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## Employing digital technologies for effective governance: Taiwan's experience in COVID-19 prevention

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## ABSTRACT

**Objectives:** In the digital era, it is important to harness digital technologies to implement effective governance. This paper aims to propose a conceptual framework for the digital governance roadmap. It mainly is the meaningful integration of digital technologies into drafting policy accompanied with comprehensive planning and flexible strategy for better governance. The high-quality, timely, and reliable database is one of the key digital infrastructures for the meaningful employment of digital technologies.

**Methods:** Taiwan's experience in COVID-19 pandemic prevention is employed as the case to explore the roadmap of digital governance. The Taiwan government and civil society harnessed the power of its National Health Insurance (NHI) database, and further employed data science and GIS to develop the Face-mask distribution system and QR code registration system. Comprehensive planning and flexible strategy were conducted to address public concerns, such as data privacy and digital divide.

**Results:** Harnessing the NHI database's power, the GIS-based Face-mask distribution system and QR code registration system contributed to reducing the infections, panics, and public concerns including data privacy and digital divide for pandemic prevention.

**Conclusions:** While exploring the systematic digital governance roadmap, it is necessary to fulfill three basic criteria: (1) comprehensive planning, (2) flexible strategies, and (3) the meaningful employment of digital technologies. As one of the key digital infrastructures for the employment of digital technologies, the high-quality, timely, and reliable database is essential to release the power of data-driven for cross-domain collaborations, multiple engagement, innovative applications, and digital empowerment, towards achieving effective governance.

**Public Interest Summary:** This paper proposes a conceptual framework for the roadmap of digital governance, which highlights the importance of the meaningful integration of digital technologies into drafting policies accompanied with comprehensive planning and flexible strategy to achieve effective governance. During the process, the high-quality, timely, and reliable database acts as a key role in facilitating the operation of digital infrastructure for the employment of digital technologies.

Taiwan's experience in COVID-19 prevention by harnessing the power of the NHI database and developing the GIS-based Face-mask distribution system and QR code registration system effectively addressed the public concerns on data privacy and digital divide towards effective pandemic prevention. This could be an example provided for other countries to balance public concerns and effective governance.

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## Introduction

In the digital era, national governments of many countries have been increasingly employing digital technologies in governance to address the challenges of the rapidly changing world. In particular, digital technologies have played an essential role in public health domains, such as healthcare and wellbeing, and epidemic prevention. Therefore, developing a framework for the roadmap of digital governance is important to support governments to provide efficient services for people and implement effective governance, as well as provide the roadmap for policymakers to explore the approaches to implement better governance through technology in various domains. However, people are still exploring how to implement effective governance through digital technologies.

Over the past years, many studies have focused on different perspectives of digital governance, but few proposed a systematic roadmap for digital governance to guide the implementation of effective governance. For instance, Milakovich emphasised the importance of information technology and public participation in achieving the transition towards digital governance [1]. Erkut argued that the main challenge in digital governance is not the technical issues, but how to create governance structures to integrate citizens into the policymaking processes meanwhile avoid the knowledge gap-induced problems [2]. Dunleavy and Margetts developed the design principles for Essentially Digital Governance (EDGE) model, which placed digital technologies at the center of government and identified the roles of organisational cultures that were mostly from outside of government [3]. However, digital governance that integrates digital technologies, planning, and strategy is still lacking.

This paper proposes a conceptual framework for the roadmap of achieving digital governance (as shown in Fig. 1). It mainly refers to the meaningful integration of digital technologies into drafting policy accompanied with comprehensive planning and flexible strategies to achieve effective governance. In other words, achieving effective governance in the digital era requires not only the employment of digital technologies but also comprehensive planning and flexible strategies that concern social issues and demands.

In the roadmap of digital governance, the most important thing for implementing effective governance is the meaningful employment of digital technologies, which relies on the comprehensive digital infrastructure. It is widely accepted that data is power and drives the operation of digital infrastructure. Therefore, database acts as a key role in the employment of digital technologies to achieve cross-domain collaboration, diverse engagement, innovative application, and digital empowerment (shown in Fig. 2), which contribute to effective governance. However, there are concerns exist surrounding the database, such as data privacy and digital divide. Therefore, comprehensive planning and flexible strategy are also indispensable in the implementation of effective governance.

In response to the digital age, Taiwan is also striving to use digital technology to assist governance through technological power. This paper employs Taiwan's experience in COVID-19 prevention as the case, in particular, the development and functions of the National Health Insurance (NHI) system, Face-mask distribution system, and QR code registration system, to demonstrate how Taiwan integrated digital

technologies into policies, by harnessing the power of data-driven, to achieve effective governance during the pandemic prevention. Drawing on Taiwan's experience in pandemic prevention through digital technologies, this paper proposes that digital governance can improve governance as a meaningful technology introduction, that is, the introduction of digital technology supplemented by comprehensive planning and flexible strategy.

## Conceptual framework of digital governance

International organisations have developed digital transformation indices. Table 1 summarises the global indices for measuring digital transformation in various scales and domains.

In recent years, many countries have implemented digital technologies to improve their economy and competitiveness, and international organisations developed various indices to measure digital transformation. Most indices pay significant attention to digital infrastructure (e.g. connectivity, data accessibility) and human capital [4,5], as these are the foundation for digital transformation. For example, DESI and I-DESI both list connectivity and human capital as important measuring dimensions [4,5]. Going Digital Toolkit [6] assesses the broadband and jobs. Networked Readiness Index [7], established by WEF, assesses the internet and skills and usage of digital technologies. The Swiss International Institute for Management Development (IMD) sets the IMD World Digital Competitiveness Ranking [8], which also measures digital infrastructure and human capital. The Toolkit for measuring the digital economy developed for G20 measures the digital infrastructure and jobs [9]. Hence, the meaningful employment of digital technologies for effective governance relies on comprehensive digital infrastructure.

Apart from digital infrastructure and human capital, these indices also measure how the government uses digital technologies to support governance. DESI and I-DESI measure the e-government development progress, digital public service, and open data [4,5], and Networked Readiness Index [7] measures how the government harnesses ICT to achieve their vision. Going Digital Toolkit [6] concerns trust in using digital technologies for business actions. Asian Digital Transformation Index measures the government's policy on technology and business, especially the effectiveness of the system in policy implementation [10]. Digital Government Index (DGI), established by OECD, measures the comprehensiveness of digital government strategies and initiatives. All these indicators reveal the importance of comprehensive planning and flexible strategy for effective governance.

Based on the above, it can be seen that relying on digital infrastructure, especially accessibility to data, the meaningful integration of digital technologies into drafting policy should be accompanied with comprehensive planning and flexible strategy to achieve better governance. This will lead the country towards a digital and sustainable future, which echoes the spirit of "Smart and Sustainable (Double S)".

## Database, the key digital infrastructure

Existing digital transformation indices indicate that digital infrastructure and human capital are the most important to successful digital transformation [4,5]. In particular, the database is one of the fundamental elements of digital infrastructure, and therefore it is critical to

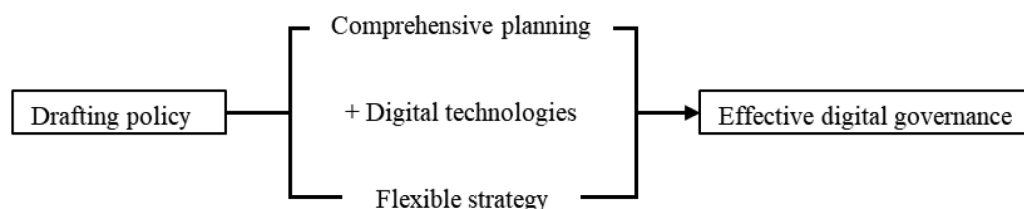


Fig. 1. Conceptual framework of the roadmap for digital governance.

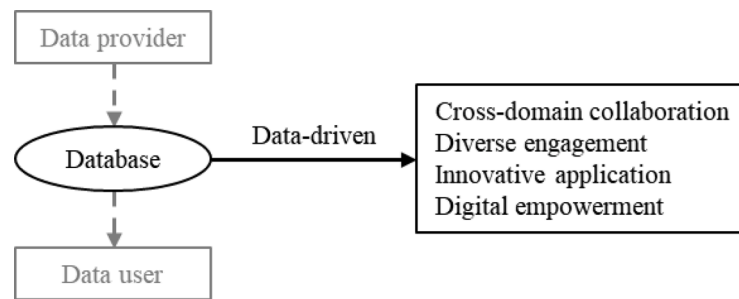


Fig. 2. The power of data-driven (gray lines: data flow).

**Table 1**  
Global indices for measuring digital transformation.

| Organization  | Indices  | Notes  |
|---|--|--|
| World Bank Group (WBG)  | GovTech Initiative                                       | Assist the digital transformation reforms  |
| World Bank Group (WBG)  | GovTech Maturity Index (GTMI)                            | Assist practitioners and advisers to design the new digital transformation projects  |
| European Union (EU)   | Digital Economy and Society Index (DESI)                 | Assess the digital development of the 28 EU member states  |
| European Union (EU)   | International Digital Economy and Society Index (I-DESI) | Assess the digital development of the EU as a whole and 17 non-EU member states  |
| Organization for Economic Co-operation and Development (OECD)             | Going Digital Toolkit                                    | Assist its member states and eight other non-member states in assessing their country's digital development and formulating policies and strategies for promoting digital transformation |
| Organization for Economic Co-operation and Development (OECD)             | Digital Government Index (DGI)                           | Measure the maturity level of digital government strategies in OECD countries  |
| World Economic Forum (WEF)  | Networked Readiness Index                                | Measure how well an economy is using information and communications technologies to boost competitiveness and wellbeing  |
| Swiss International Institute for Management Development (IMD)            | IMD World Digital Competitiveness Ranking                | Assess the digital adoption of 63 economies globally based on 340 criteria and explore digital technology to lead reforms in government, business models and society                     |
| United Nations Educational, Scientific and Cultural organization (UNESCO) | ROAM-X framework   | Assess Internet universality   |
| G20   | Toolkit  | Measure the digital economy  |

develop the high-quality, timely, and reliable database to achieve effective governance.

As early as 1995, the Taiwan government launched the National Health Insurance (NHI) system, which applied a single insurer system and aimed to provide high quality, universal coverage, accessible, and equal healthcare for all [11]. According to the Ministry of Health and Welfare, the NHI system has contracted with approximately 93% of healthcare providers in Taiwan (100% hospitals, 92.6% primary clinics, and 79.3% pharmacies), as well as the system is compulsory enrolment for all citizens and legal residents [11]. The universal coverage of the

NHI system made it possible to comprehensively collect the data of people in Taiwan, which forms a robust database. The accumulated efforts in developing the NHI system since the 1990s reflected the spirit of Universal Health Coverage (UHC) initiated by the World Health organization (WHO) in 2021. Today, the NHI system as a government-promoted system that aims to achieve universal coverage has accumulated rich data and formed a comprehensive database.

During the past decades, the NHI database has been continuously updated to ensure its high quality, timeliness, and reliability. Given that the data is sourced from different stakeholders, such as healthcare providers and citizens, the Taiwan government collated the data and further unified the data format, allowing smooth data flow between stakeholders. The comprehensive database and smooth data flow further drive cross-domain collaborations, multiple engagements, innovative applications, and digital empowerment, which contribute to the effective digital governance.

Since the beginning of the COVID-19 pandemic, the NHI database has played an important role. To name a few, the first emergency that challenged Taiwan was the Diamond Princess Cruise Ship, and the NHI database was used to conduct health surveillance for people who had contact with passengers [12]. Meanwhile, the NHI database was combined with the 14-day travel history of patients and clinical symptoms to identify people who tested positive [13]. Based on the NHI database, the Taiwan government also developed the Face-mask distribution system and QR code registration system [14], which took the power of data-driven, as well as meaningfully employed digital technologies to achieve effective pandemic prevention.

Compared with Taiwan, a universal healthcare system was lacking in the US, which negatively affected pandemic prevention. Statistics showed that adequate health insurance was not accessible to over 78 million people in the US [15]. As a result, many people were not able to receive medical treatment and the spread of coronavirus could not be contained [16].

### Meaningful employment of digital technologies

Based on the comprehensive database, the meaningful employment of digital technologies in policies is the key to implementing effective governance.

In the past decades, data science and GIS as digital technologies have been widely employed in healthcare. For example, WHO has used GIS for global epidemic surveillance. For COVID-19 surveillance, Johns Hopkins University also applied data science and GIS (as shown in Fig. 3), which intuitively reports confirmed cases, deaths, and vaccine doses administered regionally and globally [17].

At the national level, data science and GIS can also be integrated into policies to assist the government, public sectors, and individuals to prevent the pandemic jointly, as well as play the role of data-driven for cross-domain collaborations, multiple engagement, innovative applications, and digital empowerment to achieve effective pandemic prevention. In the UK, people used the NHS COVID-19 app to report and check the COVID-19 progress. The COVID Symptom Study app and the Secure



Fig. 3. COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU).

Anonymised Information Linkage (SAIL) Databank were used to help the surveillance of COVID-19 [18].

Taiwan has a long history of employing digital technologies for healthcare and welfare [19,20]. In the past year, Taiwan further integrated data science and GIS into policies with comprehensive planning and flexible strategies to implement pandemic prevention. The effective pandemic prevention during the past year relied on not only the experience of SARS, but also the meaningful employment of digital technologies [21]. This section provides two cases: the Face-mask distribution system and QR code registration system, to demonstrate how Taiwan employed digital technologies as well as made comprehensive planning and flexible strategy to prevent the COVID-19 pandemic (as shown in Fig. 4).

#### Face-mask distribution system

At the beginning of COVID-19, many countries were greatly challenged by the shortage of face masks and public panic. Several countries successfully prevented the outbreak of COVID-19 without forced lockdowns through close collaborations between the government and society [22]. Taiwan also prevented the outbreak of COVID-19 in communities for over one year through joint efforts between the government, industries, healthcare professionals, and citizens.

As a matter of fact, the Taiwan government promptly organised the National Face Mask Production Team and Name-Based Face Mask Distribution System to supply enough face masks to the public [23]. The

mask production capacity rapidly increased from 1.88 million pieces per day before the outbreak to 4 million pieces per day within a few days, allowing the government to further distribute them to people [24]. The sharp increase in face-mask production capacity allowed people in Taiwan to have sufficient personal protective equipment (PPE), which resulted in very low confirmed cases and mortality [25]. Compared with the US, the face-mask production capacity was only 35 million/month, and people were not supplied with sufficient PPE.

The Face-mask distribution system (see Fig. 5) was developed on the basis of the comprehensive NHI database, especially the location information of pharmacies, as well as the face-mask production information collected from the face-mask manufacturers of the National Face-mask Team. With the comprehensive and timely data, the Taiwan government further employed the GIS to develop the Face-mask distribution system, which displays the location of pharmacies and stock of face masks, allowing people to locate and purchase, or pre-purchase, face masks efficiently. The cross-domain collaboration between the manufacturing industry and the government promptly satisfied the public demands for face masks and reduced public panic. Moreover, the government also needs to provide accurate and timely data to the public regarding the availability of face-mask in different pharmacies. According to DESI and I-DESI [4,5], Open Data measures a country's progress in implementing Open Data policy in place and its political, social, and economic impact. Hence, as an echo of the open data spirit, the Taiwan government further made the flexible strategy by releasing related data publicly and encouraging the creative industries to further

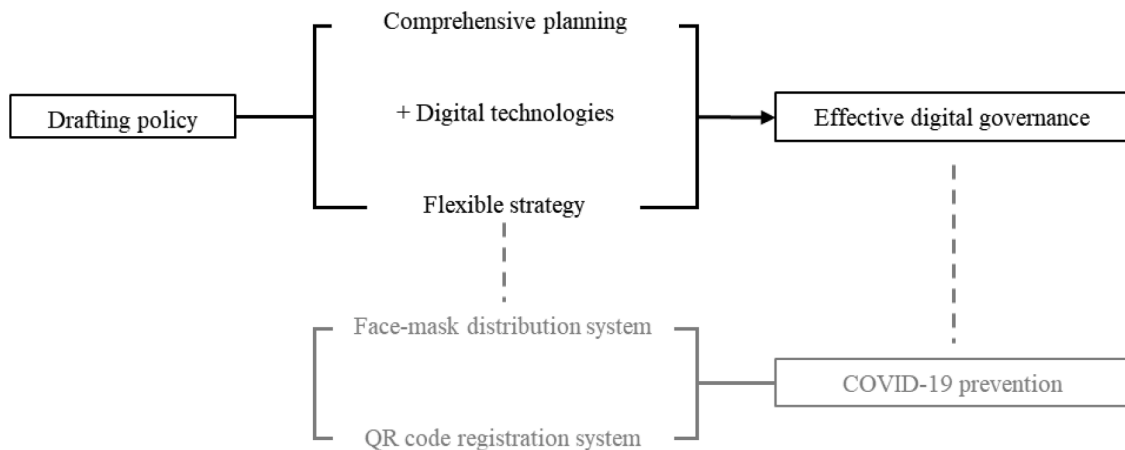


Fig. 4. Taiwan's COVID-19 prevention, a case demonstrates the proposed conceptual framework of digital governance.



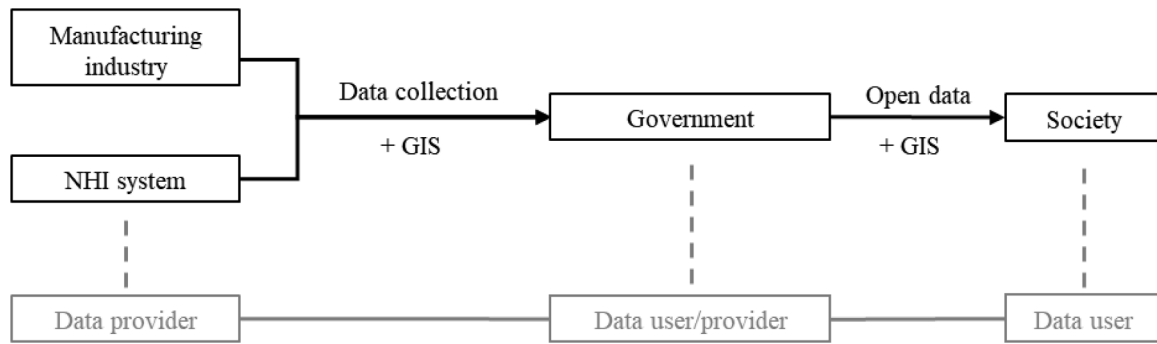


Fig. 5. Data-driven process in Face-mask distribution system.

develop GIS-based information platforms with diverse functions, as well as then the Ministry of Health and Welfare further provided the face mask supply and demand information platform [26]. Fig. 6 shows an example of a GIS-based platform displaying face mask information. These actions promoted public-private partnership and public engagement, which brought together the efforts from various stakeholders and multiple domains, and allowed the society to obtain the anticipated information conveniently [27].

During this process, people had access to transparent and reliable information sources, and therefore were able to conveniently and proactively employ digital tools to prevent infections, which significantly reduced public panics and maintained social stability, allowing the smooth implementation of other pandemic prevention measures, towards achieving effective governance.

#### QR code registration system

Given that the progress of digitalisation and digital transformation varies in different domains, while exploring the roadmap of digital governance, the employment of digital technologies in policies could

confront a series of public concerns. Many researchers have pointed out the challenges in the digitalisation of governance mechanisms, such as inclusiveness, trustworthiness, transparency and accountability, accessibility, data collection and data flow, and data stewardship [28,29]. Hence, it is still necessary to have comprehensive planning and flexible strategies to assist the employment of digital technologies in achieving effective governance [30].

In recent months, the variants of COVID-19 have broken into Taiwan and caused a significant outbreak in communities, which made the original approach for tracing and tracking no longer effective. To contain the infections, the Taiwan government has implemented a series of measures to limit gatherings, test, as well as track and isolate the people who tested positive and their close contacts. This includes the development of the QR code registration system by employing the GIS system, and integrating the location information provided by the society and the case information by the official Covid-19 Map [31], and then people could simply scan the QR code and send the text to telecommunication companies (as shown in Fig. 7) [32]. Meanwhile, comprehensive planning and flexible strategy were implemented to respond to public concerns on the risk of infection, data privacy, and digital divide.

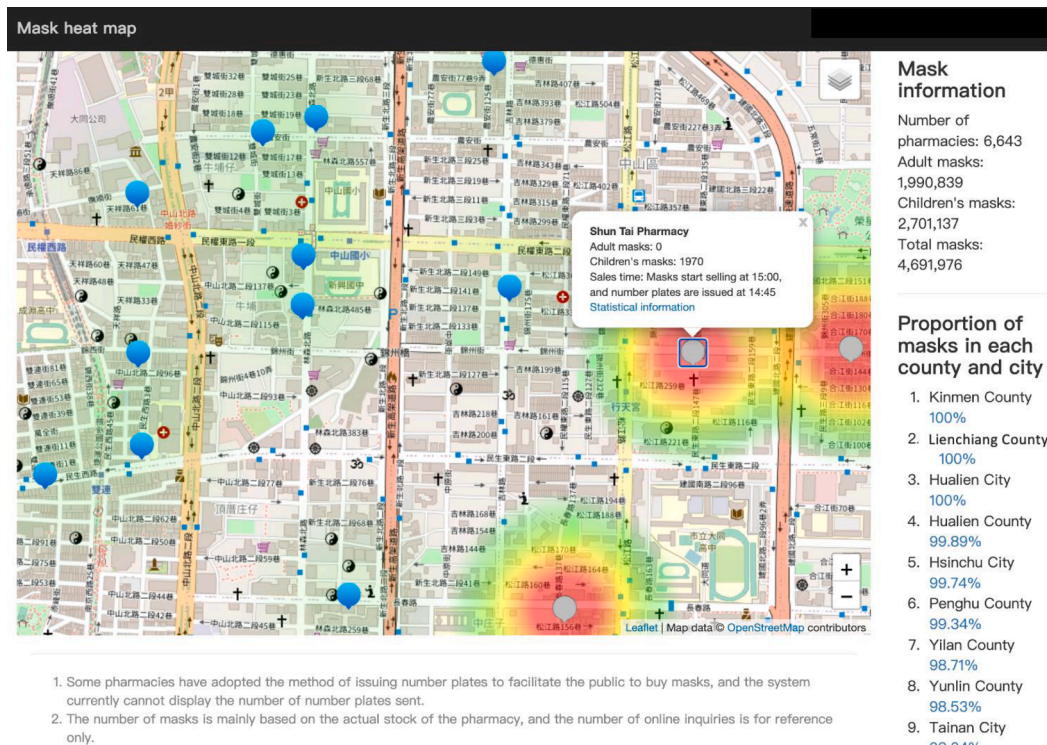


Fig. 6. Heat map of face mask information: the location of the pharmacy with its working hours, and the number of available face masks for adults and children, respectively. [26].

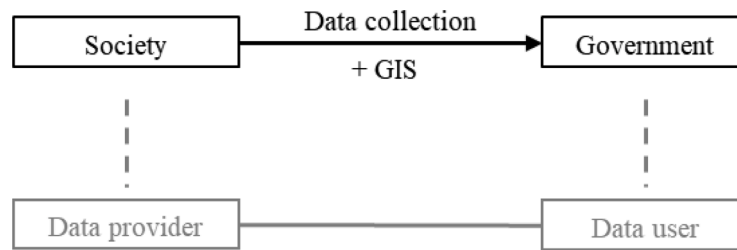


Fig. 7. Data-driven process in QR code registration system.

As a result, Taiwan successfully contained the spread of coronavirus in approximately one month, reducing the growth rate from approximately 75% to nearly 0 [33].

To implement effective pandemic prevention, the government needs accurate and timely information about where people visit and who they have close contact with for tracing and tracking. Hence, the QR code system is designed so that people don't need to contact each other while scanning the QR code and sending the text, which reduces the risk of infection. Once the confirmed case is identified, the location where the confirmed case visited will be immediately disinfected, and other people who also visited the location will be treated as close contacts and conduct further measures.

The data privacy issue has been debated for years [34], especially when the government or businesses collect data from society. Protecting people's privacy and their trust in digital technologies is essential to ensure that they don't experience privacy violations, as indicated by the Going Digital Toolkit [6]. During the pandemic, the ethics of personal data collection attracted increasing attention due to the wide application of contact tracing systems [35]. The European Union officially launched the General Data Protection Regulation (GDPR) in 2016 to address data protection and privacy issues [36]. During the pandemic prevention in Taiwan, the QR code registration system addressed this concern through comprehensive planning and flexible strategy that (1) people don't need to provide personal information to the business places they visited; (2) the location information of people is sent to and stored by telecommunication companies rather than the government; (3) the information is kept by the telecommunication companies for 28 days, which covers two incubation periods of the coronavirus, and then deleted; and (4) the information will only be used by the national health command center (NHCC) for pandemic prevention. The application of the QR code registration system facilitated the cross-domain collaborations between telecommunication companies and the government, the multiple engagements including individuals, public sectors, telecommunication companies, and the government, as well as the innovative application of digital technologies for data privacy protection. QR code registration system obeys the GDPR regulations because the information collected is temporarily stored in telecommunication companies without disclosure and deleted after 28 days. And the information is telephone number and anonymous.

Other countries also applied various tracing systems, for example, Google and Apple's intention to build a Bluetooth contact tracing system for Android and iPhone devices, which was compatible with the GDPR due to its decentralization processing by private stakeholders or centralised tracing by public health agencies [37]. Moreover, there was also a blockchain-based system developed for the COVID vaccine passport (VacciFi), which was GDPR compliant [38]. The implementation of the QR code registration system and Bluetooth technique-based contact tracing system, as well as the vaccine passport system all revealed the integration of digital technologies in the pandemic prevention measures, together with flexible strategies.

With the varying progress of digitalisation in different domains, digital divide exists and challenges the effectiveness of governance [39]. Statistics show that the smartphone penetration (percentage of population) in Taiwan was approximately 60%–80% in recent years [40],

which means that there are still over 4 million people who use conventional phones. If these people were excluded from the QR code registration system due to the digital divide, it would cause huge loopholes and even spoil the entire efforts in pandemic prevention. Hence, the system is designed to be very user-friendly as no additional APP should be downloaded, and therefore people with either conventional phones or smartphones could use the system conveniently. This contributed to plugging loopholes for effective pandemic prevention.

The implementation of the QR code registration system also echoes the digital empowerment, allowing people to be aware of how their data is collected, stored, managed, and used, as well as how the system functions, and therefore confident in the government and willing to use the system.

Single application of digital tools to collect and present data could not contribute to forming the system, and therefore the tool and data could not be effectively integrated into policymaking. Hence, Taiwan's experience in using the Face-mask distribution system and QR code registration system provided examples of flexible employment of digital tools and data, which form a systematic framework to support COVID-19 surveillance, contributing to better digital governance. Under the systematic framework, single application of digital tools could contribute more to policymaking.

The case of Taiwan's pandemic prevention echoes the spirit of World Development Report 2021: data for better lives, where governments, private sectors, and individuals could take their own roles through data, and form joint efforts for better lives.

## Conclusions

On the above basis, Taiwan developed the Face-mask distribution system and QR code registration system by harnessing the power of the NHI database and data collected from the society, integrating data science, GIS, and other digital technologies into pandemic prevention policies, as well as making comprehensive planning and flexible strategy, which contributed to the effective pandemic prevention in Taiwan.

Today, the core approach for pandemic prevention worldwide has been gradually shifting to large-scale vaccination. Many countries have prioritised vaccination in their pandemic prevention measures, with the expectation to improve the vaccination coverage and reach herd immunity. Drawing on previous experience, the Taiwan government also continues to develop the vaccination system, which employs the NHI database and GIS accompanied by comprehensive planning and flexible strategy, to guide people to book the vaccination and receive the doses in good order. This echoes the roadmap of digital governance, as well as will improve vaccination coverage in Taiwan and approach herd immunity for effective pandemic prevention.

Above all, in the digital era, while exploring the systematic roadmap of digital governance, it is necessary to fulfill three basic criteria: (1) comprehensive planning; (2) flexible strategies; (3) the meaningful employment of digital technologies. In this roadmap, the core of digital governance is the meaningful employment of digital technologies, which relies on comprehensive and robust digital infrastructures. As one of the key digital infrastructures, the high-quality, timely, and reliable database could release the power of data-driven, leading to cross-

domain collaborations, multiple engagements, innovative applications, and digital empowerment, towards achieving effective pandemic prevention.

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## Patient consent

Not required

## CRedit authorship contribution statement

**Chih-Wei Chen:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft. **James Cheng-Chung Wei:** Supervision, Writing – review & editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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