

Algorithms weighing lives and freedoms: The case of China's health code

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Abstract

In response to the COVID-19 outbreak in the beginning of 2020, Chinese local governments created a software extension on existing mobile applications to monitor citizens' movement and collect their health data. Very quickly China's health code became a key resource for the country's governments to track and contain COVID-19 cases using time, location, and personal interactions. China's health code system represents an unprecedented form of "biological" governance, which demonstrates and supports the transformation empowered by digital technologies, enhancing the access to healthcare and fusing together mass surveillance and fundamental public service provision. Digital contact tracing has attracted enormous interest among academics and legislators since the outbreak of COVID-19, which resulted in several policy papers and research works, discussing issues, such as the effectiveness and accuracy of virus detection, as well concerns in regard to discrimination and data privacy. However, most of the articles refers to technologies and its implications in the West, and less to the peculiarities and problems related to the use of Chinese health code. Present research analysis the issues related to difficulties to achieve a balance between China's "zero-COVID policy" and freedom of movement, as well those regarding multiple health code's proliferation, health code abuses and misuses by officials who do not want to miss any cases for fear of outbreak or being fired. Since China's health code system is still far from being centralized and uniform across the country, the mutual recognition system has resulted in considerable problems for those who find themselves in high-risk areas.

Keywords: Algorithms, Jian Kang Ma (JKM), mutual recognition, high risk area, zero-COVID policy.

1. Introduction

Since the outbreak of COVID-19, the Chinese government has been committed to a people-first and life-first philosophy, to an approach featuring preventing imported cases from abroad and resurgence at home, and to a dynamic zero-COVID policy. China has been adapting prevention and control protocols to the evolving situation and achieved major strategic outcomes in fighting the virus. China's dynamic zero-COVID policy is not aimed at realizing zero infection, but rather at bringing COVID-19 under control at the minimum social cost in the shortest time possible to effectively protect the health, normal life, and production of the 1,45 billion Chinese people. [1] The COVID-19 infection rate and mortality rate in China remain the lowest in the world with 0,6 per 100,000 population. [2] One of the reasons of such success is the fact that the government uses big data technologies to detect all the positive and suspected cases or "close-contact" persons. [3] Chinese national health code system, known as Jian Kang Ma (JKM) (健康码), is one of the most important tools of this mechanism for pandemic control and e-governance.

The health code system that the Chinese government has developed in response to COVID-19 builds upon long established traditions of community-based surveillance and control, which date thousands of years ago. No region in the world has a longer and more sustained

history of gathering population data than China, since various regimes that have ruled the country have used civil registers to monitor their populations since ancient times. The implementation of the health code application in China, which aims to assist governments in identifying individuals who may have been exposed to COVID-19, has been anticipated to result in more accountability, quality, efficiency, and innovation. JKM is not only used by the Chinese government to gather information for detection of outbreaks, but the main purpose is to guarantee free movement of persons. [4] The residents had to follow the same procedures to register and receive their health codes, regardless of the region of China they live in. While not officially required, a clean result (green code) must be displayed to enter most of public spaces, which people are required to scan before taking public transport or entering public spaces. [5] Therefore, during the pandemic period in China, the JKM system has emerged as an innovation that no ordinary resident can live without. Only the very young and very old are exempted because of their unfamiliarity with smartphones, which are used to run an accompanying app that displays a person's Covid-19 status after a health code is scanned.

2. The “anatomy” of JKM system and its functionality

2.1. The emergence of JKM

Given its clearly authoritarian implications, one would presume that the health code system was enforced on the population by the Chinese central government. However, it was developed as a local project. This kind of initiative illustrates the extent of discretion granted to local governments for local affair, including for developing and implementing COVID-19-specific measures. The discretion was also necessary due to the varying pandemic scenarios in different communities and their distinct health emergency management capacities. While the central government emphasized the strategy of mass social mobilization and instructed local governments to fully utilize digital technologies and big data for early detection of the coronavirus, it did not predetermine what digital tools should be used, how they should be used, and under what conditions they should be used. [6]

Since March 2020, amid the health and economic crises, local governments responded differently to facilitate the resumption of works and economic activities. JKM was one of such intended instruments. The first health code appeared in early February 2020 almost at the same time in Hangzhou, home base of Alibaba, and Shenzhen, where Tencent is headquartered. In Hangzhou, the Zhejiang provincial government considered that the resumption of economic activities is of vital importance, therefore taking advantage of the city's strong digital economy, requested Alibaba on February 6th to develop a smartphone-based health code program for the local public health management to re-start economic productions. [7] Alibaba launched its health code within only four days. Two days earlier Tencent also launched another health code on its messaging and networking platform WeChat, in response to the Shenzhen government's request for COVID-19 management and attempt to resume local economy. [8] In both cases, health code was created as a software extension embedded in existing Alipay and WeChat mobile applications that codes Chinese people's health status by tracking their geo-locative movements, thus do not require separate downloading.

Impressively, in only 39 days after the initial experiment in Hangzhou and Shenzhen, 31 Chinese provincial governments adopted health code apps, over 300 cities were claimed to have partnered with these two digital platforms and major ICT service providers in China and adopted similar programs in their respective jurisdictions, which covered more than 900 million users. [9] At least 100 similar QR-based health assessment apps have been launched by other developers apart from Alibaba and Tencent. On February 29th China's three telecom providers (China Mobile, China Unicom, China Telecom) jointly launched the "Information Big Data Itinerary Pass", pooling data on China's 1,6 billion registered phone numbers. [10] A nationwide health code system was first embedded in Wechat at the end of February 2020, following Tencent created model.

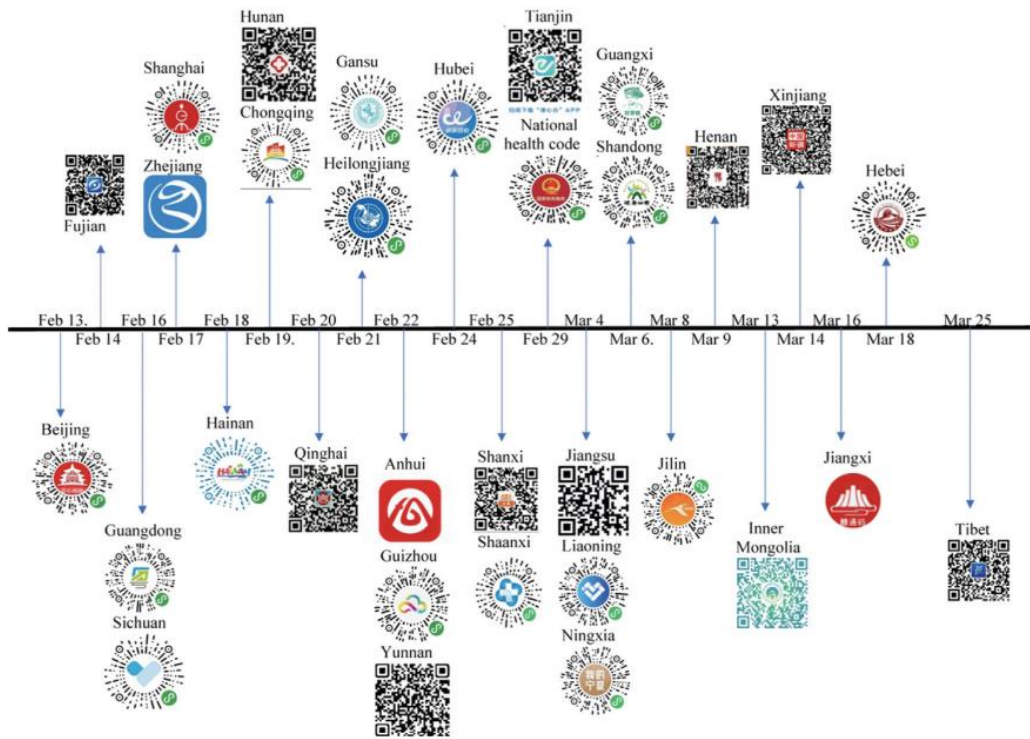


Fig. 1. Timetable for the implementation of JKM at the provincial and national levels in mainland China. Source: Cong, W (2021) From pandemic control to data-driven governance: The case of China's health code. Front. Polit. Sci. 3.

2.2. The structure and functionality of JKM

The State Administration for Market Regulation has issued national standards for the adoption of health code. According to the National Standard on Personal Health Information Code [11], health code is defined as "linked to the resident identity network credential, expressing a string of numbers that the user authorizes others or organizations to temporarily access specific personal health information or a sequence of letters." [12] JKM include the application and its service.

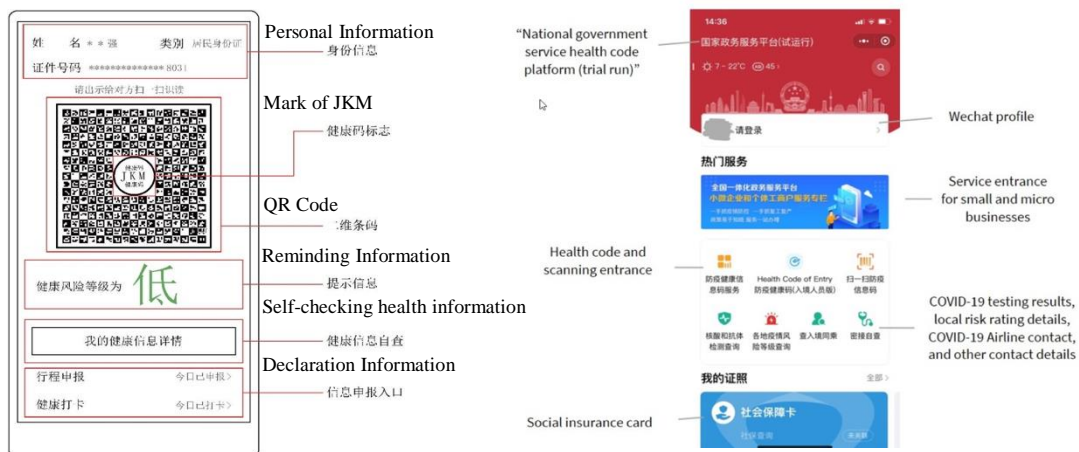


Fig. 2. Sample of user's interface of JKM
 Source: Author own work

The National Standard provides the sample format of an JKM. [13] While displaying the two-dimensional barcode of the health code, the text or symbol prompted by the information service should be provided at the same time. The National Standard recommends providing access to desensitized identity information, personal health information self-declaration, and personal health information declaration simultaneously. [14]

The desensitized identity information shall display only necessary data for checking personal situation. When the two-dimensional barcode is presented, the health code application should add a unified health code mark in the center of the two-dimensional barcode and wait for the colour changing of barcode blocks and borders. In addition to identification information in the form of two-dimensional coloured barcode blocks and frame lines, it should also be prompted obvious words or symbols. Users can view health information declared by themselves and the status of authorized access, thereby knowing their health status. Portal for information declaration provides users with self-declaration or health declaration (body temperature, related symptoms, etc.) and travel history. The unified health code sign should be clear and distinct, and the area ratio of its coverage of the two-dimensional barcode image should be less than 10%. The validity period of the health code should be set, and user can manually refresh it by clicking the QR code image in JKM application. [15]

Turning to the basic functionality of the program, a user searches JKM mini app used in his/her city or province through either Alipay or WeChat, registers on it and provide required personal information. Under health code rules initiated by local governments and later by the State Council, all Chinese citizens are required to input into this application necessary information to generate a personal health code, which could be broadly classified into four categories: basic personal information, health status, travel history, COVID-19 contact history, and medical test information. [16]

Besides data sources provided by the user and institutions (in case of medical tests) there are also spatial-temporal data recorded by Alipay, WeChat, and other apps in daily routine usage. While temporal data provides for the amount of time spent in risky regions, geolocation data, using cellphones' Global Positioning System (GPS) and network providers, can establish whether users visited areas with extensive or continuous transmission. JKM also uses online transactions and user networks to assess if users have contacted potential COVID-19 carriers.

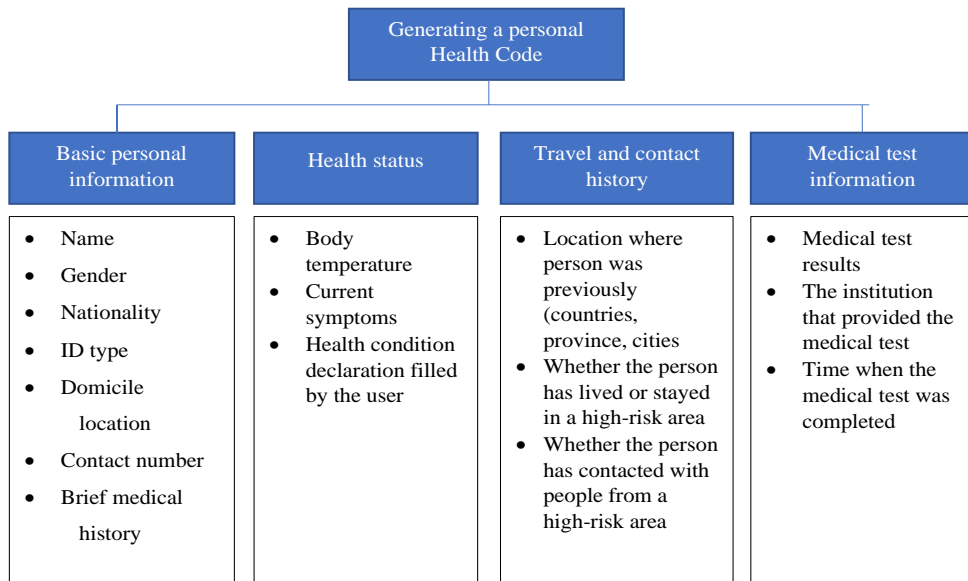


Fig. 3. Categories of information required for generating a personal health code
 Source: The General Administration of Market Supervision, National Standard Documents of "Personal Health Information Code", GB/T 38961-2020

On June 8, 2020, the State Council begin to implement a nucleic acid testing policy (NAT policy) as a part of the health code policy. The Central Leading Group for Responding to the Novel Coronavirus Pneumonia Epidemic Situation requires arrangements and efforts to improve testing capabilities and expand the scope of testing as much as possible. The central government considered that strengthening nucleic acid testing is not only conducive to consolidating the results of prevention and control, maintaining the health of the people, but also facilitating the rational free movement of person, and promoting the full resumption of work, production, and school. [17]

The policy also gives discretions for local governments to implement the policy according to the reality in their regions. Local governments can determine and dynamically adjust testing strategies and population ranges according to the needs of epidemic prevention and control work and testing capabilities. [18]

The combination of JKM and NAT set the technological foundation of the free movement policy and its balance with the anti-pandemic policies. On June 25, the State Council

promulgated the “Notice on precise health management and promoting orderly movement of person”. [19] The purpose of this policy is to guide local governments to accurately manage the health of people in areas with different epidemic risk levels and promote the orderly flow of people, effectively curb the spread and spread of the epidemic, coordinate epidemic prevention and control, and the restoration of normal production and living order.[20]



Fig. 4. Colored QR codes of JKM

In fact, JKM taxonomic project was designed to separate healthy citizens from those infected with COVID-19. The latter category is further subdivided into four groups; confirmed cases, suspected cases, those with a fever, and those who have had contact with a confirmed case. Therefore, based on the information submitted by the user as well as data collected from public services, such as ICT providers, hospitals, and public transport systems, the health code program calculates the level of virus risk and assigns a colored QR code to each individual, determining whether people have access to a variety of activities and places. Specific standards vary across provinces, but the basic color scheme rules are the same nationally and are applied as follows: a) Green QR code allows an individual for unrestricted movement; b) Yellow code indicates potential risks that require a 7-14 day quarantine at home; c) Red code imposes a 14-day quarantine either at home or at institutionalized location. After the quarantine requirement is fulfilled, the code automatically turns to green, permitting free movement again.

Those who are quarantined must update their health information on the JKM every day. To get a green code, a user with a yellow code must report his/her health status as normal on the mini app for 7 consecutive days. A red code must be reported for 14 days in a row until it becomes green. The colors vary on a daily basis, based on risk assessment and expire after a certain number of days. As a result, individuals with green codes must also report on JKM app on a frequent basis before the codes become invalid. In some regions, health code systems have been integrated with facial recognition software, requiring users only to present themselves to be scanned.

Processing the collected data, JKM detects and predicts user’s risk of being infectious via its algorithmic decision-making system. JKM’s algorithms automatically pre-empt the possible spread of the virus by imposing quarantine requirements on users who have been exposed to an infection or high-risk areas. Consequently, the automated decision-making system has sped up the process of identifying people who were in risk of being infectious and needed to be quarantined.

2.3. JKM system and the access to the state databases

Because WeChat and Alipay already store a large amount of personal data, having JKM integrated in these applications makes the health code apps more direct and intrusive. Health Code is an example of China's recent massive investment in digitalization and platform ecosystem. While Chinese health code is installed on two commercial platforms, the core premise is that governments allow IT giants to access vast data sources. The case of JKM indicates that governments and tech giants have achieved unprecedented collaborations for tracking individuals. According to a research, Alipay and WeChat "have penetrated deeply into the Chinese platform ecosystem and created institutional dependencies", offering to Alipay and WeChat a wide access for data collection in order to track and predict users' activities. [21] At the same time, governments rely massively on platforms to gather data and connect with citizens. Moreover, Liang insist that IT giants as Alibaba "is contributing to big data policing in China" by offering vast data sources and technical support. [22] At the local level, Alipay and WeChat can share data with local police.[23]

In various region of China, the local governments are in charge of the health code applications, regulation, and regional databases, and since the majority of them partnering with Alibaba, Tencent, or other technological ITC, their systems operating similarly. To generate a health code, the system must access numerous databases stored on the provincial (municipal) public data platforms, which as a rule is administrated by the Provincial (Municipal) Big Data Bureau. [24] In its turn these data platforms have access to several databases that store citizens' data, including the province-wide database of populations, the national close-contact database, the regional risk classification database, the personnel location database, which collects location data retrieved from China's three major telecommunications operators - China Unicom, China Mobile, and China Telecom, and the province-wide health code sharing database. The JKM system was also granted access to other important databases for epidemic prevention and control, including the comprehensive population database, the comprehensive legal persons database, the database of electronic certificates, the database of credit information, and the database of geographical information. [25] In addition, it was required to be established databases of foreign nationals in each administrative region in order to record information such as foreigners' names, genders, home countries, passport numbers, places of residence, contact numbers, travel history, etc. Such a system would seem to be almost impossible to implement in the West because of sensitivity of personal data collection. However, despite some concerns related to transparency and data storage, Chinese citizens are more likely to hand over personal information in exchange for conveniences and a regular rhythm of work and life. [26]

3. Strengths and shortcomings of JKM

3.1. Positive significance of the using JKM

3.1.1 Pandemic control and detection

The pandemic of COVID-19 has been presented a huge challenge to government and humans worldwide since its outbreak in December 2019. [27] However, such outbreaks in China were quickly diminished. The use JKM, combined with containment measures, such as restrictions on movement and social distance measure, shows both China's ability to

collect vast amounts of data and free use of it, as well as the ability to manage the pandemic [28]. Once there is one or a few positive cases, the government can change the color of person's JKM and inform them that they are under risk of infection. The government can take further medical and non-medical intervention to diminish the risk of transmission. As an example, during the outbreak of COVID-19 in the local area, Macao government made efforts to find all potential close contact via the check on the risk of exposure in the Macao JKM application. [29] If a person has a risky visiting history, he/she will be assigned a yellow code and are required to take NAT according to the regulation. [30] After the required NAT is completed, the JKM will be reverted to green color. Thus, the main idea behind the use of JKM, is the system of real-name registration, continuous data collection and updating, that could enable epidemic detection and intervention at an early stage, and also increase the efficiency of daily population health monitoring and contributes to economic recovery.[31]

3.1.2. Protection on free movement

As was mentioned previously, JKM is making an extensive use of popular WeChat and Alipay platform, allowing individuals to generate their own personal QR codes, which can be scanned to determine their entrance into or exit from a particular area. In this sense, JKM aims to guarantee free movement of persons. [32] At the beginning, the application was created for residents to enter and exit their neighborhood, but later it was applied for people to move freely in public areas [33] and facilitate persons' travel. [34] Free movement of persons has importance not only for personal travel but also for economic purpose. In March 2020, the State Council promulgated several policy documents to facilitate the recovery of economy and industry. [35] JKM was considered as one of the facilitators from a technological perspective since persons with green JKM can be exempted from quarantine and the government employee are saved from heavy work related to report of data on pandemics. [36]

For the past years since JKM implementation, a green health code has been required for entry to almost every public place in urban China. Citizens entering public buildings, commercial centers, shops, taking the metro or other public transportation means, need to scan their health codes when boarding and in some regions rescan them when getting off. During the pandemic outbreak, many cities assigned personnel in each metro station, bus, or public facilities to check that passengers scanned their codes correctly. [37] QR codes replaced paper passes in residential communities and universities campuses. Shop and restaurant posted their own QR codes at the entrances, and customers had to scan the codes to display their health codes. The JKM software recorded the person's movements by scanning the codes at restaurants, metro stations or other public premises where the scanning is required.

3.1.3 Convenience from digitalization of resident services

JKM in China allows travelers to display their JKM and NAT results in various scenarios. This digitalization brings convenience to people's life comparing with the early period in 2020, when people need to use paper-based certificate. [38] Even though it is still less convenient comparing with the life before December of 2019, this digitalization of certificate has made people to adapt to their life in pre-COVID-19 period. When

notification is required by the government, persons can complete such procedure at any places only if they have a smartphone. Comparing with notification through paper documents, the digitalization is faster and easier for information collection. [39] Particularly, in places, like train station or airport, where the flow of crowd is heavy, digital notification enable to avoid heavy gathering of person, which protect people's health and let them to wait for less time. [40] Persons can also get information about health information and risk of infection when there is an outbreak. When finding one's JKM is in red or yellow, a person may ask for the help for the government. [41] People can also take initiative actions to reduce the risk of transmission, for example, doing self-isolation and keeping distance with other people. [42] This makes easier epidemiological investigation. Besides, the function of JKM in Mainland China, Macau JKM provides additional functions to bring convenience to people who reside or are traveling in Macau SAR. It enables people to make notifications of their self-testing result. [43] Besides notifying testing results, people can use the JKM application to connect to appointment system before taking NAT sampling, which reduce waiting time. [44]

3.1.4. Social aspects of JKM and promoting collective responsibility

JKM how was pointed by some experts has its specific difficulties regarding efficacy assessment. The code uses big data analytics, and on the quality of data depends the result displayed on the code. [45] The health code's color-based risk computation is basically impossible to refute, especially without knowing the assumptions and inputs that went into the algorithm. According to Cong, it is possible to think of health code profiling as another "black box" activity with little external quality assurance transparency. [46] In fact, JKM does not perform solely a function of a contact tracing tool for virus detection and tracking. It is also a part of a broader technologies of ruling the population and the society. The health code is more a technology that works closely with human - powered monitoring and control methods to exercise and convey the power of directing people's movements and activities in day-to-day interactions. For example, in many regions of China health code was mandatory for scanning to allow employees and visitors to record their presence and keep at the same time a record of their health states. [47] Or using even in the recruitment processes. [48] In other regions, health certificates extracted from the JKM code are obligatory for particular professions, which are in close contact with customers or food production, such as hotel workers, beauty salons, caregivers, restaurant workers and those working with children. Thus, the use of such a technology is not determined by its accuracy and dependability but rather by its wide use, upgrading and amplifying existing tools to enhance the capacity of existing disciplinary powers, both governmental and nongovernmental. The health code turns people's health into a tool for various types of social control and discipline by making their health visible with colored codes. One would argue that some of the data rely on self-reporting, however the involvement of individuals, even just as a matter of formality, transforms the power exercised by these institutions into individual self-discipline, internalized by every user. However, this internalized type of control also helps people in developing a sense of collective responsibility, security and solidarity, during an epidemic outbreak when everyone potentially might carry the virus and infect others. A societal consensus that each person must take action to execute anti-COVID measures, such as self and mutual monitoring, is formed in part as a result of the mass social mobilization strategy as well as the collectivist culture and political

environment.

3.2. Shortcomings of JKM

3.2.1. Proliferation of multitude and different health codes

One of the main disadvantages of transferring leadership over to the private sector is the difficult and lengthy process of merging many provincial systems into a single, integrated national system, which is a requirement for resuming domestic travel. A health code given by one province for the first few weeks could not have been accepted by another, particularly if one province utilized the Tencent health code system and the other used the Alipay system. A green QR code issued in one place could not be considered green in another due to the different virus control laws in each province, which complicates regional travel.

In the first months of the implementation of JKM, user issues were also brought on by Tencent's and Alipay's lack of collaboration. Tencent specifically disabled the links that allowed users with Alipay health codes to instantly switch to Alipay applications, creating a barrier for them. [49] Users have also experienced technical difficulties, such as a mismatched profile, an inaccurate location, or a failure to update the code. Users have reported instances where a green health code abruptly turned red for unclear reasons, placing the user under an emergency quarantine and denying them access to services and public areas. [50] The system has been criticized repeatedly as a result of these abrupt and unexplained shifts in health scores, and there is growing concern that nebulous algorithms might replace human judgment with arbitrary and occasionally faulty criteria. [51]

3.2.2. JKM privacy issue and gaps in addressing personal information

In addition to users having technical issues with the app, there are also significant worries about privacy protection due to the potential for extensive data collecting. Even though Tencent revised its privacy protection policies in March 2020, several observers said that some provinces still use health code systems that are in violation of privacy laws. [52] The health code applications exposed serious problems with data control and weaknesses in the current legal system. Due to these issues, the public has become more conscious of the need to safeguard their privacy and personal information, and legislation has been pushed to keep up and control the use of digital technology. The Personal Information Protection Law (PIPL), China's first comprehensive data protection law, went into effect on 1 November 2021 [53], about two years after the COVID-19 outbreak. It shall be noted that PIPL, combined with two other significant pieces of cybersecurity and data security legislation, the Cybersecurity Law (CSL) [54] and the Data Security Law (DSL) [55], have formed a new data protection framework for China. Although the Chinese government has strengthened privacy protections as a result of the extensive use of the health code systems, it is still unclear how the government would handle the health code systems and the data that has been gathered.

In China, Article 12 of the PIPL and Article 41 of the CSL clearly set user consent as a premise for the processing of personal information. [56] Nevertheless, Article 13 of the PIPL states that an individual's consent is not required if the processing is necessary to respond to public health emergencies or to protect people's life, health, or property safety

in an emergency. [57] In the event of a public health emergency, such as pandemic, China's Emergency Response Law, Law on Prevention and Treatment of Infectious Diseases, authorize the public agencies to collect personal information without the data subject's consent.

According to Article 7 of the PIPL, "personal information shall be handled under the principles of openness and transparency, with the regulations of personal information processing disclosed, and the aims, methods, and scope of processing openly declared." [58] Which means that this provision shall be contained in a privacy notice. In many regions in China, however, the use of the health code apps indeed did not adhere to this principle. Before implementation of the PIPL there were still half of health code apps used by various provinces and municipalities without any privacy notice. In several places where privacy notices were included, however have reading clarity problems. Some of the provinces even copied the privacy notice of the Shanghai version of the health code, with mistakes [59]. A lack of adequate transparency compliance measures can result in a number of issues, the most troublesome of which is the possibility of abuse of power.

To guarantee the security of personal data, Article 51 of the PIPL require at least "de-identification" or "anonymization" in data processing [60]. However, at the moment of writing of this research, the information received by the health code applications is managed at centralized level, by being gathered and transmitted to the province Big Data Bureau, Alibaba, Tencent, and the telecommunications department for processing. [61]. Particularly when using third-party services to operate the technology, the centralized data management architecture enables data aggregation across numerous sources and subsequent user re-identification. For instance, in Beijing, in December 2020, due to a vulnerability in the Beijing Health Kit system, pictures, ID numbers, and nucleic acid test results of over 70 celebrities were made accessible for online purchase. [62] This case demonstrates that greater attention should be given when in an emergency a third party other than the public authority may engage in data processing. [63]

3.2.3. Digital divide: the people left behind by QR codes

Digital health code leaves those sections of the population who do not possess smart phones, including many elderly and impoverished people, at a distinct disadvantage. China had over 1 billion internet users as of December 2021, including 119 million users aged 60 or over, according to a government report. [64] But that means that more than half of China's elderly population - around 145 million people - remain "offline." Over 30% of seniors are unable to access their health codes by themselves. Reports of seniors suffering due to the strict virus-control rules have proliferated for several months, sparking public backlash. [65] Many elderlies could not perform daily routine because they were unable to scan the code.

One paper released in May 2021, noted that many elderly people have difficulties using smartphones because of complexity of the system in some cities or provinces.

For instance, during lockdown in Shanghai residents were required to take a NAT every 72 hours to access public places, which was tracked using the health code and a special "NAT

code.” Then, to enter a venue, they have to scan a “venue code” at the entrance that logs their location, personal information, and COVID testing history. Anyone arriving in a new city, meanwhile, has to present a separate “travel code” that carries a record of their travel history. A proliferation of many codes confused elderly people, who were struggling to operate digital devices and intensify their social isolation. Chinese authorities have made some attempts to make the system easier for seniors to use. As early as November 2020, the State Council issued new rules requiring all venues to stop relying solely on the health code as a way to verify visitors’ COVID status. Instead, there should always be an alternative method available, such as checking a person’s ID card or a paper certificate. National authorities also ordered tech companies to adjust their platforms to make them more user-friendly, offering larger fonts, simpler interfaces, and voice recognition that recognizes regional dialects in addition to standard Mandarin.



Fig. 5. Shanghai code necessary for free movement during pandemic
 Source: Ding Yining, Sixth tone, 2022.

Shanghai, and other cities created an “offline code” - a print version of the city’s health QR code - that seniors can use to access venues and launched a service that connects seniors’ ID cards with their travel cards, which should allow them to access public transport by presenting their offline code rather than scanning a venue code.

4. Mutual recognition of Chinese JKM

4.1. Difficulty of mutual recognition of JKM in Mainland China

4.1.1. Influence of the history of JKM development.

In the early period of COVID-19 pandemic, China successfully used the JKM in recording the travel history of persons and finding the potential infections. In the period as early as in January 24 of 2020, Hangzhou synchronized data of positive cases, suspected cases, and “close-contact” into the pandemic control and detection system, including information of

ticket booking, hotel check-in, smartphone signal location and traffic CCTVs. [66] After the central government found the usefulness of JKM in pandemic detection, it began to support the JKM and developed it into a nationwide used application on digital devices. [67] At that period, many different JKM appear in various zones, which are based on territorial jurisdiction. The JKM was even operated and administrated by a county level of government. For this reason, there were nearly one hundred different JKM in various regions, including provinces, cities and counties. [68] JKM was not mutual recognized between different regions. One of the reasons is that the COVID-19 has caused a huge confusion when people faced it for the first time. Local governments took actions according to emergent situation in specific areas. The infrastructure of JKM relies on the devices in local areas, therefore data were limited to a local database. [69] Experts also admitted that the storage of data for JKM is ensured at the province level. [70] Mutual recognition of JKM means that a province should be responsible for the accuracy of information in JKM from another province. [71]

4.1.2. Local policies lacking consistencies due to discretion of local government

At the national level, State Council promulgated several policies since May 2020 to face the dynamic changes of the pandemic. Such policy documents can be a guiding opinion that only provides several principles and enable local governments to make detailed policies based on specific situations in their areas having certain level of discretion. [72] National Health Commission issued the 9th version Protocol on pandemic prevention and control on 27 June 2022. [73] The proposal gives discretion to governments in city levels to determine the classification of risk zones according to the epidemiologic surveys of positive cases. [74] The discretion of local government results also in the different criteria of the assignment rules on JKM's color. For example, Shanghai Rule is less restrictive than the one in Guangxi. [75, 76] According to Shanghai Rule "close contact" is assigned as yellow color, but it is red in Guangxi. [77, 78] The Shanghai JKM assignment rule did not mark with yellow code those users that are located on time-space intersection (TSI). [79] The TSI refers to those people who appear in the small zone (like a community) with confirmed cases, suspected cases, and asymptomatic infected persons, but have not arrived yet at the level of being in close touch. This divergence shows that a traveler holding green color of JKM in Shanghai may be regarded as a yellow JKM holder or even a red JKM holder in Guangxi. According to the Guangxi rule, red JKM holders are prohibited to travel and yellow code holders are limited in travel, thus, the same person in different zones may have different levels of free movement. The lack of consistency on policies in different regions may bring obstacles to people's free movement and daily activities because trans-provincial travel would be necessary for business, work, trips, etc. Besides, JKM policy is separated from travel restriction policies. For example, the JKM policy in Shanghai only refers to the criteria on the assignment of color of JKM but the Guangxi policy contains the travel restriction as a part of the JKM policy.

Different provincial governments have different concerns. Shanghai government is concerned more about the free movement of person because it is extremely important for economic growth. From this perspective, the policy is more relaxed. However, Guangxi government prefers to choose a stricter policy and applies more limitation on free movement because it is a provincial zone at the border of China with Vietnam. [80] It faces

higher pressure of imported infections through land port. [81] The same situation may happen in Yunnan province who has boundary with Myanmar and Heilongjiang province who has boundary with Russia. [82, 83]

From this perspective, it can be found that the biggest obstacle for mutual recognition on JKM is the different criteria in provincial JKM assignment rules. The nature of JKM mutual recognition is not only a balance of epidemic prevention and control and person's free movement, but also of the discretion and responsibility of provincial government and the uniform management at the central level.

4.1.3. Unpredictability, large scale and difficult control of the regional outbreak

According to the records from the beginning of COVID-19 pandemic, it is extremely difficult for governments to predict such outbreaks. The epidemic is under control in one zone, but it can be another outbreak in another zone. It is impossible to find a common circumstances where provinces (even cities and counties) have same or similar level of COVID-transmission. Even though the same criteria of the classification of risk areas applies, the reality in different provinces might be very different. The central and provincial governments have a relatively uniform standard for setting the high-risk and medium risk areas, but the uncertainty of the specific areas still exist because people cannot know where is going to be an outbreak.

In 2020, the standing committee of CPC central committee held a meeting and decided to practice the mechanism of the regular epidemic prevention and control (MREPC). [84] The MREPC aims to resume the normal economic activity and citizens life, which was before the pandemic. The Central government continuously insist the epidemic should be under control and the free movement should be guaranteed. To balance the two values, there is a requirement to isolate immediately and control the place and persons in the infected zone. Another limitation is the scale of outbreak incidence. If the outbreak is at the large scale, the isolation measures applied only in infected zone will face huge challenges. During Shanghai outbreak, large scale of isolation requires very high level of skillful management, and it has to sacrifice the free movement of people because wide and fast transmission require longer period of time to be controlled.

Taking the factor of "timing" into consideration, any slow operation may negatively influence person's free movement because the success of pandemic management is actually based on "timing". People may be isolated during their travel or in the hotel they lived in, which is much more problematic than being controlled at home. If local government does not have enough abilities in social resource management, they may prefer to choose simple lockdown policy. Furthermore, other provinces may tighten the free movement policy towards persons who come from the province in an outbreak. Even though the person may hold a green color JKM issued by home place, it can be refused by the host place.

4.1.4. Influence of Nucleic Acid PCR Test (NAT)

The NAT result can influence the color of JKM, but it is not a part of the JKM, even though it can be displayed with JKM. It is independent from the JKM. If there is no outbreak in a specific zone, people do not need to take NAT. JKM can remain in green color even if the

person does not take NAT. With the green color JKM, the person enjoys sufficient freedom of movement and travel in local zones, usually in the same city area. [85] If a person needs to go to other provinces or cities, the government of destination [86], as well as train station or airport [87] authorities will require the NAT, even though they have green color JKM. The NAT result becomes a de facto restriction on person's free movement. [88] At the beginning, NAT also lacks mutual recognition. It would be difficult for the host government to check and confirm the authenticity of such NAT result when the source and the format of NAT certificate are different. The host government may ask the traveler to a take arrival NAT. However, persons cannot travel freely after sampling in some places if they are required to wait until the result is reported. Meanwhile, when there is a risk of an outbreak, local governments may organize mass NAT arrangements. Heavy sampling work bring challenges to immediate data update in JKM system. The color of JKM cannot be updated accurately and timely.

4.2. Attempts for mutual recognition

4.2.1 Mutual recognition of JKM

The absence of mutual recognition of JKM is the biggest reason of the limitation of free movement of people, which has been criticized by the public and media. [89] Hainan is the first province that initiated the mutual recognition work between provinces in the leader joint meeting of Pearl River Zone. [90] On February 22, 2020, Hainan begin to negotiate with Guangdong, Fujian, Guangxi, Yunnan, Sichuan and Jiangxi on trans-provincial mutual recognition of JKM. [91] The approach of JKM mutual recognition can be classified into three types. The first type refers to the uniformity of all JKM application inside on province, its system, and relevant procedures, which are developed by cities and counties. [92] The second type is the bilateral agreement of JKM mutual recognition. For example, Hainan and Zhejiang signed the first "JKM mutual recognition agreement" on February 28, 2020. [93] The third type is the multilateral agreement of JKM mutual recognition. [94] The three provinces (Zhejiang, Jiangsu and Anhui) and one city (Shanghai) in Yangtze River Zone established a common JKM mutual recognition mechanism. [95] The fourth type is mutual recognition on the leadership of the central government: [96] the State Council together with provinces and National Health Commission promoted the national JKM mutual recognition. The State Council used the national e-governance platform to provide interface to all provincial JKMs. Meanwhile, the State Council also promulgated three documents of national standards. [97] However, the previous problem still persists: the national JKM and provincial JKMs works at the same time. [98] All provinces recognize the national health code but whether an JKM from another province will be recognized depends on existence of JKM mutual recognition agreement and other local policies. [99] After the development and implementation of JKM in the country, health code was uniformed only within a province because the State Council requires that provinces should unify their JKM management procedure. [100, 101] After such unification, city and county JKM have disappeared.

4.2.2. Mutual recognition of NAT

The most significant solution on the mutual recognition work is the Notice on Further Promoting National Mutual Recognition of New Coronavirus Nucleic Acid Test Results issued by State Council on July 29, 2022. From this Notice, Central government explained

that the NAT results should be mutually recognized. Central government emphasized that it is important to efficiently implement the balance on pandemic control and the social and economic development. The goal of this policy is to guarantee that citizen will resume their normal life and make travel more convenient and safer. Through the text of Notice, the central government almost admitted that that the diverse of NAT requirements without mutual recognition create obstacles on person's free movement. By imposing direct prohibitions on conduct of local public departments, the measures that restricting person's free movement are confirmed illegal. [102] The Notice of the central government indicate on the necessity of the mutual recognition of NAT result. This shows that the most influential factor on person free movement in China is the attitude and control of the central government, which also refers to the prevention and management of pandemic. However, the mutual recognition of NAT is only one step of the mutual recognition of the JKM. On August 10, 2022, National Health Commission emphasised that they would optimize the management of JKM.

4.3. Mutual recognition of JKM between Guangdong Province and Macau SAR

4.3.1 Crossing border with JKM

In Macau SAR, JKM is considered the digitalization of health declaration. The Health Bureau of Macau SAR can require visitors to present their health situation [103], declare their symptoms, display the medical declarations and certificates of vaccination. [104] Macau JKM is considered as “a health declaration upon arrival in Macau and the declaration of health condition at a port of entry is mandatory”. [105] Travelers need to complete transcoding process when departing to Macau via Zhuhai, the city in Guangdong province, that has border with Macau SAR. Before departure, a visitor should conduct NAT testing at institutions mutually recognized by Guangdong, Hong Kong, and Macau. [106] The traveler needs to log in to the Guangdong JKM system to apply customs clearance certificate after making an entry-exit health declaration [107] and scan the code of customs clearance certificate on the machines provided by the custom on the Mainland China side before border check. When arriving at the border on the Macau SAR side, travelers need to obtain the Macau JKM by transcoding from Guangdong JKM. Finally, travelers need to process a normal border check procedure on the Macau side after displaying their Macau JKM. When to enter Zhuhai from Macau, travelers also need to make entry-exit health declaration, transcoding Macau JKM to obtain a Guangdong JKM, and complete customs clearance certificate scanning.

4.3.2. A common policy on pandemic control is necessary

The mutual recognition of JKMs between different provinces in Mainland China is already a complex matter. It is certain that the mutual recognition is even more complicated between Guangdong and Macau SAR. Even though Mainland China and Macau SAR are two different jurisdictions under the unification of PRC, one JKM cannot be mutually used in both two regions. No matter in Mainland China or Macau SAR, travelers who enter another region should apply for JKM at the destination, which is considered as a governmental certificate. To use a governmental certificate in another jurisdiction, it requires mutual recognition. However, challenges come from legal and technological perspectives. JKM contains a large volume of personal data which is an important part of people's privacy. The establishment of JKM and the security standard of use should comply

both Chinese law and Macau law. [108] Personal data on privacy is prohibited to be transferred outside of a jurisdiction. [109] Thus, mutual recognition of JKM should be through non-transnational procedure. Guangdong Province and Macau SAR used blockchain technology to solve the problem. The technical support and implementation service provider of Macau JKM admitted that the original information of the data is still stored in the local database of the health code issuer. [110]

The mutual recognition of JKM is not to validate Guangdong JKM/Macau JKM in Macau SAR/Guangdong Province, but to generate a correspondent one of another jurisdiction. Current technology can realize the transcoding procedure so that the mutual recognition seems to have no barrier from technical perspective. Thus, current obstacle is still the will for mutual recognition. Guangdong province and Macau SAR has a common leader, the central government, so that they have a channel to negotiate and coordinate. The central government encourages Guangdong province and Macau SAR to realize the mutual recognition of JKM based on “One Country, Two Systems” practice. [111] However, the mutual recognition is still limited by the anti-pandemic policies. Mainland China and Macau SAR have a common “zero policy” rather than co-existence with COVID-19. [112] The consistency of anti-pandemic policy makes it possible for the two jurisdictions to have a common policy for border-crossing without isolation procedure, which is the aim of mutual recognition of JKM.

On contrast, Hong Kong SAR, is also a part of PRC, but it chooses to apply for de facto coexistence with COVID-19 policy. [113] Even though the negotiation and coordination mechanism might also exist between Hong Kong SAR and Guangdong Province, free movement without isolation has been not realized yet. Meanwhile, Macau SAR and Hong Kong SAR also do not have mutual free movement arrangement. Macau SAR applied for stricter methods including frequent mass NAT, self-testing, and restrictive lockdown policy. It successfully achieved zero infections in the Macanese society, which is a guarantee for reopening the free movement without isolation to Mainland China. Thus, the difference in anti-pandemic policy can be one of the core issue in JKM mutual recognition.

4.3.3. Outbreak of COVID-19 challenges free movement of persons

When there were no positive cases in Zhuhai and Macau, there was a long-term period which travellers only need a green colour of JKM and a negative result of NAT, valid for 7 days when they travel between Zhuhai and Macau. However, the stability of “zero case” in both sides has been vulnerable. After the variant of Omicron emerged, such stability was challenged several times. Particularly during the Macau’s outbreak on June - July 2022, free movement between Macau SAR and Zhuhai was interrupted. Even though Mainland China did not close the border and still allowed travelers to enter Zhuhai, the requirement was much tighten than for period without infections. First, travelers must hold a negative result of NAT within 24 hours. Meanwhile, they should hold a successful booking record of isolation hotel. [114] After entering Zhuhai, people need to accept to be quarantined for 7 days and stay-home for health management since June 25, 2022. [115] Persons may hold green colour JKM, but they still cannot freely cross the border between Zhuhai and Macau. This shows that holding a JKM is only one of the necessary requirements when people need to do cross-border travel, thus JKM policy is not enough to ensure the free movement of

person. The anti-pandemic policy on social control has priority on JKM policy and free movement of person.

4.3.4. The importance of coordination between two governments

Zhuhai and Macau had a successful coordination mechanism in dealing with the consistency of the policy on both sides, which determines the trans-border free movement of persons. [116] Dynamic situation of virus transmission requires governments to react immediately. Macau and Zhuhai had frequent communication to reduce the changes of policies on both sides. Border-crossing is determined by the consistent policies of two government on the both sides. After Macau SAR has successfully controlled the transmission of COVID-19, the relaxation of free movement restriction is also made via a joint mechanism. It can be found that a flexible adjustment on border control policy relies on the efficient communication and coordination on both side governments, which is much more than a simple transcoding of JKM.

5. Misuse and abuse of JKM

5.1. Abuse of the JKM for other purposes than those prescribed by regulations

The law set very restrictive rules on the data-processing conducts and the governments, including big data management sectors, dominated the work of data-processing. It is very rare case that technology company may abuse collected data. The restriction on person's free movement is from governmental behavior rather than the Internet companies who provide basic technological service of the JKM operation. The main abuse of JKM consist in assigning the wrong color of code when there is no risk of transmissions of COVID-19. Then persons cannot enjoy free movement because they are in "red code".

Specific case concerns an abuse of health code for non-epidemic prevention and control policies for depositors of some village banks in Henan province are assigned red color in their JKMs. According to the report of Southern Metropolis Daily (Nandu), JKM of some depositors of some Henan village banks was abnormally coloured in red. [117] On June 13, 2022, information circulated on the Internet showed that depositors who went to Zhengzhou to communicate with village banks on the issue of money withdraw were assigned red color. [118] Many other depositors were given a "red code" after filling in the information even though they did not physically go to Zhengzhou." [119] However, JKM of non-depositors who went to Zhengzhou at the same period of time were not affected. On June 17, 2022, Zhengzhou Municipal Commission for Discipline Inspection and Supervision has started an investigation procedure. According to the report of investigation, a total of 1,317 depositors were assigned a red JKM. The authority of Zhengzhou confirmed that some officials violated relevant rules and they should be punished. [120] Finally, Zhengzhou corrected their wrongdoing.

5.2. Malfunctioning of JKM

JKM is an important certificate for person's free movement. It is a type of smartphone software that relies on normal operation on digital devices. Its function is determined whether the hardware and software environment can work well. Technical problems will directly influence the normal use of JKM and finally bring inconvenience to person's free movement. Particularly, in the scenarios where JKM is frequently used, malfunctioning is

troublesome. JKM in many provinces experienced frequent malfunctioning problems. Most of them are because of network problem and were quickly fixed. This kind of malfunctioning results in that the information cannot be successfully displayed on the JKM, including the color of JKM and NAT results. It will bring inconvenience when persons need to enter some indoor places, or public transportations requiring the display of relevant information. As an example of the solution, Foshan government made a system for people to scan their ID card instead of displaying their JKM. [121] Even through in some cities, paper notification on health information is available for replacement of JKM, it brings risks of fake notification, and this method is not universally applicable. A person may agree to take a NAT sampling, but it will not be timely to get a paper-based report. Another type of malfunctioning will bring more serious problems if the information on JKM is wrongly displayed. For example, on November 25, 2022, all residents in a town in Guangdong province were wrongly assigned red color of JKM. This triggered a person's gathering to do NAT sampling and caused stampede. The government explained that the reason of the wrong display is malfunctioning. Macau JKM also face several times of malfunctioning, but it was quickly repaired. [122] Besides, Macau JKM once faced cyberattack from foreign IP addresses. [123]

5.3. Abuse of data

JKM stored a large volume of sensitive personal data, including personal information, contacts, address, etc. in the first year of pandemic, PIPL was not promulgated so the health code had an extremely free environment to be implemented and developed. After the law was promulgated and took into effects on November 11, 2021 [124], JKM administrators had to comply with the rules under PIPL. PIPL authorized JKM administrators to process on personal data when there is an outbreak in specific zones without person's permission, but it does not explain the scenarios under no outbreak period. [125] JKM usually has a button on its interface for users to permit the process on personal data so it means the process on data comply the requirement in Article 13(1) of PIPL. [126] Article 6 of PIPL set the principle of minimization, which requires the process with personal data should have clear and reasonable purpose. [127] Data-processing should be directly relevant to the purpose and minimize the influence on personal rights. [128] This means if JKM is used for other purposes, it will be a violation on PIPL. The State Council also prohibited to assign HC's color based on non-epidemic prevention reasons. [129] In Zhengzhou "Red Code Case", the assignment on JKM aimed to prevent person to enter specific places without outbreak of COVID-19, even there is no identification of high or medium level of risk at home places of such travelers. These JKM users get green color from their home provinces or from the national platform but still were assigned red color when arriving at Zhengzhou or scanning the venture code at Zhengzhou station. Different from the original purpose of JKM that aims to maximally protect free movement of person and realize an accurate control on the virus transmission, the charged conduct in this case was to impose restriction on persons. The abuse of power in this case not only violates the orders given from the State Council but also the local rules of Henan province. Meanwhile, it is also infringement on PIPL and DSL. The assignment of color is a part of the data-processing so that it also needs to comply with the prescriptions from the two laws. Besides the requirement on purpose and necessity, the abuse of JKM in Zhengzhou Red Code Case also infringed the procedural requirements established in Article 32 of DSL.

6. Conclusions

China deployed data-driven solutions fast and early in the Covid-19 epidemic. Responses included upgrading and expanding components of the existing digital technology ecosystem, most notably facial recognition and application like JKM on WeChat and Alipay platforms. JKM have proved to be one of the most powerful tools in China's anti-pandemic arsenal – allowing the authorities to effectively track and control people's movements to help curb the spread of the virus. The JKM system was much easier accepted by the Chinese citizens, compared with other countries, as QR codes have long been used in China for financial and other transactions. The gatekeeper function of health control apps has offered Chinese citizens a sense of security. Large parts of China's urban society have seemingly embraced the new apps and readily installed them to gain individualized risk/health assessments. Installation and usage of apps is not mandatory in a legal sense. However, on a local level, QR code-based health application have quickly become de facto mandatory, playing a gatekeeper role for access to residential and commercial buildings. Well-established links between government and business enabled Beijing to draw on large amounts of user data, often in real-time, helping China to successfully avoid large scale of infection by efficient detection based on JKM technology.

China's data-driven management of Covid-19 has shown key benefits, such as reviving public life in a strictly controlled form based on rapidly deployed solutions to trace people's movements, contacts and health status. Digital platform solutions have improved resource management during pandemic, however, the swift roll out of data-driven solutions to manage public health also highlighted several risks and problems. Technological solutions like the QR health codes proved only partially functional. Personal data has been misused by companies to collect data for their own commercial interest. Local governments have also abused personal data in the drive to detect infected people and reduce new cases. The abuse of JKM for other purposes and abuse of data not only bring problems to people's daily life, but also infringe relevant laws. Central government prohibits such kind of abuse and emphasized that JKM cannot be used for non-pandemic control purposes. Malfunctioning is another problem, which can make JKM abnormally displayed and causes other chain effects. It is understandable that heavy maintenance work on JKM are required, but alternative solutions should be also given. Besides, the administrator of JKM should make precautions on data security issues.

It was obvious that in the first year of COVID-19 pandemic, China's epidemic management prioritizes security over privacy. Laws and regulation focus on facilitating data aggregation and sharing between stakeholders, rather than privacy rights in the beginning of pandemic. However, after the implementation of PIPL, situation changed, making important changes on data governance and difference between the norm and the exception in case of public health, while personal data being legally protected.

The biggest problem with JKM is the mutual recognition issue that may limit person's free movement. The reason of problem of mutual recognition is deeply rooted its working mechanism and governmental policies. Even though central government of China and provinces make efforts to promote the JKM mutual recognition work, this is heavily limited by policies of local governments, which have certain level of discretion on the color

assignment rules and relevant free movement policies. The same person holding JKM may receive different treatments in different provinces. If two local governments lack consistencies on policies, the free movement between such two places will be restricted. Meanwhile, the function of JKM on protecting person's free movement will be largely limited if an outbreak happens. NAT testing result also have an influence since NAT certificate is usually displayed on JKM as a digital document for free travel. When NAT lacks mutual recognition, the same goes for the JKM. Central government and provinces promoted mutual recognition work through various agreements and policy promulgation including NAT mutual recognition. However, it still require time to have a free movement of person at the national level. From the aspect of border-crossing, Macau SAR and Guangdong provinced set a good example on mutual recognition of JKM on crossing border. It again proves that free movement relies a common policy resulted from both local governments.

Indisputably, China's health code system represents an unprecedented form of biological governance. However, one of the most urgent questions we all face today is the extent to which we are willing to overlook the implications of widespread biological surveillance in order to control the pandemic. This issue is particularly complex in China, where it is not impossible to imagine the future in which less legitimate targets like COVID-19 would be subjected to the big data monitoring techniques presently under development. In fact, it is misleading to consider the response to COVID-19 as a distinction between autocracies and democracies. Many countries have implemented contact-tracing application, in some country voluntary in others mandatory. Therefore, it was important question to ask if China's health code will be a new model in post-COVID-19 life? Indeed, governments find themselves in a dilemma: the choice between controlling COVID-19 and resuming public life. In the foreseeable future, we will see more tracing tools around the world and hear more concerns about public values and privacy. As such, it is possible that tracing apps will normalize health surveillance and become a part of daily life in many countries. However, the application of tracing apps shall rely on many factors like transparency, trust in government, and citizens' cooperation.

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