

crucial role in building the brain of Hangzhou city. With the onset of Covid-19, the smart city brain developed in Hangzhou in recent years has been fully "activated". Leveraging on Alibaba's experience in establishing Zhejiang Province's smart city in transportation, medical, environmental, and industrial and other fields, it was able to quickly build a set of integrated digital solutions to tackle Covid-19.

[4.1.3] Close collaboration with the government

With the strong support from Zhejiang Province's Health Commission, Alibaba was able to develop digital services that covered the entire Zhejiang Province area. Close collaboration between the two institutions meant that the province's Health Commission was able to clearly communicate its demands and needs to Alibaba, whose team then developed the products to meet those needs. During the implementation, Zhejiang Province's Health Commission helped Alibaba cleared administrative red tape and hurdles, accelerated the launch of the Platform. Therefore, Ali's Covid-19 Prevention and Control Public Services Platform has become an exemplary public-private partnership.

[4.2] Necessary conditions to replicate Alibaba's solutions

Alibaba's Platform requires that multiple pre-conditions be met. First, the enterprise leading the project would need to have expertise in a wide range of industries — from medical, communication, urban planning, to consumer goods— to ensure that the resulting product provides comprehensive Covid-19 related services. Second, the enterprise would also need a technical team that could support the basic algorithm, internet, AI, big data, Internet of Things, and communication technology behind the Platform. Third, the area where the project would be launched needs to have basic digital and information technology infrastructure in place. Fourth, a comprehensive service platform would require a high level of support from the local government to remove administrative hurdles. At last, most residents within the region would have to be familiar with basic digital technologies, such as cell phones, lap-tops, and so on.

[4.3] Ongoing developments of Alibaba's Covid-19 prevention and control public services platform

Shortly after Alibaba launched the Platform in Zhejiang Province, the National Health Commission expressed its strong approval for the project. In mid-February, the National Health Commission sent out a feature report to encourage and urge local Health Commissions across the country to implement similar projects. Based on our current under-standing, the Platform has been provided to all local governments and com-munities across China free of charge, and it is now being used across more than 30 provinces, autonomous regions, and municipalities outside of Zhejiang Province. Due to different levels of basic digital infrastructure in place in these regions, each region is using different combinations of functions on the

Comprehensive System

Platform. The "health code" function, however, has become widely used within China, with over 70% of cities using the Alipay "health code" as travel permits and other regions developing similar products.

8.3

Values Limitations, and Challenges of Comprehensive Digital Prevention and Control System

The comprehensive digital prevention and control system is an integrated system that encompasses all of the applications of digital technology described in this report. All of which participated in the fight against Covid-19. This integrated system realizes the interconnection of various information in the region and provide accurate support on decision-making and management for the government and communities. It can also help the healthcare system improve efficiency, optimize resource allocation, and provide residents a convenient platform to report to and obtain information from.

Alibaba's "Zhejiang Covid-19 Prevention and Control Public Services Platform" is a very special case of a fully integration of digital technology in outbreak prevention and control. Considering the current level of digital technology development in China and the entire world, Alibaba's case is a high-level utilization of digital technology to support the healthcare system, and even the social governance system. This Platform fully even the social governance system. This Platform fully capitalizes on China's current public health system and will undoubtedly influence future digital health developments. The expertise, technology, scale, and basic infra-structure involved in this project, however, make it difficult to be replicated and scaled-up within a short period of time. In Alibaba's case, it has provided invaluable insights and inspirations for both China and international regions. This case demonstrates that establishing basic information technology and digital infrastructure now, is important for future disease prevention and control. The case also shows, given the urgency of the epidemic situation, prioritizing key services and functions in the comprehensive system can directly empower the country's disease prevention and control ability.

CONCLUSION
& REFLECTION

9

Conclusion and Reflection

Digital technology has emerged and released great value in response to the Covid-19 pandemic. The new generation of digital technology such as artificial intelligence, big data, and 5G has played an important role in the entire process of epidemic prevention and control. The technologies support measure from governmental decision-making support, epidemiologic research, healthcare delivery, epidemic information reporting, and professional knowledge training, to resources mobilization and donations, social governance, working and daily living. The applications of digital technology not only improved the effectiveness and efficiency of epidemic prevention and control, but also drove the digital innovation in the entire emergency response management system.

Through in-depth understanding and analysis of 12 digital technology enabled case studies, this report offers a comprehensive view on the different digital technology interventions in the fight against Covid-19 in China. The role and impact of these interventions can be summarized into the following aspects:

- Digital technology improved the quality and efficiency of governmental decision-making in response to public health emergencies by assisting the government in managing epidemic prevention and control, such as integrating data, analyzing outbreak progression, identifying and tracking high-risk groups.

  In terms of epidemiological investigation, the use of digital technology has accelerated the research of gene sequencing and protein structure of Covid-19, the prediction of the scale of transmission and epidemic trends, improved understanding of the virus, enhanced the diagnosis and treatment capabilities of the medical system, and assisted pharmaceutical companies to accelerate the development of drugs and vaccines.

- Faced with rising healthcare demands during the pandemic, the implementation of digital technology realized telemedicine and remote health management. These solutions minimized cross-infection among patients, effectively improved the diagnosis and treatment capacity and efficiency of frontline healthcare providers and alleviated the shortage of medical services and resources.

- In supportive and volunteering activities, digital technology established a platform for efficient communication between the government and the general public. It also assisted in establishing reliable platforms for medical supplies and donations and provided support for the more vulnerable and elderly population groups.

- As life during pandemic outbreak became the new norm, digital technology became, and still is, a powerful management tool in supporting work and production

Conclusion and Reflection

- resumption, and community management. Digital technology became an indispensable in helping the government to reopen the economy, accelerate social and individual recovery.

The impactful applications of digital technology in the Covid-19 pandemic was not accomplished overnight, but rather through accumulation of many technology developments and reforms. Based on 12 case studies, we analyzed the key success factors and necessary conditions for digital technology to fight against the pandemic. We summarized China's key success factors, across three levels: 1) government; 2) social; 3) enterprise, described in the table 3.

For other countries and regions, the following four conditions are indispensable learnings from China's experience in promoting the full application of digital technology in combating the pandemic: 1) user adoption; 2) technological foundation; 3) data foundation; 4) governmental support.

- User adoption: The extent of the application of digital technology in pandemic prevention and control is dependent on the level of public acknowledgment and cooperation. Only when users are able to and willing to provide feedback on information required can companies design and modify tailored digital solutions, and can government obtain effective information in a timely manner to accurately deploy prevention and control measures.

Technological foundation: The technological foundation is essential to promote digital response. Over the past two decades, China has experienced large-scale digital transformation. Thus, communication technologies, such as smart devices, Internet, and social media, have achieved widespread usage and popularity. Meanwhile, cutting-edge digital technologies, such as Internet of Things, artificial intelligence, big data analysis, and 5G network, have developed rapidly. The accumulation and usage of these technologies prompted the rapid participation of digital technology in the fight against the pandemic.

- Data foundation: The informatization of data is the most basic element for the application of digital technology. The ability to aggregate and analyze the various sources of data, while ensuring data security and privacy provided a foundational environment for the epidemic response using digital technology. Without connected networks, servers, and terminals, information and communication technology and other infrastructures, tools that can guarantee data informatization and data security, digital enabled epidemic response could not have been achieved.

- Governmental support: Fight again the Covid-19 crisis has been a battle that requires unity among all. It requires leadership from the government levels to guide and control the pandemic responses. From information dissemination, resource mobilization,

Conclusion and Reflection

Levels		Key Success Factors
Government	Policy Guidance	at the onset of the outbreak, National Health Commission clarified the important role of information system in epidemic prevention and control. In President Xi Jinping's speech on February 14, 2020, he reinforced the importance for local authorities and departments to apply digital technology in strengthening the epidemic responses. This reinforcement laid a solid foundation for promoting the in-depth application of digital technology in epidemic prevention and control.
	Ground Support	During the outbreak, the Chinese government continued to proceed with various prevention and control measures to ensure the smooth implementation of the digital technology. For example, the National Health Security Administration and the National Health Commission issued relevant guidelines at the end of February, announcing that the "Internet Plus" follow-up services for common and chronic diseases were to be included in the scope of medical insurance payment.
Social	Foundation of Information System Development	In recent years, many cities in China are exploring the establishment of medical information systems. In the process of participating in the fight against Covid-19, many medical technology companies, such as We Doctor, United Imaging, rebuilt and connected original information systems, and effectively ensured the rapid successful implementation of the digital solutions.
	User Trust	Since China entered the Internet era at the beginning of the 21st century, digital technology has been used in many aspects of society, such as social media, ecommerce, and mobile payment. This development become the foundation for digital technology to quickly obtain user participation and cooperation during the fight against Covid-19.
Enterprise	Quick Decision-Making and Input	Faced with the evolving outbreak situation, many Chinese technology companies have reacted quickly. Enterprise leaders immediately mobilized their employees to fight against the epidemic, and many companies donated much resources such as hardware equipment and software technologies, unconditionally to facilitate the rapid spread and support the overwhelmed health system.
	Technology Accumulation	Technology accumulation is an important success factor for many technology companies when providing digital solutions for combating Covid-19. In the event of a public health emergency, in order to ensure that various types of digital technology can be applied rapidly and effectively to support prevention and control measures, the company's own accumulation of technology and application experience become critical.

Table 3. Key success factors at various levels

Conclusion and Reflection

and equipment construction, to technology implementation, data integration and many more, all require high-level coordination and management. Throughout the pandemic, public support of private sector players was instrumental to rapid implement and execute epidemic responses.

Although China has integrated digital technology into its Covid-19 response, there are still areas that require further refinement and improvement:

- First, there is still a gap in public awareness and education in technology. In China, the gaps in digital infrastructure across different regions has led to much disparity in terms of technology readiness and acceptance in different populations of users. In addition, many elderly population groups and or people in lower income level tend to have less knowledge of cutting-edge technology and are less willing to trust or accept local implementation of digital technology solutions.

- Second, data sharing and connectivity need to be strengthened. Although the public opinion system has been established in China since the 2003 SARS epidemic, the data from across all governmental departments have not been fully integrated. As a result, in the event of state emergencies, there is insufficient aggregated data to support the government in making scientific, comprehensively informed and timely decisions.

- Third, innovative leading technologies still need further improvement and optimization. Though technology has contributed to many aspects of epidemic prevention and control measures, there still requires innovation in the applications and refinement upon applications. Whether it is using artificial intelligence, big data and other technology enabled solutions, technology is expected to continue to play an integral role in many aspects of our daily lives. There is much untapped potential to be discovered.

- Finally, the value of innovation in payment and pricing mechanisms needs to be recognized. During this digital enabled epidemic response, many companies have contributed considerable funding, equipment, and **manpower to support the country's fight** against the devastating virus. Some companies supported, even though they knew there would be sizable capital shortage. Therefore, how to establish reasonable financial mechanisms to mitigate potential business impact on the technology companies while they continue to fight against the devastating outbreak, still needs to be explored.

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