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Sustainable cities and communities — Case studies in how smart city operating models support an effective public-health emergency response

Villes et communautés territoriales durables — Études de cas sur la façon dont les modèles d'exploitation des villes intelligentes soutiennent une réponse d'urgence efficace en matière de santé publique

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Foreword

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This document was prepared by Technical Committee ISO/TC 268, *Sustainable cities and communities*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Dealing with public-health emergencies and eliminating their impact on sustainable development has become a common challenge globally. In recent years, the Ebola virus disease, the Middle East respiratory syndrome (MERS), Zika virus and COVID-19, have caused severe consequences to countries around the world. This has critically challenged the public-health emergency management (PHEM) systems of many countries, especially developing countries. Eliminating the impact of sudden public-health events is an important goal for achieving sustainable development globally.

The rapid development of the Internet, Internet of Things, Artificial Intelligence, Cloud Computing, 5G broadband cellular networks and other information and communication technologies is accelerating change across the economy and society at large. In smart cities and communities, new network facilities, new data environments, and new technology applications offer the potential to transform the effectiveness of PHEM. This enables monitoring and analysis, virus tracing, prevention and control treatment, resource allocation and other aspects of public-health emergencies to be managed at a faster response speed, with more efficient and transparent reporting systems, and more effective medical, social and economic outcomes.

However, technology can only make a difference when accompanied by innovative ways of working (e.g. smart governance processes), supported by interoperable standards, that enable organizations to collaborate in new ways to:

— deliver integrated action, rapidly and at scale;

— engage the public in new and more interactive forms of communication and participation;

— do this through partnership across the public sector and private sector, and collaboration across local, regional, national and international levels of government.

This document is intended to inform the development of future international standards in this area on how community authorities can effectively plan and deliver this kind of smart PHEM, by drawing together and analysing best practice case studies on how cities around the world have responded to the COVID-19 pandemic.

This document has been developed by an ad hoc group bringing together members of the ISO/TC 268 and the IEC Smart Cities Systems Committee (IEC SyC SC). Case studies were gathered by national standards organizations, using an information-gathering framework aligned with the Smart City Use Case framework previously developed by IEC SyC SC; and interviews were held with senior representatives from each city to explore lessons learned and refine the case studies in more detail.

Sustainable cities and communities — Case studies in how smart city operating models support an effective public-health emergency response

1 Scope

This document identifies good practice case studies of smart city responses to COVID-19 through the use of smart technologies, smart data, smart decision-making and smart ways of working. In particular, it aims to demonstrate how the principles for smart city operating models recommended in ISO 37106 can deliver improved outcomes in public-health emergency management (PHEM), at every stage of the command-and-control process for emergency management and incident response set out in ISO 22320.

This document is intended to inform ISO 37113[1)], which recommends a framework of good practices that can be used in responding to future public-health emergencies.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1 General

3.1.1
open data
data available without restrictions from copyright, patents or other mechanisms of control or costs, regardless of access, or use

Note 1 to entry: "without restrictions" does not mean that there is no copyright, patents, or ownership of the data, simply that users of the data are able to make use of the data under license terms that make clear that there are no restrictions on that use, other than potentially a requirement to attribute the source of the data.

Note 2 to entry: "regardless of access, or use" means that it has universal participation, and it is available to use, re-use and redistribute for any purpose, as long as the integrity of its opening and origin is preserved.

[SOURCE: ISO 37110:2022, 3.1]

1) Under development. Stage at the time of publication: ISO/DIS 37113.

3.2 Public-health emergencies

3.2.1
public-health emergency
PHE
sudden occurrence of major infectious diseases, diseases of unknown causes, major food and occupational poisoning and other events that seriously affect public health that cause or can cause serious damage to public health

3.2.2
public-health risk
likelihood of an event that can adversely affect the health of human populations, with an emphasis on one which can spread internationally or can present a serious and direct danger

3.2.3
public-health emergency management
PHEM
overall approach to preventing a public-health emergency (PHE) and managing those that occur

Note 1 to entry: In general, PHEM utilizes a risk-management approach to prevention, preparedness, response and recovery before, during and after either potentially destabilizing or disruptive events, or both.

4 Case study framework — Smart city approaches to management of COVID-19

This document supports the United Nations Sustainable Development Goals (UN SDGs) of making cities and human settlements inclusive, safe, resilient, and sustainable, and is an enabler for all six strategic purposes of a sustainable community described in ISO 37101. It identifies good practices in how communities have smart technologies, smart data, smart decision-making and smart ways of working to improve the effectiveness of their response to COVID-19. The conceptual framework used to explore these practices is illustrated in Figure 1 below.

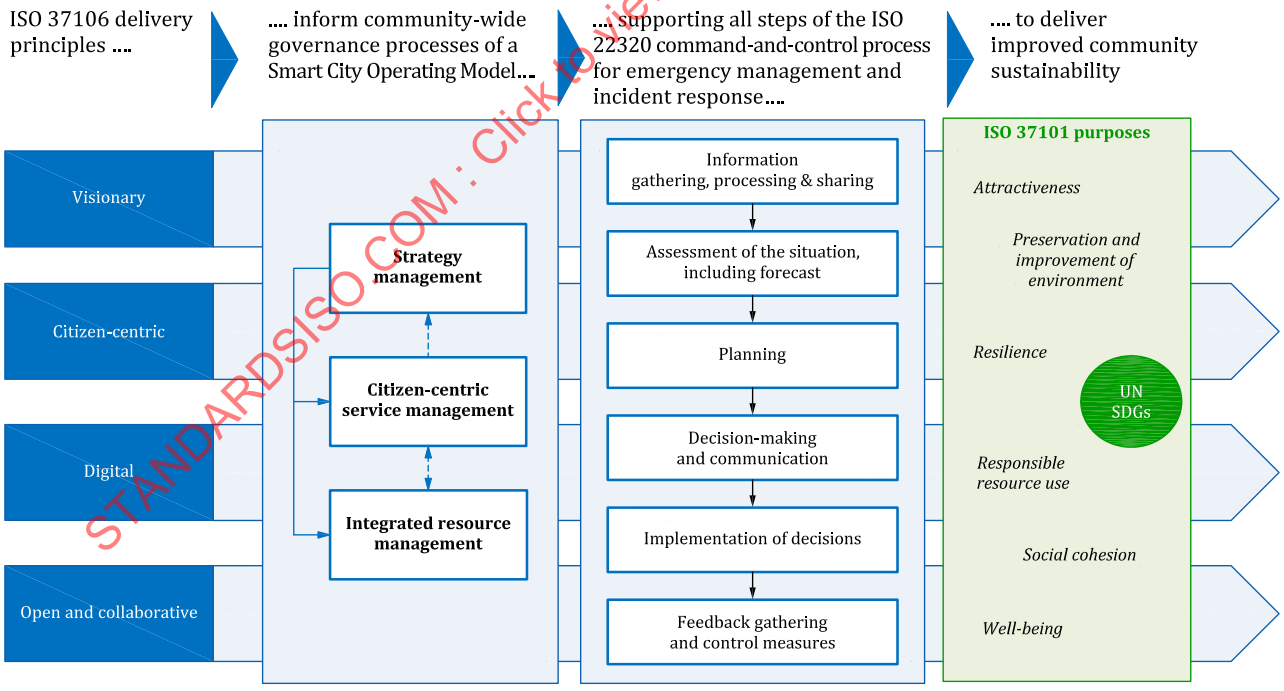


Figure 1 — Framework for Smart Public-Health Emergency Management (PHEM)

In particular, this document:

a) Is informed by

   1) the four delivery principles for a 'smart city operating model' described in ISO 37106:

      i) establishing a clear, compelling and inclusive vision for the sustainable future of the community;

      ii) taking a citizen-centric approach to all aspects of service design and delivery;

      iii) enabling a ubiquitous, integrated and inclusive digitization of community spaces and systems;

      iv) embedding openness and collaboration in the way the community works;

   2) the smart city operating model described in ISO 37106, which enable cities to implement the above principles by addressing city-wide challenges of joining up across city silos, in three areas:

      i) Strategy management: the key aspects of governance, planning roadmap development and decision-making that need to be managed at a whole-of-city level in order to provide effective responses to community-wide challenges.

      ii) Citizen-centric service management: the provision of public services for citizens and businesses that are built around user needs, accessibility, inclusivity and co-created with users.

      iii) Integrated digital and physical resource management: ensuring that data on the performance and use of the community's physical, spatial and digital assets is available in real-time and on an interoperable basis, in order to enable real-time integration and optimization of city resources; and opening up community data (in secure and privacy-protective ways) in order to enable innovation by citizens, businesses and civil society.

b) Provides good practice case studies for community authorities on how these ISO 37106 delivery principles and smart city operating models can support more effective PHEM at each stage of the command-and-control process for emergency management and incident response set out in ISO 22320.

Although Figure 1 illustrates the ISO 22320 command-and-control process as a simplified, linear one, in practice it is a non-linear process with multiple feedback loops across multiple stakeholders, as illustrated in Figure 2.

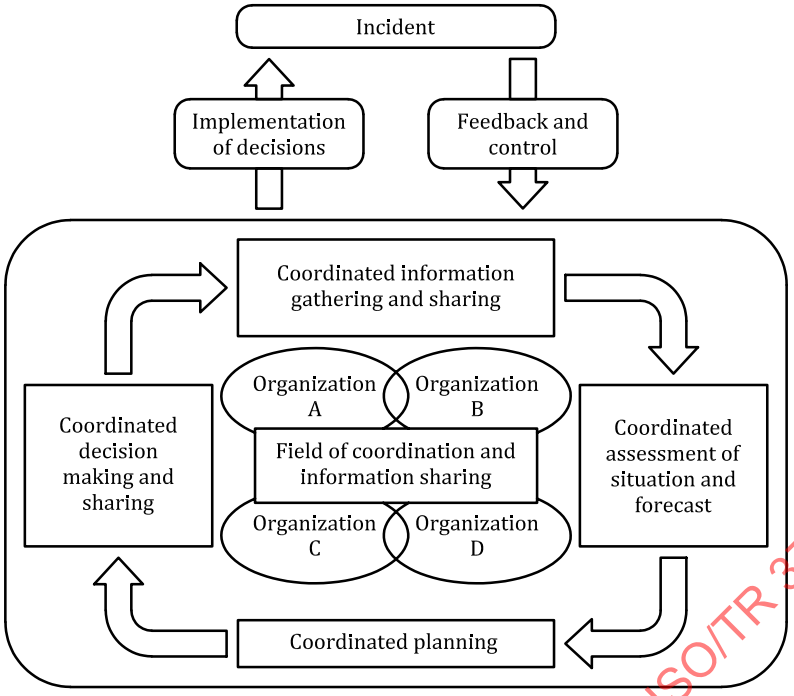


Figure 2 — Multiple stakeholder coordinated command-and-control process for emergency management and incident response

Smart PHEM uses new technologies and new ways of working to help improve each step of this process, and to facilitate speedier and more effective collaboration across the wide range of stakeholders that need to be involved at each step. Case studies on how cities have done this during COVID-19 are described below. The case studies were selected in collaboration with national standards organizations and through outreach to cities in collaboration with the IEC SyC SC and were documented in consultation with senior officials from the different cities.

5 Good practice cases across all phases of the ISO 22320 command-and-control process for emergency management

5.1 General

This clause highlights six good practice case studies. Each one focuses on a separate aspect of the ISO 22320 command-and-control processes for emergency management and incident response (as shown above in Figure 1) and demonstrates how the case study implements the ISO 37106 principles of visionary, citizen-centric, digital, and open and collaborative.

5.2 PUTRAJAYA — Observation, information gathering, processing, and sharing

5.2.1 Overview — Using the city command centre to provide integrated data sensing and sharing across all agencies involved in COVID-19 management

Putrajaya is the new Federal Government Administrative Centre for Malaysia, with a population of 109,000 and an area of 49 km^2. The Putrajaya Command Centre is an integrated data centre that monitors the city 24/7 to promote the safety and wellbeing of the community, from routine traffic management through to disaster relief. The Centre collates data from across the city, including through sensors, panic buttons and a network of CCTV cameras, and applies AI analysis of video and other unstructured data to allow for easier processing and decision-making. In doing so, it allows information to be shared between key agencies with the city, including the police, fire, and hospital emergency departments.

The Centre was core to the city's COVID-19 response. During COVID-19, the Putrajaya Command Centre became the focal point of the city's response to COVID-19, integrating data sources from across the city's infrastructure and agencies into a central location.

5.2.2 Objectives of the initiative

The Putrajaya Command Centre had three key objectives in the city's management of COVID-19:

a) To collate and interpret data points from across the city's smart city infrastructure and from the city's key agencies (e.g. police, health, transport and emergency response) into a central location for smoother and more intelligent data processing and decision making.

b) To facilitate communication and engagement between the main organisations working to control the spread of COVID-19 through the shared use of that integrated data.

c) To use insights to develop and implement a cohesive response to the PHE. This includes both:

   — coordinating actions across all relevant city agencies;

   — direct deployment of the Command Centre's own response system (a network of speakers allowed the City Command Centre administration to broadcast personalized warnings to individuals violating Putrajaya's social distancing guidelines).

5.2.3 What was achieved

Putrajaya's response to COVID-19 was informed and enabled by the Smart City Blueprint for Putrajaya, published five years previously in 2017. Informed by extensive dialogue and engagement with city stakeholders, this established a comprehensive framework to achieve the city's transformational goals by 2025. The Smart City Blueprint sets out 93 initiatives across seven smart city domains:

— smart transportation and mobility;

— smart home and environment;

— smart government services;

— smart infrastructure and utilities;

— smart safety and security;

— smart economy;

— smart community.

These initiatives are citizen-centric and aim to improve urban sustainability and quality of life through the use of innovative technology as an enabler. They are prioritized along an implementation timeline divided into quick wins, short-term, medium-term, and long-term priorities, with an initial focus on prioritizing smart city security and the enabling infrastructure.

The City Command Centre was established as a key early initiative in delivering the Smart City Blueprint. A centre for all data across the city, it also built a comprehensive set of 'standard operating procedures' (SOPs), enabling a unified and collaborative response to city incidents by police, fire, hospital and other services. These SOPs cover both daily incidents, e.g. traffic accidents, and environmental disasters such as flood or fire.

The City Command Centre quickly became the centre of Putrajaya's COVID-19 response; multiple data sources were pulled into a single dashboard and COVID-19 case information was used to populate a map of the city, providing easily visualised ways of processing and analysing the information. Daily meetings were held with the mayor, hospitals, and the public-health department to share aggregated data around case numbers, locations, and potential hot spots. This integrated approach allowed the city to make informed decisions and a number of SOPs were developed to allow rapid response to new challenges.

The Centre was also used to co-ordinate related work between key city agencies. For example, if the police needed to block a road in order to minimise entry and exit to Putrajaya, this could be managed collaboratively across the related agencies to ensure a smooth response. The Command Centre also played its own role in the enforcement of social distancing protocols, allowing administrators to administer warnings to individuals violating these protocols. Nearly 100 % of people amended their behaviour to obey the social distancing guidelines following the verbal warning over the speaker system.

Through the smart integrated response to COVID-19, Putrajaya was able to effectively control the spread of the disease. Apart from a few instances when the whole nation was under lockdown, Putrajaya navigated the pandemic without needing to implement a city-wide lockdown. Instead, Putrajaya was able to implement specific, localized lockdowns in areas of high infection.

5.2.4 How the project applied ISO 37106 guiding principles

Table 1 below summarizes the core ways that the Putrajaya Command Centre put into practice the guiding principles for a 'smart city operating model' set out in ISO 37106.

Table 1 — Mapping the actions taken by Putrajaya against the guiding principles of ISO 37106

Guiding principles of ISO 37106	Putting principle into practice
Visionary: **Establishing a clear, compelling and inclusive vision for the sustainable future for a community**	The Putrajaya Command Centre is an integral part of Putrajaya's broader ambition to become a leading example of smart city best practice. The Centre features prominently in the city's Smart City Blueprint document and promotes the smart operation of the city. It also has clear leadership support and the Mayor interacted with the Command Centre daily during COVID-19.
Citizen-centric: **Taking a citizen-centric approach to all aspects of service design and delivery**	The Command Centre has several citizen-centric design elements, including panic buttons that are available at key locations around the city or within the city's mobile app. Citizen privacy is a core consideration. Clear strategies are put in place to safeguard personal data within the City Command Centre and the technology itself was designed with citizen privacy in mind. For example, the CCTV coverage is restricted to public areas, and is equipped with a privacy-masking function which automatically blocks doors and windows from being monitored, apart from some notable exceptions such as children's playgrounds.
Digital: **Enabling a ubiquitous, integrated and inclusive digitization of community spaces and systems**	The Command Centre leverages a wide array of technologies to process multiple data streams. This promotes faster decision-making and facilitates greater collaboration between city agencies through technology-enabled communication. The use of artificial intelligence, in tandem with aggregated data dashboards, allows the Command Centre administrators and city leaders to identify new trends and to respond rapidly and appropriately.
Open and collaborative: **Embedding openness and collaboration in the way the community works**	The Putrajaya Command Centre promotes co-operation between core agencies within the city, such as the mayoral team and the police, fire, and hospital departments. This integrated way of working allows for faster and more effective response times by ensuring that accurate information about an emerging crisis is shared with the relevant agencies, allowing them to co-ordinate their response more effectively.

5.2.5 Lessons learned

Table 2 summarizes the key lessons that the Putrajaya Command Centre administration have identified in order to better inform the management of future public-health crises. It also highlights the relevant components of ISO 37106 that can be usefully applied as these lessons are implemented.

Table 2 — Identifying key challenges faced by Putrajaya and lessons learned to better prepare for future public-health emergencies

Issue	Lessons learned	Relevant components of ISO 37106
In the early stages of COVID-19, there were a lack of SOPs to cater to the management of public health emergencies	Developing SOPs around data collection in the event of health emergencies will allow for a more rapid response in the future. At its start, the Putrajaya Command Centre only interacted with the hospital emergency department. More agencies related to public health, e.g. as the Public-Health Department, were then invited to work with the City Command Centre during COVID-19. These partnerships could have been established earlier in order to ensure the proper SOPs were in place at the onset of COVID-19.	— [B2] Leadership and governance provides guidance on bringing together city leaders on a cross-sectoral basis into effective governance arrangements at both the strategic and delivery levels. — [B13] IT and data resources mapping and management provides guidance on how to ensure these collaborative governance arrangements can be applied to enable effective exploitation of common data resources.
Importance of personal human contact in addition to digital collaboration	While data integration and AI analytics are vital to the operation of the City Command Centre, Putrajaya's experience during COVID-19 also highlighted the importance of bringing people together in a physical location. Key decision makers from different agencies were able, with appropriate social distancing protocols, to use the coordination room above the Command Centre as a shared meeting space. This enabled leaders to coordinate the emergency response more effectively.	— [B12] Managing smart city developments and infrastructures emphasises the importance of taking an integrated approach across digital, physical and human domains, and provides guidance on to embed such an integrated approach in city planning systems.

5.3 New York — Assessment of the situation, including forecasts

5.3.1 Overview — Use of precision spatial data to support COVID-19 operations

New York is a state in north-eastern United States of America, with a population of 20,2 million and an area of 141,300 km^2. New York State and New York counties, pioneered by Suffolk County and Rockland County, used highly-granular GIS mapping and geo-coding of individual COVID-19 infections to enable real-time assessment of pandemic development, giving city officials new insights into the current situation and predictions for how the situation was evolving. These were used to inform policy decisions, enable more targeted interventions at local level informed by "micro-cluster strategies", and to share relevant information with both the public and key organisations in real time.

5.3.2 Objectives of the initiative

There were four core objectives to Suffolk County and Rockland County's approach to driving the geospatial data project pandemic management:

a) To capture highly detailed geocoded data to track each COVID-19 infection from the point of initial reporting, and to map it against the city in order to provide precise identification of potential clusters of infection (providing a more comprehensive and accurate image of the situation than tracking infections by zip code as was being done across the rest of New York State).

b) To then use these insights to develop targeted strategies for responding in real time to new clusters of infection as they emerged; this could include implementing locally specific restrictions, warning other residents, or distributing resources more effectively.

c) To then use these insights to develop a predictive model that would allow city officials and other major stakeholders to prevent or limit infection before a cluster develops, to mobilise aid in advance, and to target a communication strategy around those most at risk.

d) To identify good practice in geospatial pandemic management and share with other New York counties and city stakeholders.

5.3.3 What was achieved

SOURCE Reference [30], reproduced with the permission of the Suffolk County Government, New York, US.

Figure 3 — Example of the data dashboards shared with Suffolk County Police, split by precinct

Both Rockland and Suffolk County were able to geocode information on COVID-19 infections in the laboratories. Analysis of these geocoded addresses were then used to create a micro-cluster strategy that targeted areas showing spikes in infection and to develop tiers of strategies in and around those at-risk areas. These predictions and insights influenced policy decisions around the risk management of COVID-19, and comprehensive, interactive data visualisations were made available to both citizens and key city organisations.

For example, Suffolk County Police were provided with access to highly-granular geocoded data to allow them to understand the risk by precinct and able to show whether an individual house was high risk when responding to a call (see Figure 3). Enabling police to identify if there were any positive COVID-19 cases in any house before entering gave the opportunity to take proper precautionary measures, further limiting the spread of the disease.

The GIS data was a core component of public briefings, in particular during the implementation of the micro-cluster strategies. The geocoded data was also used to create early warning dashboards (see Figure 4).

By mapping geocoded data of COVID-19 infections against key metrics, such as hospital capacity, the counties were able to ensure they were better prepared for the forecasted scenario.

Figure 4 — Screenshot demonstrating Rockland's Early Warning Dashboard, comparing metrics such as new infections, severity of infections, and hospital capacity

The success of these initial projects in Rockland County and Suffolk County later informed a modified state-wide initiative.

5.3.4 How the project applied ISO 37106 guiding principles

Table 3 below summarizes key ways in which the project put into practice the guiding principles for a 'smart city operating model' set out in ISO 37106.

Table 3 — Mapping the actions taken by Rockland and Suffolk County against the guiding principles of ISO 37106

Guiding principles in ISO 37106	Putting principles into practice
Visionary: **Establishing a clear, compelling and inclusive vision for the sustainable future for a community**	The project had clear support from political and administrative leaders at the highest levels, and at both County and State levels. Moreover, it was able to build on a long-standing vision for Geographic Information Systems as a key enabler for New York. New York has been a global pioneer of GIS to drive city planning and operations, both using it to underpin key city services such as 911 and also providing geo-coded data as Open Data to support development of city applications by the private sector and civil society.
Citizen-centric: **Taking a citizen-centric approach to all aspects of service design and delivery**	Linking the individual citizen to spatial data lay at the heart of this project. Throughout, great care was taken to ensure the protection of personal privacy of citizens. Through the creation and sharing of data visualisations with the wider community, individual citizens were enabled to understand the evolving situation and use that to inform their own behaviour.
Digital: **Enabling a ubiquitous, integrated and inclusive digitization of community spaces and systems**	The comprehensive and integrated nature of the digital geo-coding helped to reduce the scope for human error in pandemic response systems, improved data quality, and enabled high levels of protection for personal and sensitive data. It also enabled greater sharing and interactivity of data dashboards, so that they could be applied to meet differing requirements.
Open and collaborative: **Embedding openness and collaboration in the way the community works**	The success of the GIS-mapping of COVID-19 infections relied on the partnership between multiple data partners and city organisations to ensure an accurate understanding of the situation. Open data feeds enabled community organizations to work with and add value to the data.

5.3.5 Lessons learned

Table 4 below summarizes key lessons that leaders of this initiative have drawn from the experience to inform management of future public-health emergencies, and highlights components of the ISO 37106 smart city operating model that can be applied as they do this.

Table 4 — Identifying key challenges faced by Suffolk County, Rockland County, and New York State more broadly and lessons learned

Issue	Lessons learned	Relevant components of ISO 37106
Organisational silos can limit effective information sharing	Mobilizing multiple organizations to ensure rapid implementation of new GIS-enabled systems is challenging. At a state-wide level, not all departments of health had a strong initial understanding of the potential for spatial data and systems to support their COVID-19 response. Rockland and Suffolk Counties were able to move rapidly because of pre-existing collaborative governance structures between geo-data, health and other specialists, and an ability to draw on strong personal relationships at the senior level in defining strategies for responding rapidly to the COVID-19 challenge.	— [B2] Leadership and governance provides guidance on bringing together city leaders on a cross-sectoral basis into effective governance arrangements at both the strategic and delivery levels. — [B13] IT and data resources mapping and management provides guidance on how to ensure these collaborative governance arrangements can be applied to enable effective exploitation of common data resources, including spatial data.
Pre-existing protocols around geocoding personal health data	The lack of a clear and pre-agreed model for how to apply granular geo-coding in the context of personal health data in a privacy-protective way presented significant challenges. In the US, the Health Insurance Portability and Accountability Act of 1996 (HIPAA) establishes national standards for the protection of certain health information, including safeguards organisations must put in place to manage security risks and ensure confidentiality of patient data. At the start of COVID-19, there was wide-spread concern amongst health professionals that geocoding medical information might infringe on HIPAA. Rockland and Suffolk Counties demonstrated that it was possible to collect and deploy precision location data without jeopardizing patient privacy and HIPPA compliance; for the future, the city, counties and state of New York would benefit from having a clearly agreed framework in advance.	— [B10] Identity and privacy management provides guidance on development of a 'citizen-centric trust model' to support privacy-protective use of data within a secure, federated IT and governance architecture.

5.4 China-Singapore Tianjin Eco-city (CSTEC) — Planning

5.4.1 Overview — Pandemic management map to plan COVID-19 management

China-Singapore Tianjin Eco-city (CSTEC), in Binhai district in Tianjin City, China, is a strategic cooperation project between China and Singapore, with a population of 120,000 and an area of 150 km^2. In order to prevent and respond to COVID-19 on an accurate and timely basis, when facing a large amount of COVID-19 data, CSTEC, capitalizing on its advantages as a smart city, developed a pandemic management map. This map combines pandemic information with spatial information on resource planning and brings together relevant pandemic statistics, including six sections comprising: citizens, traffic and vehicles, enterprises, construction sites, big data analysis, and pandemic notification.

This case focuses on the ISO 22320 'planning' aspect. It enables the CSTEC Administrative Committee to:

— delineate mock control areas based on big data analysis;

— make prevention and control decisions to aid in the execution of accurate pandemic prevention and control work;

— deliver timely risk information to the public and key organizations for effective communication.

The creation and implementation of the pandemic management map reflected the guiding principles in ISO 37106 and can be used as an example of smart city management. The CSTEC Administrative Committee

used this map to reduce the likelihood of infection in CSTEC and take steps to ensure effective recovery, which also reflects the PPRR steps in ISO 37113.

5.4.2 Overview of the objectives

The pandemic management map included three objectives for achieving the goal of CSTEC pandemic control and smart management.

a) Gather, integrate and update data related to the pandemic in multiple fields, such as population, vehicles, enterprises, and construction sites, through the pandemic management map. The map enables all departments of CSTEC Administrative Committee to plan service support for pandemic prevention and control work, within a scientific and technological platform for refined management and decision-making on pandemics.

b) Enable CSTEC Administrative Committee to keep abreast of the pandemic situation immediately and establish a good information communication mechanism with major organisations and citizens in CSTEC. To disseminate information on the pandemic risk in a timely manner and provide a convenient enquiry service for pandemic prevention information.

c) Establish and maintain CSTEC's dynamic urban resources information of space, public facilities, public buildings, and idle assets via a visual map.

5.4.3 What was achieved

a) The pandemic management map allowed for quick community targeting and hierarchical response.

— This map established a network of citizens that can be traced back to specific communities and buildings. The CSTEC Administrative Committee has used this map as the foundation for establishing a communication mechanism with the community.

— Citizens provided information to the CSTEC Administrative Committee on the spatial distribution of residents in the community, e.g. confirmed diagnosis, observation, home quarantine, close contact, return to Tianjin from key areas.

— Then, based on the data, the CSTEC Administrative Committee used the pandemic management map to visualize the mapping of citizens and the quarantine situation at home. By clicking on the corresponding map spot for both historical and current information, information on outbreaks in each community can be displayed in detail.

— Simultaneously, the CSTEC Administrative Committee developed an analysis model of the risk factors influencing community pandemic control, and to formulate decisions to classify different communities into different risk level.

— Community managers made targeted prevention and control decisions based on changes in the regional pandemic situation and the community's risk level, including the dynamic adjustment of required pandemic prevention staff and supplies.

The left section of Figure 5 shows the number of travellers in observation and traffic, as well as the number of vehicles entering and exiting. The radar chart on the right depicts the risk factors influencing community-based pandemic prevention and control, such as travellers, the pandemic in the community, spatial layout, and household count.

SOURCE Reference [29], reproduced with the permission of the CSTEC.

Figure 5 — Analysis model of the risk factors influencing community pandemic control

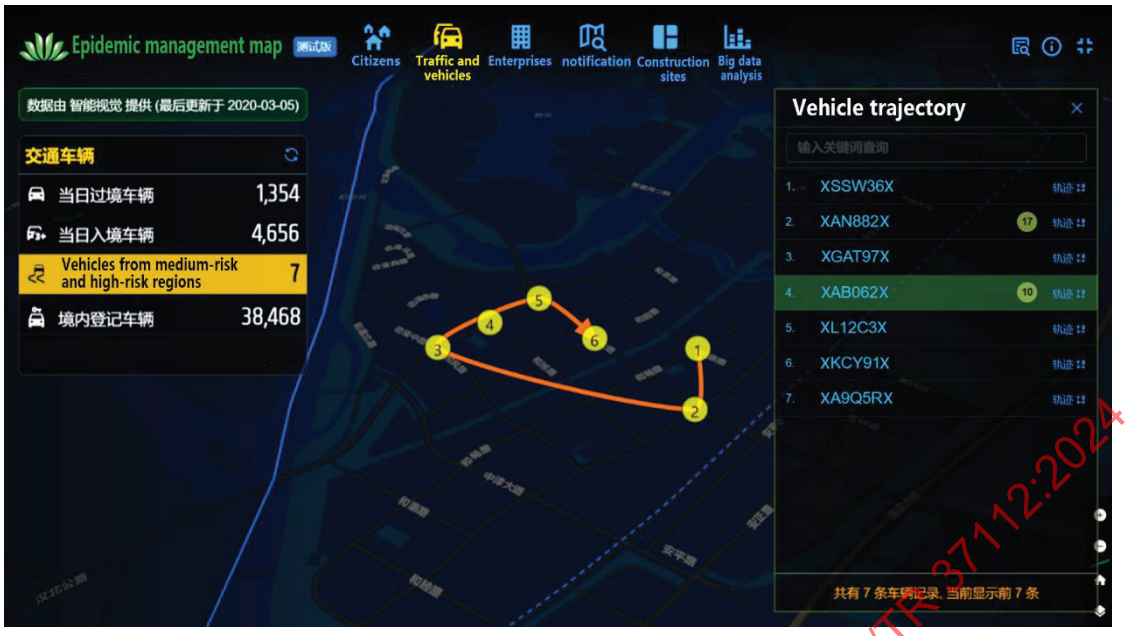
b) Smart vehicle tracking was made possible by the pandemic management map.

— Using IOT equipment such as camera sensors at CSTEC intersections and smart video analysis, the pandemic management map not only displayed data on vehicles registered, in transit, and entering CSTEC on the same day, but also highlighted data on vehicles entering and transiting CSTEC with a Wuhan license plate on the same day, based on real-time dynamic monitoring of nearly 3,000 surveillance videos in the area.

— CSTEC Administrative Committee can check the travel time and route of each vehicle within CSTEC, as well as trace the vehicle history within a specific time period, by clicking on the map.

— Once a confirmed or suspected case is identified, members of the CSTEC Administrative Committee have access to all types of information in the map, greatly improving the efficiency of emergency response and decision-making. CSTEC Administrative Committee managers will be able to exercise management by sealing off entities and practicing pandemic prevention at district borders.

Figure 6 displays the "vehicle" in the dashboard. The vehicle information for the day (including transit/inbound vehicles, transit/inbound vehicles from medium-risk and high-risk regions, local registered vehicles, disinfection vehicles, and the number of new vehicles in the community) can be tracked and the domestic trajectory of all vehicles easily viewed. Figure 3 depicts the trajectories of a vehicle from medium-risk and high-risk regions, along with the precise location and order of the vehicle's stay.



SOURCE Reference [29], reproduced with the permission of the CSTEC.

Figure 6 — Transport Module Showcase (vehicles with Wuhan license)

c) The pandemic management map provided real time information on the prevention of COVID-19 in public places, which produces transparency and improves public participation.

— The pandemic management map displayed corresponding risk alert information on various shopping malls and supermarkets, primary and secondary schools and kindergartens, hotels, scenic spots, medical institutions, enterprises, construction sites, office buildings and other public places within CSTEC.

— CSTEC Administrative Committee announced such risk alert information to the public for effective communication. Communication channels used included SMS, email and internet.

Figures 7 shows that risk warnings were differentiated according to the place, e.g. communities, supermarkets, enterprises, office buildings, medical institutions. On the right, the name of the specific location and the associated risk warning information are displayed. The locations were ranked from 1 to 15 and coloured based on their risk level.

SOURCE Reference [29], reproduced with the permission of the CSTEC.

Figure 7 — Pandemic risk prevention and control tips

d) The pandemic management map enabled effective enterprise pandemic prevention management and control.

During the process of resuming work at CSTEC, the CSTEC Administrative Committee used the map's enterprise data module to track changes. Enterprises returning to work reported daily data on personnel arrival information and temperature measurements of employees returning to CSTEC from other locations in the pandemic management map via the enterprise pandemic prevention information system. This enabled efficient management and decision-making on pandemic prevention for those returning to work.

Figure 8 shows how to retrieve company information, by clicking on a specific company icon to display the company's location, the employees returning to work from each company, and their hometown information.

SOURCE Reference [29], reproduced with the permission of the CSTEC.

Figure 8 — Specific company information

5.4.4 How the project applied ISO 37106 guiding principles

Table 5 summarizes key ways in which the project put into practice the guiding principles for a 'smart city operating model' set out in ISO 37106.

Table 5 — Mapping the actions taken by CSTEC against the guiding principles of ISO 37106

Guiding principles of ISO 37106	Putting principles into practice
Visonary: **Establishing a clear, compelling and inclusive vision for the sustainable future for a community**	— The pandemic management map was strongly supported by CSTEC Administrative Committee. CSTEC wants the achievements of the map to be developed to provide a useful reference for global use, to form replicable and scalable pandemic prevention experience. — The pandemic management map is based on the long-term vision of CSTEC as a smart city. CSTEC has been committed to using the good data resource base and data analysis advantages of the "City Brain" to promote the management and operation of CSTEC. This map has multi-dimensional management functions for (e.g. citizens, vehicles, communities and enterprises), which strongly promoted CSTEC's smart operation.
Citizen-centric: **Taking a citizen-centric approach to all aspects of service design and delivery**	— The pandemic management map allows residents to receive risk alert information about key institutions in CSTEC, such as hospitals and pharmacies, and to use such information to guide their own behaviour. — The protection of citizens' privacy data runs through the entire data life cycle, including data collection, data storage, data processing and data transmission. Data involving personal privacy and personal information were kept strictly confidential during the system development and data processing stages, with a dedicated server set up for storage. Data processing staff were trained in security awareness, and data storage media was only allowed to be used by internal staff, and sensitive information was not allowed to be taken out of the office. Personal information storage devices were not to be incorporated into the internet.
Digital: **Enabling a ubiquitous, integrated and inclusive digitization of community spaces and systems**	The pandemic management map achieves the integration of pandemic information with spatial information of resource planning, which can summarize and share a large amount of pandemic data information quickly. The data included citizens, traffic vehicles, enterprises, construction sites and other boards, which achieved data connectivity and met the requirements of smart city management.
Open and collaborative: **Embedding openness and collaboration in the way the community works**	— The pandemic management map takes full advantage of the data aggregation platform of CSTEC and the database and analysis of the "City Brain". It was a collaboration between multiple data providers, the technical team and CSTEC Administrative Committee. The pandemic management map also gave value to open information data from communities, enterprises and others.

Table 5 *(continued)*

Guiding principles of ISO 37106	Putting principles into practice
	— The pandemic management map provided CSTEC information in a visual format, preventing confusion for users and panic caused by rumors during COVID-19, and contributing to an orderly fight against the pandemic. — Future plans include creating open-data sources that will be accessible to the public, with the permission of the provider and after encrypting to protect privacy.

5.4.5 Lessons learned

Table 6 summarizes key lessons drawn from this initiative to inform management of future public-health emergencies, as well as components of the ISO 37106 smart city operating model that can be usefully applied.

Table 6 — Identifying key challenges faced by the pandemic management map and lessons learned

Issue	Lessons learned	Relevant components of ISO 37106
The general public was unfamiliar with the pandemic management map and did not follow the information in a timely manner	The public's acceptance of smart city-related programs may have an impact on the effectiveness of a city's emergency response to public-health events. The smart city program's value to emergency response is increased the more that individuals and businesses choose to collaborate. As a result, daily dissemination and promotion of the smart city program is critical. The long-term strategy aims to make this data and the mapping available to citizens on an open basis, providing increased value to the community, encouraging participation and facilitating innovative use by organizations and citizens to obtain better city services.	— [B3] Collaborative engagement: By emphasizing awareness and participation in interested parties, the program ensures that all interested parties (e.g. users, suppliers, delivery partners elsewhere in the public, private and voluntary sectors, politicians, the media) have a clear understanding of the smart city program and how they will benefit from it, as well as effective and inclusive routes to engage with and participate in the program. — [B8] empowering the city community through city data: Cities need to drive change upstream of the data platform, i.e. work on internal culture change with data owners across the city (from the public, private and voluntary sectors) to ensure a willingness and capability to provide data into the platform, as well as to address data-opening barriers.
The severe pandemic situation has hampered map development, with functions such as fixed asset management and municipal infrastructure operations adjustment not yet fully developed and utilized	The CSTEC Administrative Committee should actively seek the use of new technologies and equipment in relevant management processes, collaborate with the technology team to provide sources of information and data, and continue to develop additional functions in areas such as fixed asset management and municipal infrastructure operations in the future.	— [B13] IT and data resources mapping and management: Emphasis on sharing and reuse of city assets and services — [B12] Managing smart city developments and infrastructures: Taking a holistic approach across all types of city infrastructure

5.5 Cities in Scotland — Decision-making and communication

5.5.1 Overview — Building on Scotland's smart city ambitions to connect with and engage residents during the pandemic

Seven cities in Scotland (Aberdeen, Dundee, Edinburgh, Glasgow, Inverness, Perth, and Stirling) have a combined population of 1,6 million. In 2015, Scotland launched an ambitious programme to promote digital transformation across Scottish cities, enhancing the delivery of city services and making Scotland's cities more attractive, liveable, and resilient. This programme is called 'Scotland's 8th City – the Smart City' and involves all seven Scottish cities. The £48 million programme is partly funded by the European Regional Development Grant (ERDF) of over £20 million awarded via the Scottish Government's ESIF Operational Programme 2014-2020.

The 8th City programme is managed by Glasgow City Council as ERDF Lead Partner, with the cities working in close partnership with the Scottish Cities Alliance and the Scottish Government. Its work is aligned with Scotland's overall ambition (as set out in the 2017 Digital Strategy for Scotland) to make Scotland "an international pioneer of citizen-led service design".

As COVID-19 began, the collaborative data-sharing framework and citizen-centric planning processes that the cities had already established provided a key asset for Scotland to deploy in managing the virus. City councils were able to map vulnerable populations by pooling data with Public Health Scotland and NHS Scotland, manage the new resources and service requirements of each city, and shape their COVID-19 management strategies in response to detailed data visualisations and insights. Resources and tools were also shared between cities to prevent duplication of work. And the use of open data and interactive digital communication enabled the Scottish cities to engage closely and collaboratively with citizens throughout the pandemic, improving health, social and economic outcomes.

5.5.2 Objectives of Scottish inter-city collaboration during the pandemic

While each city had specific requirements due to variations in population demographics, geography, and resources available, there were several common goals underlying each city's response:

a) To integrate data sources from key stakeholders in order to create a single view of COVID-19's evolution and to inform strategic decisions regarding the management of the virus.

b) To ensure that all citizens were supported and cared for throughout the pandemic by identifying and mapping vulnerable populations using shared data from multiple stakeholders, and to then ensure that skilled individuals and adequate resources, including COVID-19 business grants, were dispatched to the areas that needed it the most.

c) To engage with the community to understand what their new needs and priorities were, both in the immediate pandemic response and in planning for longer-term social and economic recovery.

d) To empower citizens to manage their own and their communities' health through the provision of enabling tools and data.

5.5.3 What was achieved

While collaborative data sharing was already a core focus of the 8th City ERDF Programme, COVID-19 generated new urgency around identifying ways to share data between key stakeholders, e.g. the councils, agencies of the Scottish Government and NHS Scotland. The cities were able to use data from multiple partners to create a central index of their most vulnerable populations, which was then mapped across the city to facilitate the distribution of resources. Data dashboards were also developed to visualise the progression of the pandemic and allow city leaders to make more informed responses.

While much of the focus was inevitably on internal data-sharing within the public sector, Scottish cities also sought, throughout the pandemic, to implement the core 'citizen-centric' philosophy set out in the 2017 Digital Strategy for Scotland. This commits Scotland to:

— design and deliver digital public services around the needs of their users;

— share and open up non-personal data as a source of innovation and efficiency.

Examples of this citizen-centric approach and the benefits it delivered in the context of COVID-19 are:

— Intensive citizen consultation and engagement: Dundee Partnership launched two large-scale engagement exercises in October and November of 2020, enabling citizens to inform the Dundee Partnership on their lived experience during and immediately after the first wave of COVID-19. A range of survey methods were used to provide a way for citizens to share the impacts of COVID-19 on them, how individuals experienced services during the lockdown period and what impacts if any there had been particularly in relation to their health and wellbeing. The resulting information helped to assess and plan the priorities in communities going forward, e.g. by identifying changing needs of residents in their community due to change of lifestyles brought about by the pandemic.

— Working with the community to fill key skills gaps in the pandemic-response through volunteering: With many city services facing unprecedented pressure during the pandemic, Perth & Kinross Council (PKC) was able to use its digital services platform rapidly to create an online registration process enabling citizens to register as a volunteer. These forms asked citizens to list areas in which they had skills or experience, and this was used to allocate volunteers more effectively to areas needing support. This was used to respond to issues and demands at both urban and rural level, as PKC covers many settlements beyond Perth.

— Data sharing with citizens: Scottish cities were able to re-use the platforms and processes they had developed as part of earlier smart city work to empower their citizens with direct access to data during the pandemic. For example, information by the Glasgow City Council used to inform its decision-making is available within interactive apps available from Glasgow's App Gallery. Some of the data used is also available as open data and is available from Glasgow's Open Data Hub.

— Citizens leveraging open data to create new resources for disadvantaged groups: Digital dashboards on the progress of COVID-19 were published on a daily basis by the Scottish government and formed a vital tool in informing the city and government response to the pandemic. In addition, the underlying data was released as open data (at a level of summarization that protected personal privacy). This allowed individual citizens and community groups to use the data to create their own services. For example, a group of volunteers called the Scottish Tech Army were able to create a website that used a special sonic interface to provide 'sonic graphs', making COVID-19 data accessible to visually impaired users. This is believed to be the first time this technology has been used in a public-health setting and has empowered visually impaired Scottish citizens to make more informed decisions about their own daily activities.

— Convening a citizen's jury to understand the community perspective on the ethics of artificial intelligence (AI) tools for public-health management: Developed at the University of Oxford, the QCOVID risk model uses AI to identify individuals with the greatest risk of death or serious illness should they become infected with COVID-19. At the UK national level, it was used to identify 1,7 million people who should be added to the shielded patients list. In Scotland, the government wanted to explore wider use cases for this powerful tool but were conscious that the ethical dimensions for doing so needed to be understood and support widespread consensus. A "Citizens' Jury" was therefore convened in February and March 2022 to better understand the public's views on four potential use cases: for clinicians to determine patient risk; for the general public to determine their own risk; to be used at a population level to identify and notify people at high risk; and at a population level to inform planning and resourcing. The jury ultimately agreed to principles and 'red lines' for each of the four use cases, providing a clear basis for future work.

5.5.4 How the project applied ISO 37106 guiding principles

Table 7 below summarizes key ways in which the initiative put into practice the guiding principles for a 'smart city operating model' set out in ISO 37106.

Table 7 — Mapping the actions taken by Scottish cities against the guiding principles of ISO 37106

Guiding principles of ISO 37106	Putting principle into practice
Visionary: **Establishing a clear, compelling and inclusive vision for the sustainable future for a community**	The 8th City ERDF Programme was developed with support of the Scottish government and with buy-in from all seven cities. Moreover, the pre-existing work provided a clear framework for the city councils to repurpose their resources and skills to manage COVID-19, and the lessons learned from this process are being embedded in future digital transformation strategies. At national level, lessons learned have recently been embedded in an updated Scottish Digital Strategy published in 2021.
Citizen-centric: **Taking a citizen-centric approach to all aspects of service design and delivery**	Supporting and caring for the community was at the core of the COVID-19 response from all Scottish cities. This process was supported both through consultation and engagement and through the provision of tools and data to enable citizens themselves to engage directly in the management of COVID-19.
Digital: **Enabling a ubiquitous, integrated and inclusive digitization of community spaces and systems**	A clear, collaborative framework for sharing data ensured that digital strategy underpinned each city's response. This facilitated smoother collaboration between different teams or stakeholders.
Open and collaborative: **Embedding openness and collaboration in the way the community works**	The Scottish cities shared lessons learned and tools they had developed to support other communities. The existing data cluster workgroup provided a framework for collaboration, from the Scottish government and NHS Scotland, to the local government data taskforce, to the city councils.

5.5.5 Lessons learned

Table 8 below summarizes key lessons that leaders of this initiative have drawn from the experience to inform management of future public-health emergencies, and highlights components of the ISO 37106 smart city operating model that can be applied.

Table 8 — Identifying key challenges faced by Scottish cities more broadly and lessons learned

Issue	Lessons learned	Relevant components of ISO 37106
Duplication of work	At times it became clear that work was being duplicated between organisations (e.g. the City Council and NHS Scotland both working to identify vulnerable populations from their individual data sets). Better collaboration and communication are needed between stakeholders to ensure resources are not wasted by duplicating work.	[B2] Leadership and governance provides guidance on bringing together city leaders on a cross-sectoral basis into effective governance arrangements at both the strategic and delivery levels.
More consistent data standards needed to ease sharing of data	Common identifiers are needed to be able to match data from varying sources; the variation in these information formats meant more work was required to clean and match data. Greater clarity around data standards, along with where your data is and who is responsible for maintaining it would help to address these issues.	[B13] IT and data resources mapping and management provides guidance on how to ensure these collaborative governance arrangements can be applied to enable effective exploitation of common data resources, including common identifiers.
"Fire-fighting" in early stages of a public-health emergency can crowd out citizen engagement	Despite the strong commitment across the Scottish government and the seven cities to engaging citizens directly in decision-making and co-creation of services (informed by the Community Empowerment Act (Scotland) 2015 and other legislation) this was difficult to prioritize during the early stages of the pandemic when staff were focused primarily on internal data sharing and data analysis. Some of the innovations developed during the pandemic (e.g. use of a citizens' jury to advise on AI ethics) took time to put together, and there would be a benefit in the future to have clearer models ready to deploy.	[B9] Delivering integrated citizen-centric services provides guidance to citizens on public services that are built around user needs, and on the channels and inclusive engagement processes that can support this.

5.6 Wuhan — Implementation of decisions

5.6.1 Overview — Ten-day construction of smart emergency hospital to prevent COVID-19

Wuhan is located in the central part of China, and is the capital of Hubei Province, with a population of 12,445 million and an area 8,569 km^2. As the epidemic situation in Wuhan deteriorated in 2020, in order to combat the spread of COVID-19 and respond to the rapid increase of patients, the authorities decided to build Huoshenshan Hospital (34,000 m^2) and Leishenshan Hospital (79,900 m^2). China Construction Third Engineering Bureau Co., Ltd. (hereinafter referred to as "CCTEB") was tasked to take the lead in building two smart emergency hospitals. The two hospitals went into service about ten days after design started. More than 2500 beds were built for patients, and approximately one-third of the COVID-19 patients in Wuhan at the time were received and cured, relieving significant pressure on the existing designated hospitals and reducing cross-infection. More patients are being treated. This case uses new technologies such as 5G smart diagnosis and treatment, smart scheduling construction, cloud platform operation, and maintenance. Using these technologies to quickly implement decision-making in this case corresponds to the chapter on 'implementation of decisions' in ISO 22320, which achieves effects such as rapid and accurate resource allocation, "zero contact," reducing the risk of infection, and rapid treatment and diagnosis based on smart technologies. It corresponds to the visionary, citizen-centric, digital, open, and collaborative principles of ISO 37106 during the implementation phase and can be used as a case study for smart city emergency implementation.

5.6.2 Overview of the objectives

There were three core objectives for CCTEB to building the hospitals:

a) Realize integration of various human and material resources through smart technologies, and quickly build smart emergency hospitals through improving the efficiency of construction site management.

b) Apply mature and smart diagnosis and treatment measures to quickly diagnose and treat COVID-19 patients.

c) Remote operation and maintenance protection in hospital via smart technologies, to avoid staff exposure to COVID-19 infection.

5.6.3 What was achieved

a) Smart construction site technology was implemented to encourage rapid construction and coordination on different resource

The builders researched and developed the container management platform, which uses both the Internet-of-Things and big data. Smart construction site information technology, smart equipment management technology, and vehicle positioning management monitoring technology are used in the platform to solve the problem of various resource scheduling in the Huoshenshan and Leishenshan emergency hospitals under special circumstances. It enabled the efficient and orderly organization of all relevant resources.

b) Comprehensive smart construction management was implemented to enable a flexible and open construction process

The constructor adjusted the drawing designs in real-time to respond to the construction situation, supported by AI and video smart analysis. To create an outdoor surveillance and prevention area, an outdoor CCTV camera was installed every 50 m along the hospital walls, and an integrated dome CCTV camera was installed in key areas. This not only realizes the hospital's outdoor CCTV system, but also ensures the expected functions of the hospital's smart system.

c) Whole-process smart monitoring and supervision was implemented for improve the speed of construction

A smart monitoring system for epidemic prevention projects based on AI technology is used to monitor project progress. The platform, which is based on cloud services, solves the integration of big data. It enables the sharing, processing, analysis, and judgment of various information data in order to monitor a whole-process of site circumstance.

d) Smart hospital operation and maintenance:

— Wireless technology was being used in the construction and maintenance of emergency hospitals, as well as in the rapid diagnosis of medical conditions. The smart hospital system integrated all the functions such as wireless intercom, medical intercom, smart fire protection, patrol, 5G remote consultation, AI smart film review, and patrol to realize the hospital's wireless operation and management. During the pandemic period in Wuhan, many expert groups in Wuhan, Beijing, Shanghai, and Guangzhou studied and discussed COVID-19 conditions and clinical treatment plans to cure ill patients in the Huoshenshan and Leishenshan hospitals using 5G and medical cloud platform, which significantly improved patient cure rates.

— To achieve "zero contact" treatment with patients, cloud computing and information technology are used to maintain the COVID-19 prevention project. A new model of "zero contact" operations and maintenance in the emergency hospital is proposed through the research, development, and application of the "zero contact" operation and maintenance management cloud platform for the emergency hospital. An operations and maintenance management cloud platform was used. The "zero contact" operation and maintenance cloud platform is based on mobile internet technology and was designed for the management of completed hospitals. The system was developed using a combination of APP and PC management platforms. The APP provided a convenient service for maintenance engineers to report

repairs. The PC management platform provided a mobile management office platform for administrators to visualise the progress of maintenance work in the form of charts.

5.6.4 How the project applied ISO 37106 guiding principles

Table 9 below summarizes key ways in which the project put into practice the guiding principles for a 'smart city operating model' set out in ISO 37106.

Table 9 — Mapping the actions taken by China Construction Third Engineering Bureau (CCTEB) against the guiding principles of ISO 37106

Guiding principles of ISO 37106	Putting principle into practice
Visonary: **Establishing a clear, compelling and inclusive vision for the sustainable future for a community**	— Good feedback was received from patients and the public. Huoshenshan and Leishenshan emergency hospitals achieved the requirements on schedule, with zero infection of medical staff and zero pollution of the surrounding environment. — Smart construction, operation and maintenance of emergency hospitals were applied in other smart city projects.
Citizen-centric: **Taking a citizen-centric approach to all aspects of service design and delivery**	— The two hospitals were designed and built with input from patients and medical staff to ensure close alignment with user needs, in particular drawing on feedback from patients and medical staff during the construction and operation of the Beijing Xiaotangshan Hospital during the 2003 SARS outbreak. — The construction process was streamed live on a 24-h basis, enabling citizens to choose between close-up and panoramic views and to give feedback. — During operation of the two hospitals, a user engagement team was on-site to seek feedback from patients and medical staff and drive improvement of the project. — Through smart technology, a patient-centric medical service was developed to provide medical services in a flexible, professional, and convenient manner. It improved the quality and efficiency of medical services significantly. The hospitals achieved the highest cure rate, lowest mortality rate, zero infection for medical personnel, and had zero complaints.
Digital: **Enabling a ubiquitous, integrated and inclusive digitization of community spaces and systems**	The smart operation and management platform was created using information technologies such as 5G, AI, cloud computing, big data, and building information model (BIM). The platform connects 17 information systems across five hospital categories in order to achieve smart security, smart logistics, smart diagnosis, and "zero contact" in operation and maintenance.

Table 9 *(continued)*

Guiding principles of ISO 37106	Putting principle into practice
Open and collaborative: Instilling openness and collaboration in the way the community operates.	— The computer simulates 360,000 m of pipelines and over 6,000 information points on the BIM platform to generate three-dimensional digital simulation models, data, and numbers. It can be corrected in real-time based on the situation on-site. These computers connect data for hundreds of subcontractors, thousands of processes, and over 40,000 builders. — During operation, video communications from psychologists and medical staff were regularly posted online to help keep the public informed about the situation in the hospital.

5.6.5 Lessons learned

Table 10 below summarizes key lessons that leaders of this initiative have drawn from the experience to inform management of future public-health emergencies, and highlights components of the ISO 37106 smart city operating model that can be applied.

Table 10 — Identifying key challenges faced by China Construction Third Engineering Bureau (CCTEB) and lessons learned

Issue	Lessons learned	Relevant components of ISO 37106
A smart emergency hospital needs to integrate a high number of human and material resources to construct in a very short time; lack of reserved facilities and capacity within existing city plans makes this challenging	It is suggested that the emergency infrastructure and a long-term emergency management strategy should be included in the planning and implementation of a smart city.	[B12] Managing smart city developments and infrastructures: Taking a holistic approach across all types of city infrastructure.

5.7 Hangzhou — Feedback gathering and control measures

5.7.1 Overview — Health code in the city management to prevent COVID-19

Hangzhou is located in the eastern part of China, and is the capital of Zhejiang Province, with a population of 12,2 million and an area of 16,850 km^2.

In order to efficiently respond to COVID-19 underneath the hierarchical and classified PHE management strategy, Hangzhou Municipal Government developed a colour-coded QR code that indicates the user's health status using big data, mobile communication technology, and internet technology. More than 200 cities in 25 provinces have since promoted the use of health codes. The medical facilities and human resources would be insufficient to meet COVID-19 requirements if they relied on passive tracking as usual which is only activated once symptoms are shown. The application of the health code allows government parties to collect information and adopt control measures to manage personnel flow and the viral transmission chain. This case reflects the ISO 22320 command-and-control method 'feedback gathering and control measures' and ISO 37106 guiding concepts.

5.7.2 Overview of the objectives

a) Manage the epidemic transmission chain in real-time using technologies such as big data, mobile communication technologies and the internet, in order to interrupt transmission routes and personnel flow and to improve the effectiveness of risk management processes in the event of a PHE.

b) Realize normal management and daily pandemic prevention link to smart city systems, by enabling cross-regional and cross-platform data connectivity among the different systems of government, community, medical and transport departments.

c) Develop a 'common health code application guideline standard' that standardizes the generic requirements, technical requirements and processes for the management of health code, for re-use as a tool by other stakeholders.

5.7.3 What was achieved

a) Individuals and organisations use the Hangzhou Health Code (QR code) in common daily life

The health code is built on the use of big data, mobile communication technology, the internet, Internet-of-Things technology, and the popularity of domestic mobile Internet. A QR code (in red, amber, or green) is automatically generated when the smart analysis process is finished. It can confirm and prove the holder's health status after reading the code, as well as dynamically display the holder's personal risk level of COVID-19. The holder can use this QR code to enter places where the certificate is required. The QR code dynamically displays the individual's risk level of COVID-19 and enables effective personnel management.

The feedback-gathering and control is reflected in the following elements:

— The green code means safety. The government does not exercise control over green code personnel.

— If the resident begins to display one of the high-risk symptoms (e.g. fever, cough, fatigue), the colour of their health code is changed to amber. The government limits the person's travel before the COVID-19 test can be taken. Their health code is automatically changed to "green code" after completing the isolation period. Personnel with an amber code must go to the nearest medical facility or a third-party testing facility for the COVID-19 test. When the test result is negative, the code changes to green automatically. If a resident has a negative 48-h test certificate, the local prevention and control department will notify the provincial level and carry out the necessary procedures to change the "green code".

— The colour of the code will turn red if residents test positive for COVID-19, or for confirmed cases, asymptomatic infections, and suspected cases, or if they spend more than 14 days in a high-risk area. The resident would be isolated either at home or in a central facility and would be prohibited from traveling. The government would conduct flow and medical examinations.

— The health code improves the efficiency of the government's risk management process in public-health emergencies.

Figure 9 — Green code, amber code and red code

b) One of the potential additional challenges for the Hangzhou Health Code project is multi-type code integration

There are numerous types of codes that can integrate information which also use the QR code technology. The integration of various codes is not technically difficult, but related departments must share their data with each other. Multi-code integration eliminates information barriers in this project. The health code and the transportation code are intertwined. Residents could use the health code to take public transportation, such as bus. It is more convenient for citizens to travel because they only need to show one QR code instead of multiple codes. This is a useful service that benefits all citizens.

Currently, the Hangzhou Health Code has been linked to the food safety sector, which made the health information of catering enterprises open and transparent. The Hangzhou Health Code is accessed with 'health Code for catering enterprises' and 'the health certificate system of the Hangzhou Health Commission'.

It has been used by 1,560 large catering enterprises (87 % of the total large catering enterprises in Hangzhou), 5,612 small- and medium-sized catering enterprises, and 57,972 health code information of related employees until May 12, 2020. By scanning the “health code for catering enterprises", consumers can view the food safety information of the catering units. City managers can also immediately check the health information of catering businesses and notify red code and amber code businesses to improve their health.

c) Standardization also helps the health code to be improved and replicated

The Hangzhou municipal local standard "Hangzhou Health Code Management and Service Guide" unifies the standard and facilitates replication and promotion. Based on the Hangzhou Health Code, the Office of e-Government of the General Office of the State Council has developed a nationwide unified health information code for pandemic prevention and control.

5.7.4 How the project applied ISO 37106 guiding principles

Table 11 below outlines significant ways in which the project put into effect the guiding principles of ISO 37106 for a "smart city operational model".

Table 11 — Mapping the actions taken by Hangzhou Health Code against the guiding principles of ISO 37106

Guiding principles of ISO 37106	Putting principle into practice
Visionary: **Establishing a clear, compelling and inclusive vision for the sustainable future for a community**	— The health code project is supported by Hangzhou Municipal Government. — Hangzhou benefits from local digital technology. In the future, it will be able to connect to other public service platforms and combine with residents' health records and medical data to promote Hangzhou's smart management.
Citizen-centric: **Taking a citizen-centric approach to all aspects of service design and delivery**	— Application: The health code is simple to use and can be applied to personal devices (including mobile devices) as well as websites. It is simple to use for residents and reduces the risk of virus infection. — Privacy: Residents' data will be managed by technical companies that have signed a confidentiality agreement with the Hangzhou Municipal Government. The agreement clearly states the application scope, data source, data security, personal privacy protection, and related rights involved in the Hangzhou health code project, ensuring the project's orderly progress in accordance with the law and regulations. — Function: The health code had to be integrated into existing systems used by citizens to promote ease of access. a) The Hangzhou citizen card APP can display "health code" as long as the citizen card is on the back of a mobile phone with NFC function. b) The Hangzhou Health Code application has established a link with the electronic health card and the electronic social security card. Passengers who have applied for a Hangzhou health code can complete the code verification process by directly swiping their ID card rather than showing their mobile phone health code.
Digital: **Enabling a ubiquitous, integrated and inclusive digitization of community spaces and systems**	— Health codes can be used in multiple scenarios, e.g. traffic management, community management, workplace management, and public place management. — The data connection with the social security card, bus card, and ID card has been realized by the Hangzhou Health Code. There are no data barriers in public platforms such as health and transportation.
Open and collaborative: **Integrating openness and collaboration into the way the community operates**	— The creation of a health code necessitates the collaboration of stakeholders. e.g. Hangzhou Municipal Government, Hangzhou Data Resources Administration Bureau, Hangzhou Municipal Health Commission, Ant Financial Services (a subsidiary of Alibaba Group), Hangzhou citizens. — CDC can use health codes to identify, analyze, and warn about public-health risks. Health codes can be used to assess the pandemic risk levels of different groups and regions and to implement appropriate prevention and control measures. The value of big data aggregation is high.