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MOBILE TELECOMMUNICATION BIG-DATA, INFECTIOUS DISEASE SIMULATIONS, AND EPIDEMIOLOGICAL STRATEGIES: SEOUL'S EXPERIENCE

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Foreword

Established in March 2018, the Seoul Institute of Technology (SIT) is a research institute funded by the Seoul Metropolitan Government. Our institute conducts comprehensive and systematic research projects on various technology policies for efficient city management.

Innovation in technology has led to constructive changes for our society and innovation in mechanical, electrical, and IT sectors has accelerated the industrial revolution. With the help from technological innovation, our society will be likely to see unprecedented changes in the era of the so-called Fourth Industrial Revolution.

The Seoul Metropolitan Area has been vulnerable to the highly contagious infectious disease amid the urban health crisis of the COVID-19 pandemic. The environments of high population density and hyper-connectivity within and beyond Korea have aggravated the health threat. At this point in preparation for a step-by-step recovery of daily life with a high vaccination rate and coexistence with COVID-19, the use of infectious disease tracking and management technology using Mobile telecommunication Big-Data (MBD) will support citizens to live their ordinary daily life. In addition, the urban health authority, in charge of social distancing, can enhance the efficiency of patient tracking. We expect that this research will be able to contribute to establishing a better quarantine management system. This report introduces an epidemiological strategy for the smart city using the COVID-19 analysis algorithm and the dynamics of MBD under the theme of “Development of a smart city epidemic prevention model in the metropolitan area using Mobile telecommunication Big-Data”.

This report addresses international inter-city cooperative governance. The cooperation with IT research institutes can serve not only in responding to COVID-19 but also in developing joint-collaborative actions to deal with emerging global urban issues. Based on the research results of the SIT, it is expected that the efficiency of epidemiological investigation and patient management can be improved by using MBD for targeted quarantine.

Thank you

Jinsoon Park, Acting president of the Seoul Institute of Technology

Voice from the Asia Pacific City Network

Uncertainties brought forth by the COVID-19 pandemic have continued to dominate our lives for the past few years. All nations on earth have valiantly struggled to keep their spirits and economies afloat despite these challenges. The pandemic is not only a threat to public health but a social and economic problem that endangers marginalized populations the most. For this reason, it is critical for both central and local governments to duly address the issue in a timely manner while considering local contexts. In this regard, the need for multilateral cooperation must been emphasized more than ever to combat this shared global challenge. In light of this situation, ICT infrastructure and technological availability have proven to be important preconditions for cities around the world to cooperatively overcome the problems presented by COVID-19.

In this regard, the strategies to fight COVID-19 laid out in Seoul Institute of Technology's newly published report, *"Mobile Telecommunication Big-Data, Infectious Disease simulations, and epidemiologic strategies: Seoul's experience"* have the potential to be very helpful in the global struggle if shared with other cities. As the situation develops, cities must keep demonstrating effective resilience and innovation. Bolstered by technology, measures such as social distancing and contact tracing have contributed greatly to the containment of the pandemic. As introduced throughout this report, the technology of Mobile telecommunication Big-Data (MBD) as implemented in the urban management system of South Korea is expected to improve the efficiency of such measures. The report's keen analysis shows the highly promising potential of Mobile telecommunication Big-Data contribution to the effective management of infectious diseases for countries around the globe. This research will contribute to not only helping cities to recover and build resilience during these challenging times, but also help them prepare for potential future endemic diseases.

As CityNet is a network of cities and organizations in the Asia-Pacific with the foundational goal to engender more livable and resilient cities through cooperation and knowledge sharing between cities, I believe that this instructive research will provide urban stakeholders with a prime example of good practice to manage this highly infectious disease.

Despite the sustained challenges that the world expects to face in the new year, we hope that every member of our global society keeps strong and steady. I believe the Seoul Institute of Technology will lead the way for developing innovative initiatives to address further challenges that arise.

Vijay Jagannathan
Secretary-General
CityNet

Summary

We have come to recognize the need for a realistic urban quarantine decision-making model that analyzes individual mobility as we have experienced the urban health crisis of the COVID-19 infectious disease. In this study, with a focus on the nature of the highly contagious virus, we conducted a study on the algorithm for the spatial spread of COVID-19 in Seoul and developed a model for smart city quarantine management by utilizing Mobile telecommunication Big Data (MBD).

“Database design for COVID-19 analysis based on MBD”

MBD can identify changes in individual population mobility and infection clusters, and provide implications for epidemiological management by identifying high-risk areas for which disease transmission patterns can be analyzed. This study draws on movement data from mobile phone signals for the simulation of the diseases spread. Two types of datasets are constructed. The first is a contact-based movement database and the second is a traffic volume matrix between administrative units, called dong in Seoul.

“Infectious disease simulation using MBD”

Three types of infectious disease simulations are conducted using the database combined with population information that is counted by MBD. In this report, scenario-based contact simulation is performed by reflecting the average incubation period of five days after tracking the location of the confirmed patient by using the records of the movement with improved location accuracy. In the epidemic simulation, an infectious disease spread model is developed for each municipality (called gu) considering the effect of social distancing and non-social gathering restrictions with the application of the SEIR mathematical model. In the analysis of real-time information transmission through disaster alert text messages, it is confirmed that the number of people decreases when specific information about the outbreak such as cluster information is included in the text message. This decrease is statistically significant for 6 hours after the text message is sent.

“Smart city quarantine model necessary in the era of coexistence with COVID-19”

Effective COVID-19 management is extremely important to allow ordinary daily life without implementing intensive social distancing measures through testing, mass quarantine, and tracking. As a model for urban epidemiological management with the coexistence of COVID-19, a three-step smart urban quarantine system is proposed in this report. Finally, with the verification of research results, it is proposed to introduce a pilot system for customized services for high-risk areas based on infection spread simulation with MBD.

Abbreviations

CCNR	National Tracking Contact Center in Colombia
CCTVs	Closed-Circuit Televisions
CLM	Corona Likelihood Metric in Indonesia
CMCO	Conditional Movement Control Order in Malaysia
COVID-19	Coronavirus disease 2019
DID	Difference-in-Differences
DSS	Decision Support System
EISS	Epidemiological Investigation Supporting System
ERR	Rapid Response Teams in Peru
G2G	Government-to-Government
GPS	Global Positioning System
IDF	Inverse Document Frequency
IMSI	International Mobile Subscriber Identifier
ITS	Intelligent Traffic System
KDCA	Korea Disease Control and Prevention Agency
KOICA	Korea International Cooperation Agency
MAMPU	Malaysian Administrative Modernization and Management Planning Unit
MBD	Mobile telecommunication Big-Data
MCMC	Malaysian Communications and Multimedia Commission
MCO	Movement Control Order in Malaysia
MOLIT	Ministry of Land, Infrastructure, and Transport
NRP	National Recovery Plan in Malaysia
O-D	Origin-Destination
ODA	Official Development Assistance
OSS	Operation Support System
PPKM	Community Activities Restrictions Enforcement in Indonesia
PRASS	Test, Trace, and Sustainable Selective Quarantine Program in Colombia
PSBB	Large-Scale Social Restrictions in Indonesia
RCCE	Risk Communication and Community Engagement in Ethiopia
RMCO	Recovery Movement Control Order in Malaysia
RMSE	Root-Mean-Square Error
RSRP	Received Signal Reference Power
SEIR	Susceptible-Exposed-Infectious-Recovered
SINR	Signal to Interference and Noise Ratio

SMG	the Seoul Metropolitan Government
SOP	Standard Operating Procedures in Malaysia
TA	Timing Advance
TF	Term Frequency

Citizens waiting for COVID-19 PCR test at Seoul City Hall Square (c) Hyungwoong Chang, December 2021

Chapter 1. Introduction

1. Backgrounds and objectives
2. A review of academic research
3. International benchmarks for infectious disease control by MBD

1. Backgrounds and objectives

Coronavirus disease 2019 (SARS-COV-2 or COVID-19) has been spread worldwide since it was first detected in Wuhan, China. In South Korea, since the first case was confirmed, there have been a series of waves. After the Delta variant appeared, the number of confirmed cases increased to over 2,000 a day.

South Korea has employed Mobile telecommunication Big-Data (MBD) for contact tracing in response to the spreading infectious virus. Along with extensive tests, facial mask-wearing, and social distancing, the MBD approach contributed to the detection of the spread of the virus. MBD was also actively used to alert risks by sending text messages which included social distancing measures and exposure sites. South Korean contact tracing approaches adopted all available data sources such as information about credit card expenses and the location of transport cards. The outcome of contact tracing was used to identify those who require tests and self-quarantine.

South Korea has developed an urban management system to tackle the highly infectious disease. This report explores the possibility to make use of MBD for efficient infectious disease management. MBD can provide an opportunity for tracking the locations of individual mobile phones. For the sake of privacy, MBD can be used after removing private information of the mobile phone holders. This research demonstrates that the MBD approach can contribute to better responding the global health crisis with an intention to share Seoul's experience.

This report explores how individuals contact and spread the very infectious virus by tracking the location of mobile phones based on MBD. The analysis from this approach will enhance the efficiency of contact tracing and epidemiological management. This research develops simulation models that can show how the virus is spreading with MBD in Seoul.

Two datasets have been established for this research. The first dataset is to analyze contact tracing and the second set is to analyze mobility. With these datasets, three sets of analyses are performed with MBD. First, an algorithm for the spread of COVID-19 has been developed for simulation. Second, how COVID-19 has been spread is analyzed based on the clusters of outbreaks. Third, the effectiveness of alert text messages has been investigated.

Then, a proposal for epidemiological urban management has been made based on those findings. To leverage the research findings, this research explores how the MBD approaches can be shared with other cities in developing countries. Inter-city collaborations have been discussed followed by conclusions and policy implications.

2. A review of academic research

This section provides an overview of existing research that has investigated the handling of COVID-19. Firstly, How COVID-19 is spread has been analyzed by mathematical approaches among which the Susceptible-

Exposed- Infectious-Recovered (SEIR) model has attracted attention. The SEIR model categorize people into four groups to identify their risks and analyze reproduction. Numerous research projects have adopted the SEIR model to analyze the spreading pattern and modified the model to predict future virus spread in certain circumstances. For instance, Choi and Ki (2020) added one more group – those who are hospitalized (H), making a SEIRH model to analyze the reproduction number and to predict future confirmed cases. Their research confirmed the significance of social distancing and wearing a facial mask in reducing the virus spreading. Mbuvha and Marwala (2020) combined SIR and SEIR models with Bayesian methods to infer time-varying spreading rates. They found out travel bans reduced the spreading rate. The SEIR model has provided insights for the following models in this report.

Secondly, the significance of mobility data has been discussed. Oliver et al. (2020) collected call data records and established four datasets to analyze the spreading pattern of COVID-19: (1) Origin-Destination (O-D) matrices, (2) Dwell estimations and hotspots, (3) contact matrices, and (4) amounts of time spent. Badr et al. (2020) used O-D data collected from Teralytics to analyze mobility, mobility ratios, and COVID-19 infection rates.

Third, mobility has been analyzed along with mathematical models. At the beginning of COVID-19, Wu et al. (2020) estimated the basic reproduction number by analyzing the number of passengers in train stations and the airport in Wuhan based on the SEIR model. They alerted that other major cities were likely to sustain localized outbreaks. Kondo (2021) analyzed the spatial pattern of COVID-19 by establishing an O-D matrix in Japanese prefectures. Chang et al. (2021) used mobile phone data to predict infection rates in different racial groups. They analyzed the hourly movements of 98 million people from neighbourhoods to the points of interest such as restaurants and religious establishments.

Fourth, algorithm and simulation approaches have been employed for virus containment. Liu et al. (2021) computed a ranking model with city Global Positioning System (GPS) spatial dynamics data to determine the likelihood of asymptomatic carriers. They proposed a machine-learning algorithm. In their continuous learning and inference of individual probability (CLIIP) algorithm, they categorized people into which are susceptible (S), susceptible and quarantined (Sq), exposed (E), exposed and quarantine (Eq), infected (I), hospitalized (H), and recovered (R). Based on mobile location data at a certain time, they developed a model to identify people with a high risk of getting infected. Ferguson et al. (2020) proposed two non-pharmaceutical intervention strategies before vaccines were developed: (1) mitigation and (2) suppression. Mitigation attempts "slowing but not necessarily stopping epidemic spread – reducing peak healthcare demand while protecting those most at risk of severe disease from infection". Suppression is to "reverse epidemic growth, reducing case numbers to low levels and maintaining that situation indefinitely". To evaluate these two approaches, they applied microsimulation.

These four approaches provide a framework for this research. The SEIR model is modified to predict the spatial spread of COVID-19 and mobility is analyzed with MBD in Seoul. Simulation is conducted in one selected local government area, Gangseo-gu, in Seoul.

3. International benchmarks for infectious disease control by MBD

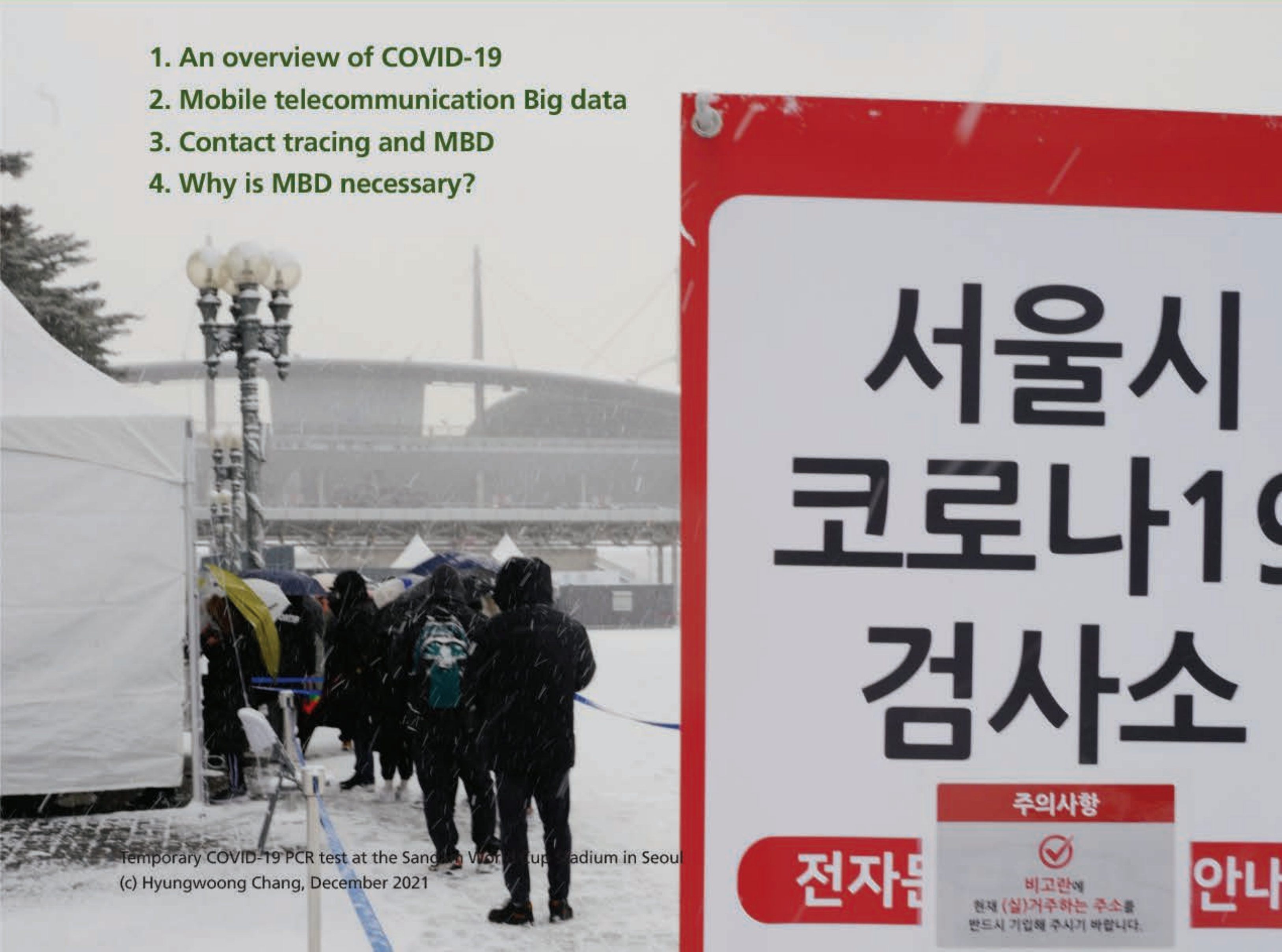
There have been growing interests in telecommunication data given the global health threats. In the report “Utilizing mobile big data and AI to benefit society: Insights from the Covid-19 response”, published by the Global System for Mobile Communications Association (GSMA) in 2021, how MBD has been used in response to COVID-19 (Table 1). That report explored MBD uses illustrating that at least epidemiological modeling, logistics and infrastructure monitoring, and economic modeling can be supported by MBD.

Table 01 MBD analytics use cases for the Covid-19 response

Population mapping	Population mobility	Epidemiological modelling	Logistics and infrastructure monitoring	Economic modelling
Provides insights on the characteristics of a given population, including location and density. Useful where population statistics are lacking or obsolete.	Monitor compliance with lockdown measures and movement patterns as these restrictions are eased.	Used to reveal how a disease is behaving and how quickly it is spreading to help identify transmission hotspots or sources of infection. MBD can be combined with public health data on confirmed cases to enhance insights.	Inform decision-makers on resource needs across different locations and support the effective allocation of resources (e.g. hospital beds, test kits and test centers, PPEs and healthcare personnel) to areas of greatest need.	Provide insight on the impact of lockdown and how the easing of such is evolving to help governments assess the cost benefit balance of different types of interventions on vulnerable populations. Communities, regions, and industries that are disproportionately impacted can be identified and supported.
Mobile Network Operator Data				
		+ Public health data	+ Geographic information system (GIS), infrastructure logistics and stock data	+ Airtime purchase, mobile money and cash transfer data

Source: GSMA (2021), p.12

Chapter 2.
COVID-19 and Mobile telecommunication Big Data



Temporary COVID-19 PCR test at the Sangam World Cup Stadium in Seoul
(c) Hyungwoong Chang, December 2021

1. An overview of COVID-19

COVID-19 has been spread worldwide and the World Health Organization declared a Pandemic on 11 March 2020. Although COVID-19 is highly infectious, it is unclear whether the size of the city and population density are critical factors for the virus spread. As seen in the average confirmed cases per 10,000 people (Table 2), the world's largest cities have shown varying degrees of the virus spread. For instance, Seoul had 32 per 10,000 people while Bangalore had nearly 1,000 cases although these cities had the similar number of residents. These differences are from multiple factors including social distancing and lockdown measures, contact tracing, testing, and facial mask-wearing. This report attempts to examine Seoul's MBD approaches in mitigating the virus spread.

There have been multiple sources of infection in Seoul. Infection clusters were identified in the virus spread such as gyms, religious establishments, dance halls, restaurants and karaoke, protests against social distancing measures, nightclubs, and hospitals. Social distancing measures were in place depending on the volume of infections. As new daily confirmed cases decreased, those public areas were opened to the public with reduced capacity.

2. Mobile telecommunication Big data

This section illustrates how MBD is created and processed by SK Telecom (hereafter SKT) that has the largest market share of South Korean mobile phone subscribers.

2.1 Key aspects of MBD and Call Log

MBD refers to real-time data that LTE/5G handsets access the mobile base station for mobile telecommunication services. It includes Received Signal Reference Power (RSRP), Signal to Interference and Noise Ratio (SINR), and Timing Advance (TA) that details the time and the length a signal takes to reach the base station from individual handsets.

Subscribers to SKT generate approximately 20 billion access a day to the base station. The operating team within SKT collects and analyzes these MBD for quality control of its services.

MBD has been unitized in the Intelligent Traffic System (ITS). By tracking the location of subscribers, traffic volumes and speed can be estimated for efficient traffic management. Access information by each handset, whether the access is properly completed, handed over, or terminated abnormally, generates Call Log along with information about the mobile service quality. The Call Log is forwarded to the Operation Support System (OSS) on a real-time basis. Then, network managers can figure out the quality of mobile networks from the Call Log information.

Table 02 Largest metropolitan areas and COVID-19 infection

#	Metropolitan area	Country	Population 20151) (thousand)	Confirmed cases per 10,000 2) (as of 31 March 2021.)
1	Tokyo	Japan	37,256	32
2	Delhi	India	25,866	256
3	Shanghai	China	23,482	0
4	Ciudad de México (Mexico City)	Mexico	21,340	285
5	São Paulo	Brazil	20,883	1,172
6	Mumbai (Bombay)	India	19,316	1,436
7	Kinki M.M.A. (Osaka)	Japan	19,305	26
8	Al-Qahirah (Cairo)	Egypt	18,820	-
9	New York-Newark	USA	18,648	1,004
10	Beijing	China	18,421	0
11	Dhaka	Bangladesh	17,597	344
12	Buenos Aires	Argentina	14,706	666
13	Kolkata (Calcutta)	India	14,423	406
14	Karachi	Pakistan	14,289	186
15	Istanbul	Turkey	14,127	2,320
16	Chongqing	China	13,372	0
17	Rio de Janeiro	Brazil	12,941	498
18	Manila	Philippines	12,860	243
19	Tianjin	China	12,516	0
20	Los Angeles-Long Beach-Santa Ana	USA	12,345	988
21	Lagos	Nigeria	12,239	18
22	Moskva (Moscow)	Russia	12,049	-
23	Guangzhou, Guangdong	China	11,695	2
24	Kinshasa	Congo	11,598	-
25	Shenzhen	China	11,275	2
26	Paris	France	10,734	-
27	Lahore	Pakistan	10,369	213
28	Jakarta	Indonesia	10,173	-
29	Bangalore	India	10,141	979
30	Seoul	South Korea	9,897	32

Source:1) https://population.un.org/wup/Download/

Source:2) COVID-19 confirmed cases (https://news.google.com/covid19/map) on 31 March 2021

Note: There might be a spatial mismatch in these two information sets in defining the metropolitan area.

The abnormal termination of the call from the LTE/5G handsets requires analysis with the Call Log that details the reasons for it. When it is due to the quality of mobile networks, the location of the abnormal termination is tracked to improve the quality of mobile services in that location. The accuracy of the location from Call Log is 200m in urban areas, but it can be enhanced up to 50m if Call Log-based mobile network quality information is used. By doing so, the managers for quality assurance can reduce the geographical scope to 1/16 for their field inspection work.

SKT provides location tracking services for various purposes such as by the location of children and the elderly by the request from their guardian and the location of the citizens with criminal records by the request from the police agency. For these services, SKT operates a database based on mobile network quality. When analyzing Call Log-based mobile network quality information, the route of handset movements can be traced by linking the previous location and the later location.

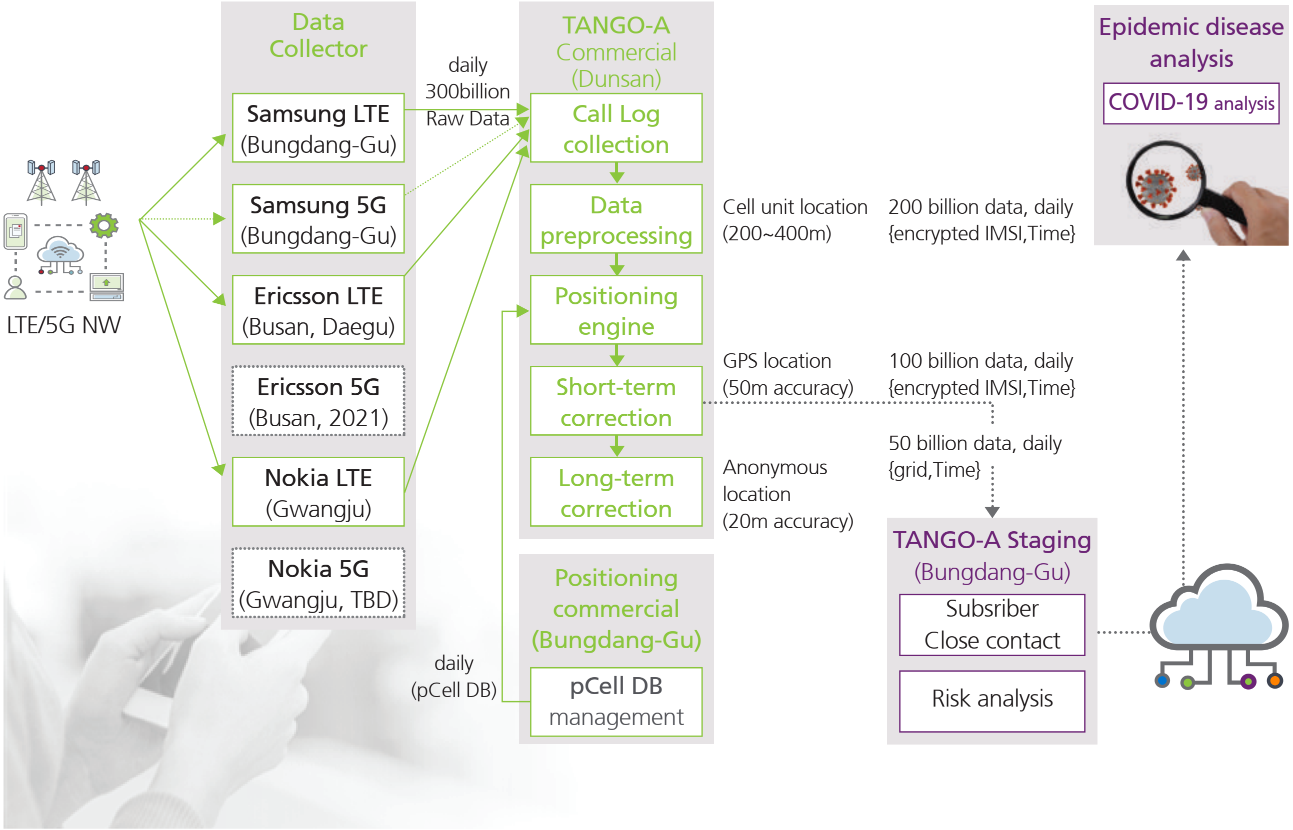


Figure 1 The processing of MBD

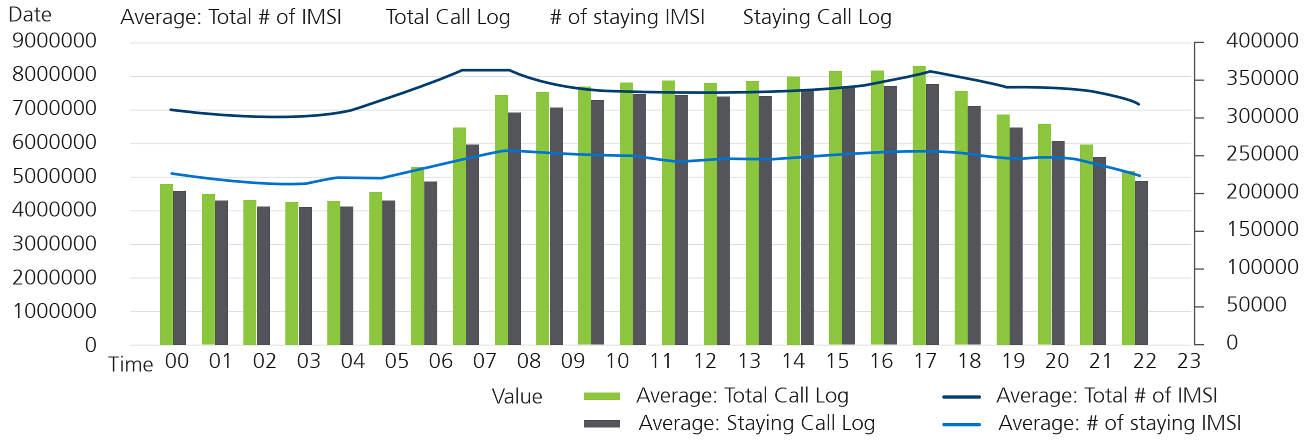


Figure 2 Call Log records in Gangseo-gu, Seoul (on 2 September 2021)

2.2 Processing MBD

This section details how MBD is processed for this research. It undertakes MBD collection, pre-process, lining with a positioning engine, and short-term adjustment for location identification by Call Log. The outcomes from these processes are used for tracking which generates O-D matrices.

MBD Collection: Raw data about access to the base station is collected in entire South Korea including the mobile network quality information. Approximately 30 billion access are recorded daily on average.

Data pre-process: The raw data is transformed to a standardized format for analysis. Then, it becomes approximately 20 billion records a day.

Linking with a positioning engine: The coordinates at geographic coordinate system information are added to the collected network quality information for location tracking. With the reference to the grid-based map database, the outcome of location tracking is produced.

Short-term adjustment: By analyzing past movement patterns, the reliability of the current coordinates is tested and adjusted to improve accuracy. It processes approximately 10 billion records a day.

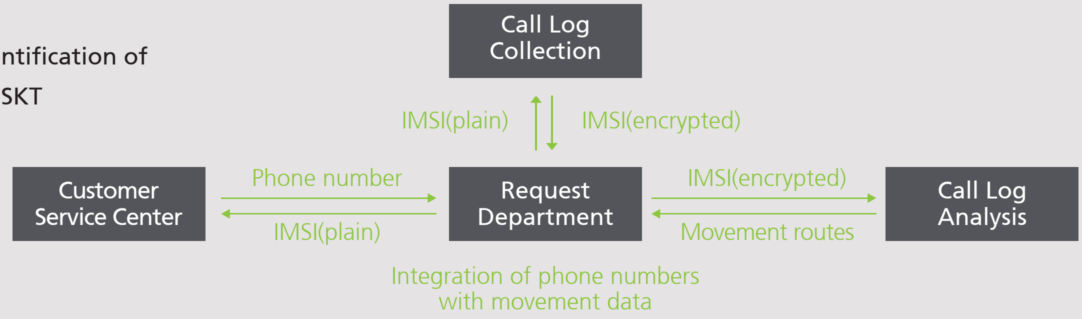
The processed data is anonymized by removing personal profiles to be used for simulation. With the processed MBD, O-D matrices are produced by a 50m x 50m grid (or administrative district, called Dong). The simulation is based on a real outbreak accident and plausible assumptions in one municipality – Gangseo-gu in western Seoul. In the simulation, risks are measured by tracking the locations of confirmed COVID-19 cases and the duration of their stays (see Figure 2).

2.3 Descriptive statistics of SKT's MBD

MBD includes details about the time and space of mobile phone subscribers. In Gangseo-gu alone, there are approximately 200 thousand subscribers to SKT who produce 6.3 million access records a day.

Figure 3

The process of the identification of COVID-19 patients by SKT



The staying handsets are identified if they generate Call Log for more than 15 minutes. Call Log is recorded every 5 minutes and, thus, the staying handsets should have four or more Call Log records. Even if there are only 2 to 3 Call Log records, when their time gap is more than 15 minutes, these handsets are identified as staying. The trends of Call Log varied between week days and weekends. There were more Call Log records in peak hours during the weekdays and the Call Log records started growing from noon. The staying handsets accounted for approximately 60% of the total sub scribers, but their Call Log records accounted for 95% of the total Call Log records. However, the number of staying handsets does not refer to the precise number of residents due to Machine-to-Machine devices and the ways to identify the staying handsets. When there is a request for the location information of COVID-19 cases, the International Mobile Subscriber Identifier (IMSI), de-coupled from personal information, is used to preserve animosity (see Figure 3).

3. Contact tracing and MBD

3.1 The process for epidemiological investigation in South Korea

The epidemiological investigation has become a very significant process to identify potential infection cases. It has been directed by the Korea Disease Control and Prevention Agency (KDCA) under the Ministry of Health and Welfare. The epidemiological investigation has been performed on those who are diagnosed with COVID-19. Those confirmed cases are recorded on the COVID-19 information management system (https://covid19.kcda.go.kr/). Indeed, Figure 4 outlines how South Korean epidemiological investigation is being carried out undertaking five steps: (1) Identifying the case, (2) Preliminary investigation and recording, (3) Investigation of close contacts and recording of them, (4) Interviews, and (5) Reporting. These processes involved possible data sources including the GPS, the records of credit card expense, and Closed-Circuit Televisions (CCTVs). These processes clarify the profile, the commencement date of the symptom, the date of infection, and locations where the confirmed case had visited/stayed. There is a form to be filled in by the epidemiological

Case	Confirmed case occurs	Additional Confirmed case
Subject	Confirmed patient	Confirmed among contacts or self-quarantine
① Situation evalution	· Identify the size of the occurrence	· Determination of cluster infection · Sharing the situation of other region
② Basic investigation and registration	· Basic epidemiological investigation · System regisration	· Cluster infection investigation · System registration
③ Contact investigtn and registration	· Conduct contact investigation · System regisration · Investigation of route (GPS / Credit card / CCTV / DUR)	· Designation of prior confirmed cases · Syetem registration · Investigation of route (GPS / Credit card / CCTV / DUR)
④ Case identification	· In-depth epidemiological investigation · Retrospective contact investigation (Infection source investigation)	· In-depth epidemiological investigation · Retrospective contact investigation (Infection source investigation)
⑤ Registration	· System regisration of In-depth investigation report	· System regisration of In-depth investigation report

Figure 4 The process of epidemiological investigation

Source: KCDC, January 2021

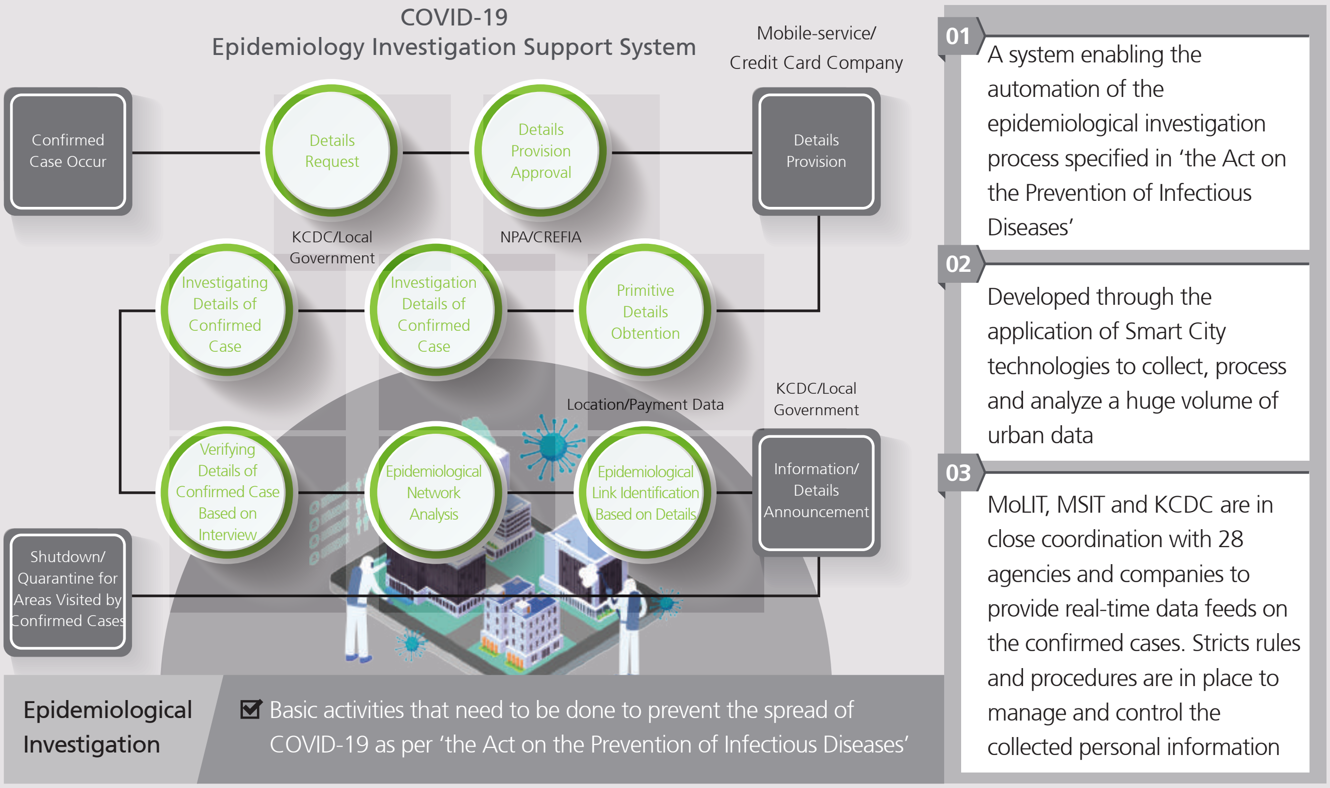
investigator to detail key information about the confirmed case, symptoms, how the case had been contacted with the virus, and whether the case is related to COVID-19 clusters. The ways of epidemiological investigation have been further strengthened by ICT-assisted approaches known as the Epidemiological Investigation Supporting System (EISS).

3.2 COVID-19 Epidemiological Investigation Supporting System

The EISS is an automated process of epidemiological investigation based on the "Infectious Disease Control and Prevention Act" enacted in 2020. This system is to identify hotspots and infection chains through time-space analysis on the confirmed cases. The system is designed to support to detect exposure sites and the links of infection promptly and easily by analyzing real-time data such as the location information and the credit card expenses of the confirmed cases. This system is to conduct time-space analysis by which the hot spots and the chain of the virus can be identified. Before this system, the Minister of Health and Welfare should make a formal request to the National Police Agency. Then, the National Policy Agency consulted with the local police station and telecommunication companies to access information, which took a maximum of 24 hours. However, the EISS has enabled the entire process, including the request, approval, and transit of request information, to be processed within 30 minutes. The EISS was updated by a pilot operation from 16 March 2020, and it has been in full operation since 26 March 2020. There was a shift in the management of the system from the Ministry of Land, Infrastructure, and Transport (MOLIT) to the KDCA. The KDCA is a formal institution managing the system in partnership with the National Police Agency, three telecommunication companies, 22 credit card companies, and the Credit Finance Association. Through the system, faster contact tracing investigations are allowed with accuracy. There are three primary functions in the EISS:

- Data collection about confirmed cases: Epidemiological investigators record the confirmed case to the system and collect data about where these cases had visited.
- Refining the data about their contacts: by analyzing mobile phone location data, the actual locations of where the case had visited are traced with assistance from machine learning.
- Identifying primary contacts: by analyzing credit card payments and telecommunication location data, primary contacts and virus hot spots can be identified.

Smart Safe City for Covid-19 Response



Epidemiological Investigation

☑ Basic activities that need to be done to prevent the spread of COVID-19 as per 'the Act on the Prevention of Infectious Diseases'

01 A system enabling the automation of the epidemiological investigation process specified in 'the Act on the Prevention of Infectious Diseases'

02 Developed through the application of Smart City technologies to collect, process and analyze a huge volume of urban data

03 MoLIT, MSIT and KCDC are in close coordination with 28 agencies and companies to provide real-time data feeds on the confirmed cases. Stricts rules and procedures are in place to manage and control the collected personal information

Figure 5 Epidemiological Investigation Supporting System

The EISS has mitigated the workload of contact tracing investigators and sped up the time to access the required information for precise contact tracing. Also, the system will be able to accumulate data about the spread of the infectious disease, which will be useful for the prevention of future possible incidents.

3.3. Current big data sources for epidemiological investigation

1) Credit cards

Korean credit card companies have expense information of their cardholders including the locations

Table 03 Seven ethical principles

Ethical principles		Detail
1	Justice	Justice, or fairness, encompasses two different concepts. The first is equity, which refers to fairness in the distribution of resources, opportunities and outcomes. The second aspect of justice is procedural justice, which refers to a fair process for making important decisions.
2	Beneficence	Beneficence refers to acts that are done for the benefit of others, such as efforts to relieve individuals’ pain and suffering.
3	Utility	The principle of utility states that actions are right insofar as they promote the well-being of individuals or communities.
4	Respect for persons	The term “respect for persons” refers to treating individuals in ways that are fitting to and informed by a recognition of our common humanity, dignity and inherent rights.
5	Liberty	Liberty includes a broad range of social, religious and political freedoms, such as freedom of movement, freedom of peaceful assembly, and freedom of speech.
6	Reciprocity	Reciprocity consists of making a “fitting and proportional return” for contributions that people have made.
7	Solidarity	Solidarity is a social relation in which a group, community, nation or, potentially, global community stands together.

Source: WHO (2016), pp. 8-9

and industry types of the shop along with the paid amounts. While credit card expense data is useful for estimating the risks of infection by point-of-interest in some contexts, high-density and mixed land-use patterns have difficulty in performing accurate analysis. Also, it lacks precise retail shop information.

2) Transport cards

Transport cards are the primary tool to pay for the fare in Korean public transport. Transport card touches are recorded and kept by the card operator. That data includes the time, the location of the station, and the routes of transport cardholders when they touch on and off. This is a useful dataset for analyzing travel patterns of public transport users. However, there has been no reported case of massive transmission of the virus within public transport facilities. Nevertheless, the transport card data can support analyzing future mobility patterns.

3.4 Privacy protection

The World Health Organization provided “Guidance for managing ethical issues in infectious disease outbreaks” (WHO, 2016). In this guidance, seven ethical principles are discussed. Collecting data for infectious diseases should also follow these principles (Table 3). Personal information is securely protected, but the Infectious Disease Control and Prevention Act exceptionally allowed the process of personal information for the sake of public health. The Act enables the public authority to disclose the routes of movements, close contacts, and visited medical facilities of the infected patients through press releases and/or ICT platforms for infectious disease control.

4. Why is MBD necessary?

When mobile phones, in particular smartphones, are widely used, their location data can be an important source for contact tracing. According to the PEW Research Center, South Korean mobile phone ownership was 100% in 2018 and 95% of these phone holders had smartphones (Silver, 2019). Owing to the widespread of smartphones, there is growing interest in making use of MBD for contact tracing. Accordingly, recent research has developed models for predicting the spread of COVID-19 by using telecommunication data and those models have identified vulnerable groups to the infection with enhanced accuracy (Chang et al., 2021). The location data of individual smartphone holders have contributed to controlling and preventing the spread of the virus. There is great potential to improve initial reactions in prompt ways and, therefore, to curb the trend of virus spreading.

Chapter 3.
Developing simulation algorithms for infectious disease control

1. The establishment of datasets
2. Analysis I: Simulation models for
   the spread of the virus through close contacts
3. Analysis II: Simulations for
   the spread of infectious disease and non-pharmaceutical
4. Analysis III: The effects of real-time information through text messages

1. The establishment of datasets

1.1. Contact-based datasets

Three-month contact-based datasets, composed of Call Log, are established with MBD of Gangseo-gu as a testbed in the period 30 March 2021 – 30 June 2021. The size of MBD ranges 4GB to 6GB per day. On 31 May 2021, the dataset included 89,031,151 rows and 718,148 IDs of the IMSI. The dataset includes the anonymized identifier (ID) of IMSI, time, and longitude, and latitude (Table 4).

Table 04 An example of Call Log dataset in Gangseo-gu

IMSI ID	Year	Month	Day	Hour	Minute	Latitude	Longitude
T0kvPxXVwwLZrDhGjXFA	2021	5	31	0	0	37.555216	126.870564
T0kvPxXVwwLZrDhGjXFA	2021	5	31	0	5	37.555216	126.870564
T0WdngxJ4Zem9KZHEWPY	2021	5	31	0	6	37.554716	126.870426
…	…	…	…	…	…	…	…
T0q0UHEnkoz9a2HOdC9n	2021	5	31	8	21	37.555475	126.85639

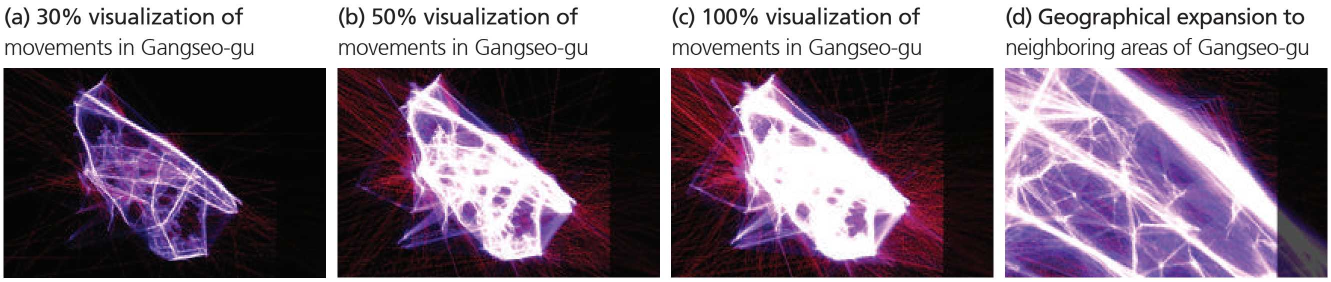
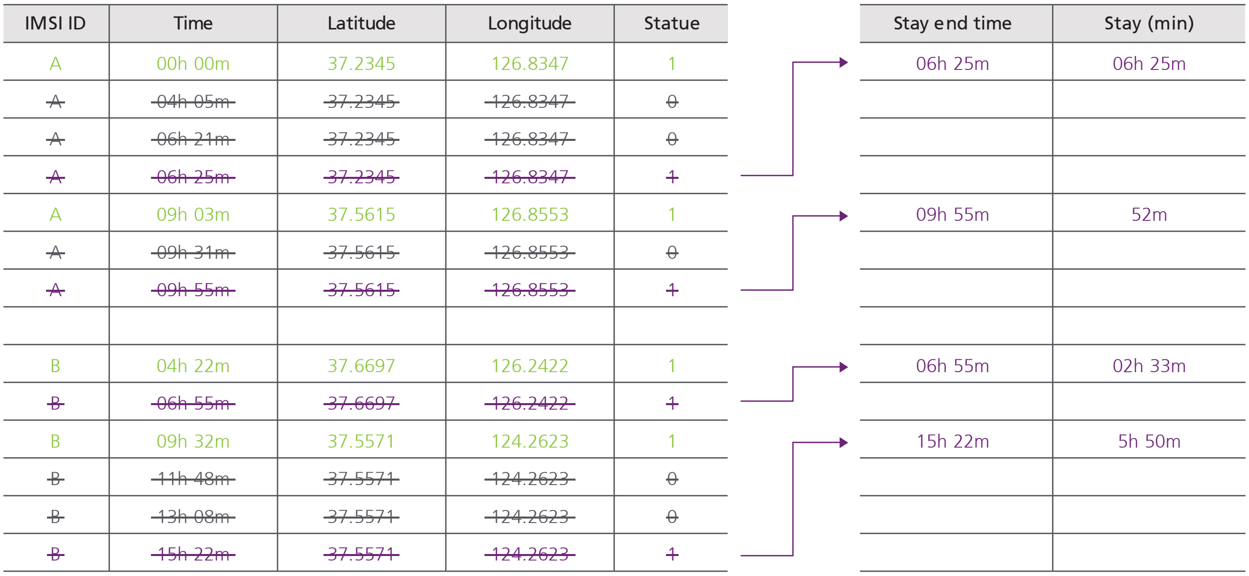

(a) 30% visualization of movements in Gangseo-gu
(b) 50% visualization of movements in Gangseo-gu
(c) 100% visualization of movements in Gangseo-gu
(d) Geographical expansion to neighboring areas of Gangseo-gu

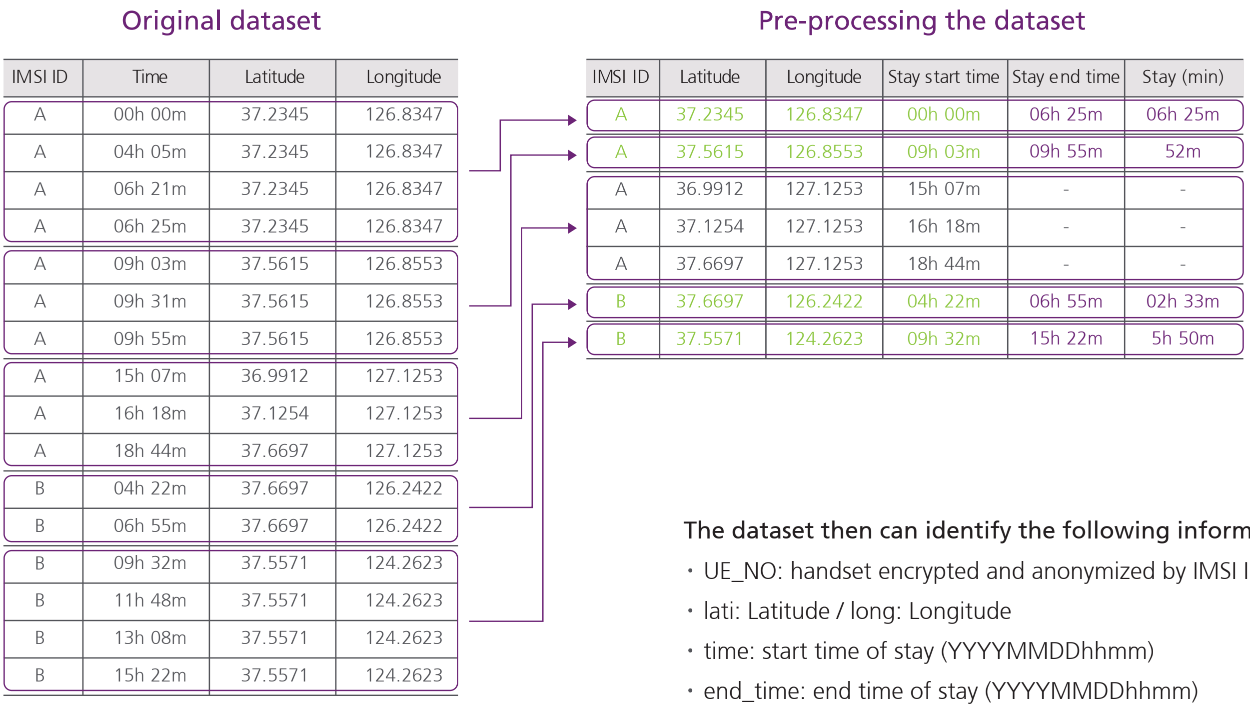
Figure 6 Visualization of movements in Gangseo-gu

To analyze the exposure sites and contacts, the pre-process of the Call Log records is required. It is difficult to figure out the duration of stay with the unprocessed Call Log that is accumulated irregularly (or repeatedly if the handset stayed) by the IMSI ID. To analyze the duration of stay and reduce the size of the dataset, the raw data was sorted by the IMSI ID and time. Then, the repeated Call Log records in the same location were reduced by including the initial and the last moments of the stay only as seen in Figure 7.



IMSI ID	Time	Latitude	Longitude	Statue	Stay end time	Stay (min)
A	00h 00m	37.2345	126.8347	1	06h 25m	06h 25m
~~A~~	~~04h 05m~~	~~37.2345~~	~~126.8347~~	~~0~~		
~~A~~	~~06h 21m~~	~~37.2345~~	~~126.8347~~	~~0~~		
~~A~~	~~06h 25m~~	~~37.2345~~	~~126.8347~~	~~1~~		
A	09h 03m	37.5615	126.8553	1	09h 55m	52m
~~A~~	~~09h 31m~~	~~37.5615~~	~~126.8553~~	~~0~~		
~~A~~	~~09h 55m~~	~~37.5615~~	~~126.8553~~	~~1~~		
B	04h 22m	37.6697	126.2422	1	06h 55m	02h 33m
~~B~~	~~06h 55m~~	~~37.6697~~	~~126.2422~~	~~1~~		
B	09h 32m	37.5571	124.2623	1	15h 22m	5h 50m
~~B~~	~~11h 48m~~	~~37.5571~~	~~124.2623~~	~~0~~		
~~B~~	~~13h 08m~~	~~37.5571~~	~~124.2623~~	~~0~~		
~~B~~	~~15h 22m~~	~~37.5571~~	~~124.2623~~	~~1~~		

Figure 7 An example of Call log data simplification



Original dataset

IMSI ID	Time	Latitude	Longitude
A	00h 00m	37.2345	126.8347
A	04h 05m	37.2345	126.8347
A	06h 21m	37.2345	126.8347
A	06h 25m	37.2345	126.8347
A	09h 03m	37.5615	126.8553
A	09h 31m	37.5615	126.8553
A	09h 55m	37.5615	126.8553
A	15h 07m	36.9912	127.1253
A	16h 18m	37.1254	127.1253
A	18h 44m	37.6697	127.1253
B	04h 22m	37.6697	126.2422
B	06h 55m	37.6697	126.2422
B	09h 32m	37.5571	124.2623
B	11h 48m	37.5571	124.2623
B	13h 08m	37.5571	124.2623
B	15h 22m	37.5571	124.2623

Pre-processing the dataset

IMSI ID	Latitude	Longitude	Stay start time	Stay end time	Stay (min)
A	37.2345	126.8347	00h 00m	06h 25m	06h 25m
A	37.5615	126.8553	09h 03m	09h 55m	52m
A	36.9912	127.1253	15h 07m	-	-
A	37.1254	127.1253	16h 18m	-	-
A	37.6697	127.1253	18h 44m	-	-
B	37.6697	126.2422	04h 22m	06h 55m	02h 33m
B	37.5571	124.2623	09h 32m	15h 22m	5h 50m

The dataset then can identify the following information:

- UE_NO: handset encrypted and anonymized by IMSI ID
- lati: Latitude / long: Longitude
- time: start time of stay (YYYYMMDDhhmm)
- end_time: end time of stay (YYYYMMDDhhmm)
- stay: duration (minutes)

Figure 8 Pre-processing the dataset

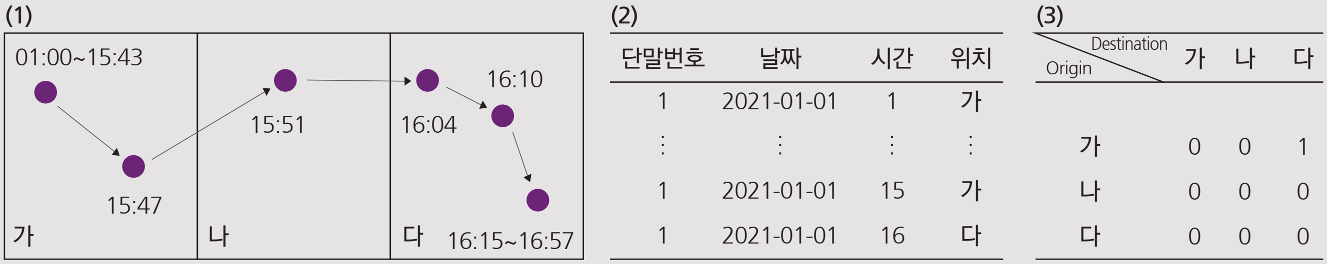
1.2 The establishment of O-D data for mobility analysis

Spatial units should be specified in establishing the O-D table. There are 25 municipalities (called gu) and 425 administrative districts (called dong) in Seoul. The O-D table is produced based on these 425 districts to analyze inter-municipality movements. The data is collated daily consistent with the COVID-19 statistics.

Figure 9 Administrative districts in Seoul

The O-D table is created in the following ways:

Step 1 On an hourly basis the administrative districts are recorded if the handsets had stayed for more than 30 minutes. When the duration of stay was less than 30 minutes, it is not recorded assuming those handsets are moving.



단말번호	날짜	시간	위치
1	2021-01-01	1	가
⋮	⋮	⋮	⋮
1	2021-01-01	15	가
1	2021-01-01	16	다

Origin \ Destination	가	나	다
가	0	0	1
나	0	0	0
다	0	0	0

Figure 10 Step 1 – 3: Identifying stay or moving handsets, location data, and O-D table

Step 2 Through Step 1, location data is produced by the handsets

Table 05 An example of datasets

ID	Age	Gender	Time point	Location of stay
Individual 1	25-29	Male	1	Oksu-dong
			2	Jamsil 2-dong
			3	Jamsil 6-dong
			4	Seongnae 3-dong
Individual 2	25-29	Male	1	Oksu-dong
			2	Nonhyeon 2-dong
			3	Oksu-dong

Step 3 Through Step 2, data are collated by the administrative district to roduce the O-D table.

	Destination					
Origin	25-29yr male	Oksu dong	Jamsil 2 dong	Jamsil 6 dong	Nonhyeon 3 dong	Nonhyeon 2 dong
	Oksu-dong	0	1	0	0	1
	Jamsil 2-dong	0	0	1	0	0
	Jamsil 6-dong	0	0	0	1	0
	Nonhyeon 3-dong	0	0	0	0	0
	Nonhyeon 2-dong	1	0	0	0	0

Figure 11 A simplified example of the O-D table

This process allows one handset to be recorded multiple times through which various movements can be included in the O-D table.

2. Analysis I: Simulation models for the spread of the virus through close contacts

While close contacts are considered major sources for the spread, certain characteristics of the place increase the risk of infection such as 1) closed and unmasked environments and 2) indoor space with public access. Cluster infection refers to the concurrent infection case that makes more than two people from the same infection source in the same location. With the close contact environments, three cluster infection scenarios are developed (Table 6).

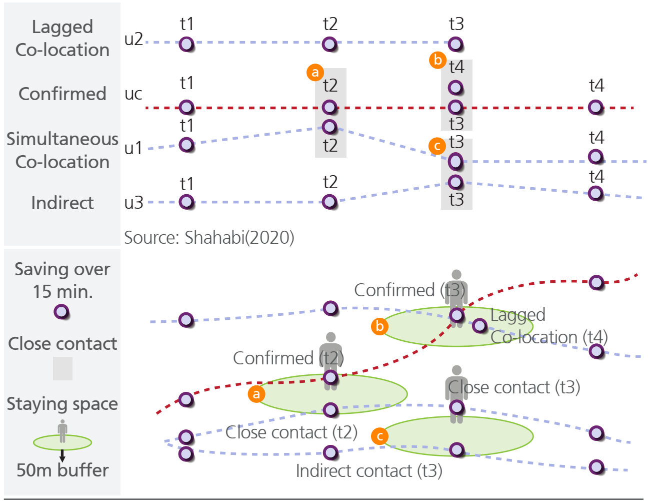
Table 06 Three infection cluster scenarios for simulation

Setting	Simulation Scenario	Analysis
School	(Spread of confirmed cases) Student→ Student/Teacher→Other students→Family	The same area within the time range from 9AM to 4PM of real infection cluster occurred.
Church	(Spread of confirmed cases) Church member→Family and acquaintance	The same area within the time range from 9AM to 3PM of real infection cluster occurred.
Aged care facility	(Spread of confirmed cases) Patients and staff of the facility→Other patients and staff→Family and acquaintance	Tracing the movement of people who stay in the facility all-day

- Identification of close contacts by tracking the movement of the presumed confirmed case 5 days ago
- Specific infectious disease risk areas and hotspot extraction

2.1 The spread of COVID-19 simulations

The KDCA traces the confirmed cases and their close contacts over the previous two days from the time that their symptoms appeared. In the process of close contact identification, , it also investigates their symptoms, mask wearing, and the detail of the exposure such as the contact location and the duration. In the USA and Canada, contact refers to “someone who was within 2 meters of an infected person for at least 15 minutes within a 24-hour period” (CDC, 2021).



Source: Shahabi(2020)

Figure 12 MBD-based close contacts

2.2 Identifying contacts

For simulation purpose, COVID-19 patients are selected randomly based on real infection cluster incidences. Hence, they are called the scenario-based confirmed cases here. By combining the locations of these scenario-based confirmed cases with the contact-based dataset, their locations of stay and visits can be identified. Given the 50-meter accuracy of SKT's data, this identification of close contacts applied for a 50-meter butter zone. Where the scenario- based confirmed cases had stayed for more than 15 minutes are the exposure sites. The locations of their stay and visits over the last five days are used to identify their contacts. The entire process is summarized in Figure 13.

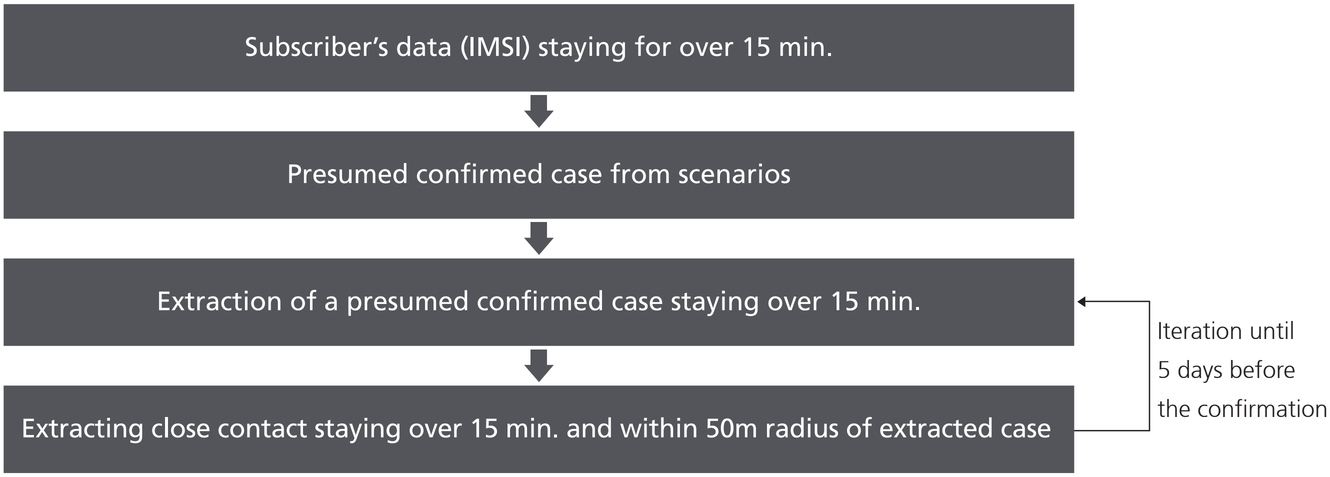


Figure 13 Identifying close contacts by scenario-based confirmed cases

IMSI ID	Longitude	Latitude	Address	Stay start time	Stay end time	Stay (min)
T02+is/JU	126.8577	37.5384	서울특별시 강서구 화곡동 477-1	2021.06.05.00.02	2021.06.05.07.15	433
T02+is/JU	126.8577	37.5384	서울특별시 강서구 화곡동 477-1	2021.06.05.18.01	2021.06.05.20.05	124
T02+is/JU	126.8598	37.5356	서울특별시 강서구 화곡동 814-12	2021.06.05.20.06	2021.06.05.20.38	32
T02+is/JU	126.8577	37.5384	서울특별시 강서구 화곡동 477-1	2021.06.05.20.54	2021.06.05.23.58	184
T02+is/JU	126.8577	37.5384	서울특별시 강서구 화곡동 477-1	2021.06.06.00.03	2021.06.06.10.05	602
T02+is/JU	126.8563	37.5361	서울특별시 강서구 화곡동 493	2021.06.06.10.06	2021.06.06.11.05	59
T02+is/JU	126.8577	37.5384	서울특별시 강서구 화곡동 477-1	2021.06.06.11.14	2021.06.06.11.52	38
T02+is/JU	126.8577	37.5385	서울특별시 강서구 화곡동 477-1	2021.06.06.12.07	2021.06.06.13.37	90
T02+is/JU	126.8396	37.5307	서울특별시 강서구 화곡동 355-64	2021.06.06.14.11	2021.06.06.14.36	25

Figure 14 Examples of exposure sites by scenario-based confirmed cases

With the identification of contacts by the scenario-based confirmed cases, infection risks are measured including

- The number of contacts with the scenario-based confirmed cases within the 50-meter zone for more than 15 minutes
- Duration of contacts with the scenario-based confirmed cases within the 50-meter zone
- The lengths of travel (regardless of contacts with the scenario- based confirmed cases)

The higher number of contacts, and the longer duration of contacts, and the longer travel distance mean higher risks. A real infection cluster case is selected for simulation as a case study. In an aged care center in Gangseog-gu, 24 infections were reported. This aged care center offered services during the daytime only requiring commuting to the center daily (see Figure 15, 16).

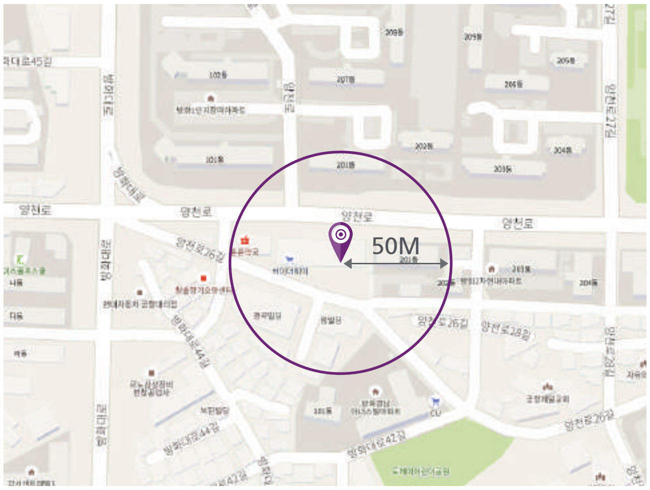


Figure 15 The location of an aged care center for simulation

Location: An aged care center in Gangseo-gu
Features: 24 COVID-19 cases were confirmed on 8 April 2021. Therefore, 24 scenario-based confirmed cases were randomly selected for simulation.

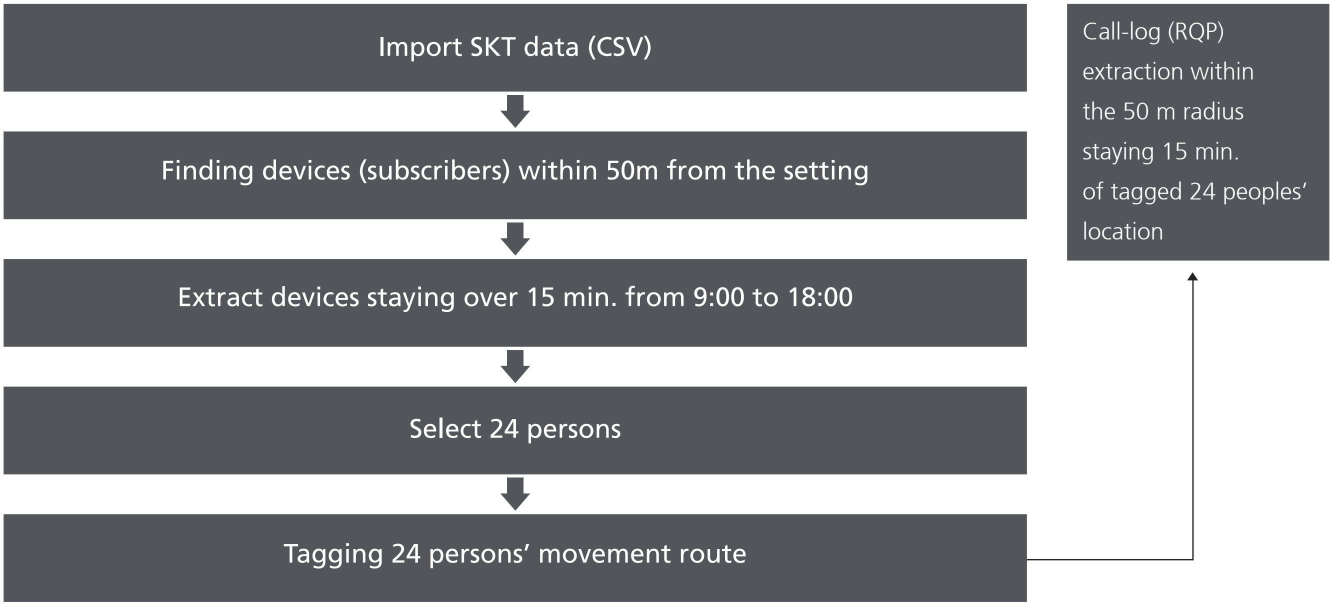


Figure 16 The process of identifying scenario-based confirmed cases and their contacts

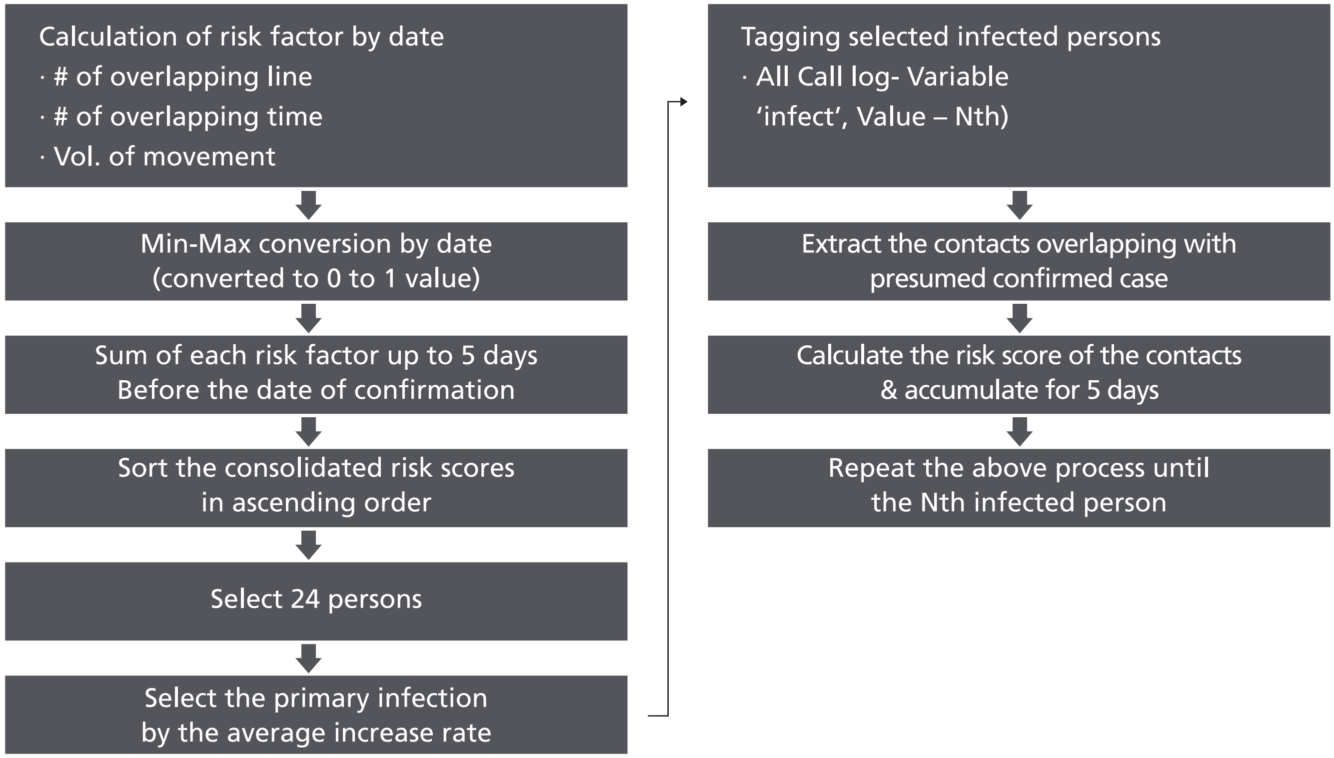


Figure 17 Predicting new confirmed cases

The next step is to measure infection risks by the three measurements: 1) the number of contacts, 2) the duration of contacts, and 3) the total travel distance. Those risks are converted to Min-Max ranging from 0 to 1 daily. Over the five days, those risks are summed to generate the risk index for everyone who had contacts with the scenario-based confirmed cases. Then, the risk index is sorted from the highest to the lowest. By multiplying the average spread rate daily, the total number of infected people is computed. Those selected new cases are presumed to be infectious and their contacts are analyzed repeatedly (see Figure 17).

In the period 4 April 2021 – 8 April 2021, the average COVID-19 spread rate is calculated (see Table 7). By multiplying the average spread rate with the number of confirmed cases on 8 April 2021, new infection is estimated.

Scenario-based confirmed cases (C) are randomly selected for the simulation purpose among those who stayed in the aged care center for more than 15 minutes on 8 April 2021 between 9.00am and 6.00pm. Infected cases (I) are selected from those whose infection risk index is the highest and the calculation repeats 5 times.

Contacts mean those who had stayed with the scenario-based confirmed cases or the infected cases for more than 15 minutes within the 50-meter zone. The infection risk index is a sum of the three measurements: 1) the number of contacts, 2) the duration of contacts, and 3) the total travel distance.

Where UE_No is the handset ID, x and y are coordinates, time is the start of the contact and end_time is the end time of the contact, STAY is the duration of stay in minutes, infect is one if they are predicted to be infectious, and contact_risk_day refers to the infection risk index.

Those groups are visualized on a map (Figures 19-21). Simulations are performed based on three scenarios - (1) an aged care center, (2) a church, and (3) a school, which enables to identify contacts of (scenario-based) confirmed cases and their close contacts. The aged care center was not stand-alone but a mixed-use building including apartments and shops. There were 476 close contacts per one (scenario-based) confirmed case for five days. In the scenario of the church cluster, the number of contacts increased on Sunday. There were 438 close contacts per (scenario-based) confirmed case. The school had a smaller number of close contacts than the aged care center and the church.

Table 07 Estimating the average spread rate

Date	The number of COVID-19 confirmed case	Increasing rate	Average spread rate
2021-04-04	473		
2021-04-05	478	1.011	
2021-04-06	668	1.397	
2021-04-07	700	1.048	
2021-04-08	671	0.959	1.104

IMSI ID	Longitude	Latitude	Stay start time	Stay end time	Stay (min)
T02+is/JU	126.8577	37.5384	2021.06.05.00.02	2021.06.05.07.15	433
T02+is/JU	126.8577	37.5384	2021.06.05.18.01	2021.06.05.20.05	124
T02+is/JU	126.8598	37.5356	2021.06.05.20.06	2021.06.05.20.38	32
T02+is/JU	126.8577	37.5384	2021.06.05.20.54	2021.06.05.23.58	184
T02+is/JU	126.8577	37.5384	2021.06.06.00.03	2021.06.06.10.05	602
T02+is/JU	126.8563	37.5361	2021.06.06.10.06	2021.06.06.11.05	59
T02+is/JU	126.8577	37.5384	2021.06.06.11.14	2021.06.06.11.52	38
T02+is/JU	126.8577	37.5385	2021.06.06.12.07	2021.06.06.13.37	90
T02+is/JU	126.8396	37.5307	2021.06.06.14.11	2021.06.06.14.36	25

+

Infection risk index
0.188
0.296
0.337
0.527
0.758
0.904
1.01
1.129
1.22

Figure 18 Infection risks

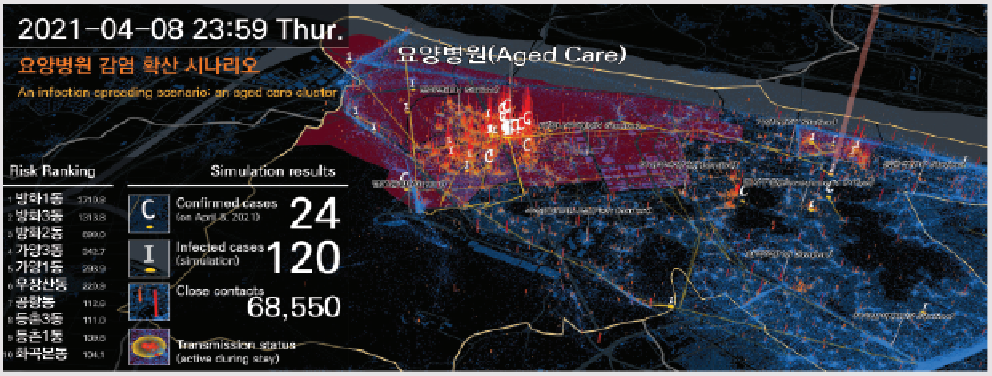


Figure 19 Virus spread simulation of an aged care center (24 confirmed cases on 8 April 2021, Thursday)
Note: For full simulation see, YouTube https://bit.ly/3B70FVP

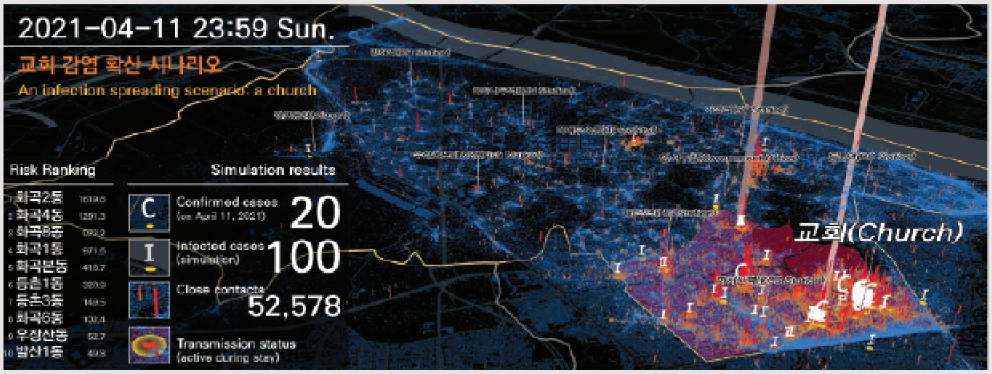


Figure 20 Virus spread simulation of a church (20 confirmed cases on 11 April 2021, Sunday)
Note: For full simulation, see YouTube https://bit.ly/3pDJjxN

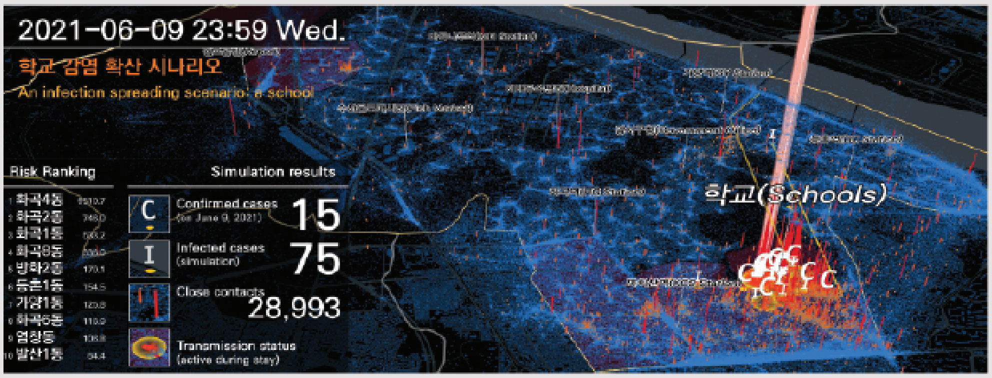


Figure 21 Virus spread simulation of a school (15 confirmed cases on 9 June 2021, Wednesday)
Note: For full simulation, see YouTube https://bit.ly/3jur0r5

Where,
C: (Scenario-based) confirmed cases
I: Infected cases conjectured by the movements of confirmed cases
Red bar: the number of contacts showing the level of risks (accumulated value for five days prior to the confirmed date)
Yellow lines: estimated movement routes of Is and Cs.
Close contacts: Contacts of Cs and Is for more than 15 minutes within 50 meters

2.3 Policy implications

Current South Korean contact tracing is carried out by questionnaire surveys and interviews by epidemiological investigators. Those new patients rely on their memory when filling in the questionnaire and answering the investigator. Check-ins with QR codes, thus, are used to support this contact tracing process. However, with high numbers of daily confirmed cases, this manual approach faces difficulty given the limited number of epidemiological investigators. The proposed approach by using MBD can be a useful tool to enhance the quality of contact tracing. The MBD approach even allows longer time horizons more than two days depending on the infected timing. This approach also offers an opportunity to warn people with high infection risks by sending a text message and asking for a PCR test.

3. Analysis II: Simulations for the spread of infectious disease and non-pharmaceutical intervention

This section analyses the effect of social distancing measures on mobility. Strict social distancing measures such as non-social gatherings over 5 people were implemented during the third wave to mitigate the spread of the virus(see Figure 22). The analysis here is to support public decisions on social distancing in a timely manner when there is a growing trend in infectious disease. The analysis focuses on the effect of non-social gathering measures on mobility among other non-pharmaceutical intervention approaches.

3.1 O-D traffic volume dataset

There had been varying trends in the spread of COVID-19 by three municipalities of Seoul as seen in Figure 23. There were differences in the timing, pace, and size of the spread. To reflect these local differences, analyses are performed by the municipality.

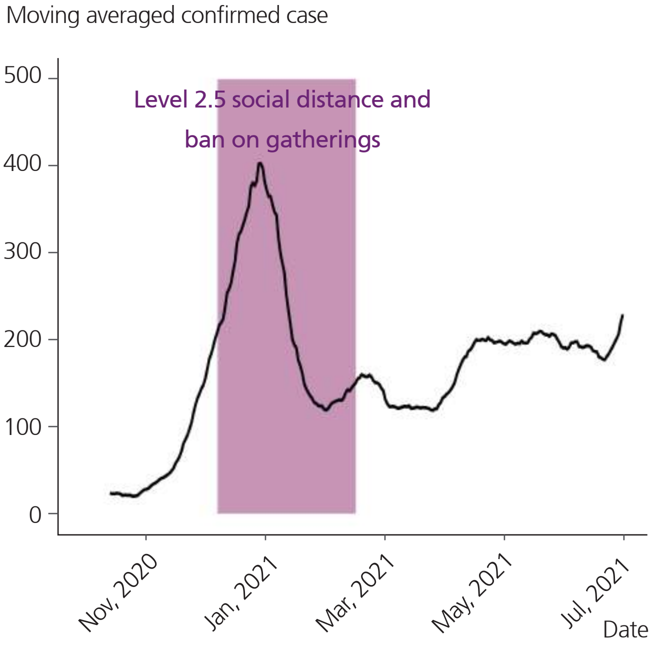


Figure 22 The spread of COVID-19 and social distancing measures (phase 2.5): social gathering capped at 5 people
Note: 14-day moving average

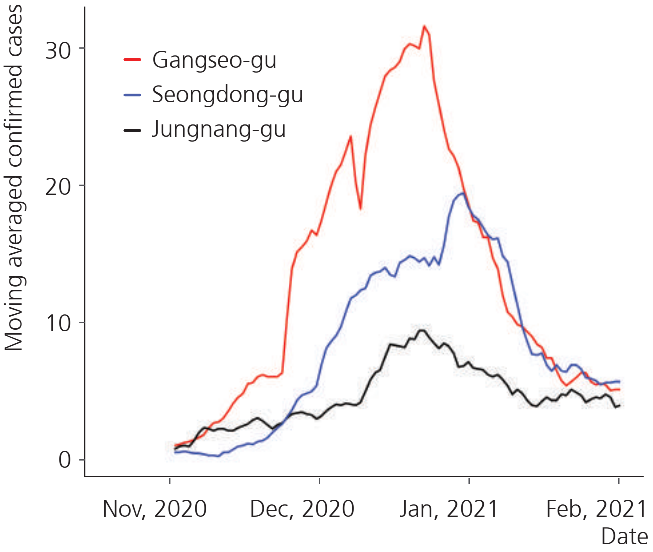


Figure 23 Trends of the virus spread in three municipalities: Gangseo-gu, Seongdong-gu, and Joongrang-gu
Note: 14-day moving average

The model reflects the differences between intra-city infection and inter-city infection to analyze the effect based on the O-D table that expresses inter-urban mobility (Figure 24). The O-D dataset shows distinctive features of each municipality as seen in correlation with neighboring municipalities (Figure 25).

3.2 Modelling for the spread of COVD-19

In all municipalities of Seoul, S, E, I, R groups are defined.

$$N_{c_i} = S_{c_i}^{(t)} + E_{c_i}^{(t)} + I_{c_i}^{(t)} + R_{c_i}^{(t)}$$

Where N is a total population, and S, E, I, and R denote susceptible, exposed, infectious, and recovered residents, respectively.

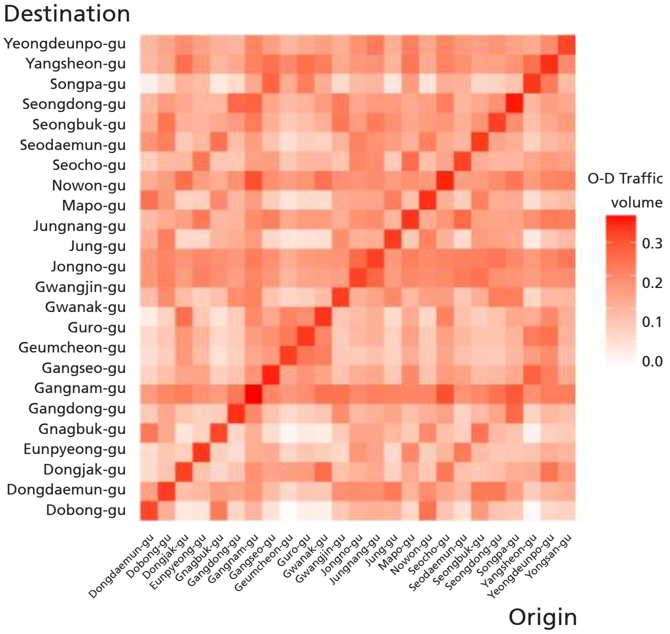


Figure 24 A heat map of traffic volume by O-D data

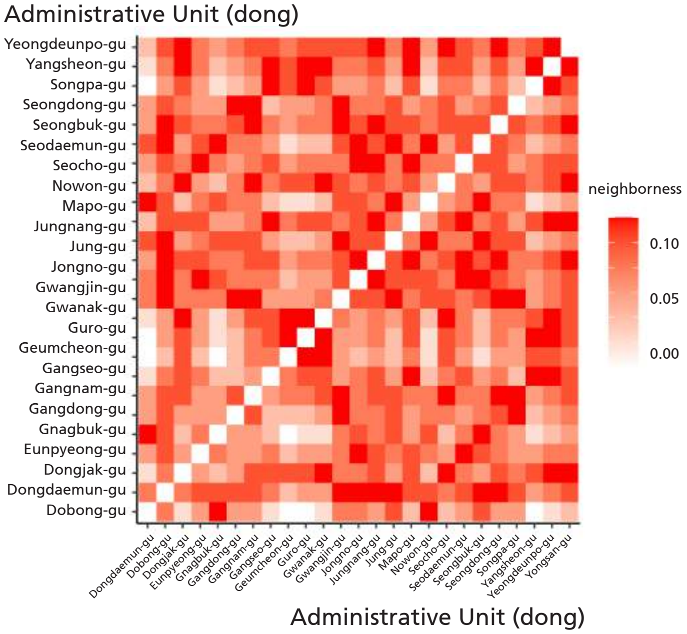


Figure 25 Geographical correlation by neighborness

Then, susceptible residents are specified by

$$S_{c_i}^{(t)} = N_{c_i} - E_{c_i}^{(t)} - I_{c_i}^{(t)} - R_{c_i}^{(t)}$$

This is computed in all 25 municipalities of Seoul. $w_{ij}^{(t)}$ refers to travel volume from municipality i to municipality j. The same incubation period δ_E and the recovery period δ_I are applied to all municipalities with reference to Kondo (2021).
Mobility had decreased by 30% after the social distancing measure was implemented as seen in the change in total travel volume (the first and the third red lines in Figure 26). Hence, the spreading trend is simulated assuming there was a 30% decrease in mobility, which is reflected by multiplying 0.7 with $w_{ij}^{(t)}$. Additionally, the non-social gathering is reflected into an adjustment coefficient α by multiplying 0.8 (see the blue line in Figure 27).

The details of the data used for simulation is as follows:

- Before social distancing measures from 1 November 2020 to 7 December 2020
- During the social distancing measures from 8 December 2020 to 24 December 2020
- Tests of the prediction with data after April 2021

The results of the simulations are presented in Figure 27 showing the new confirmed cases would be lower if social distancing measures were in place as seen in blue and green lines in comparison with red lines.

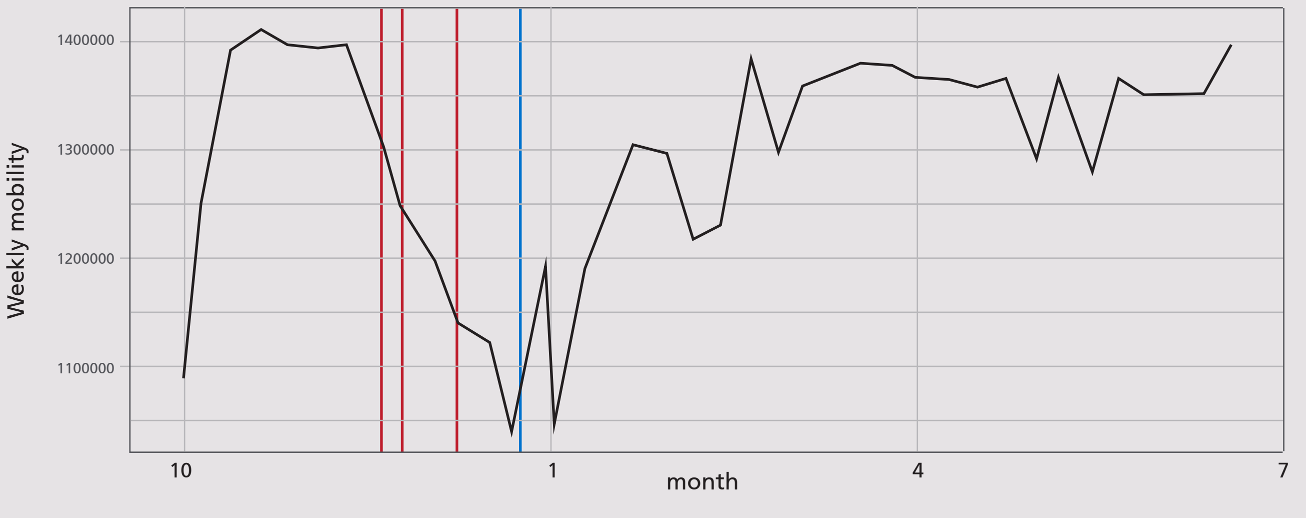
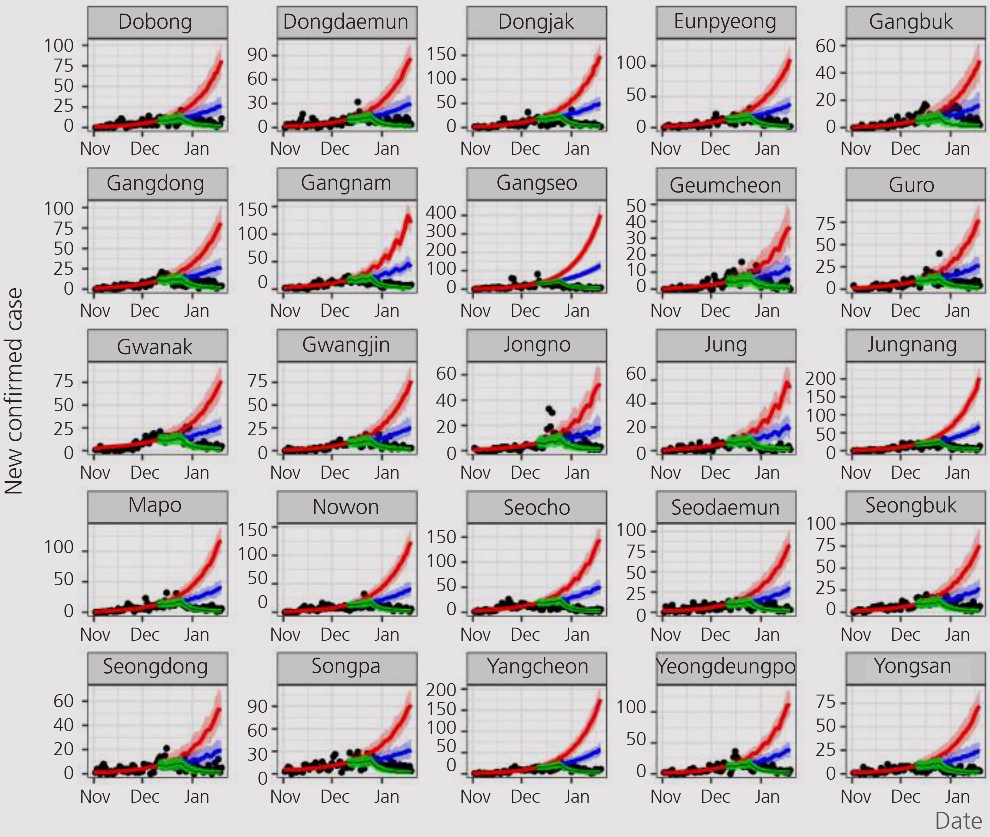


Figure 26 Changes in mobility and social distancing measures



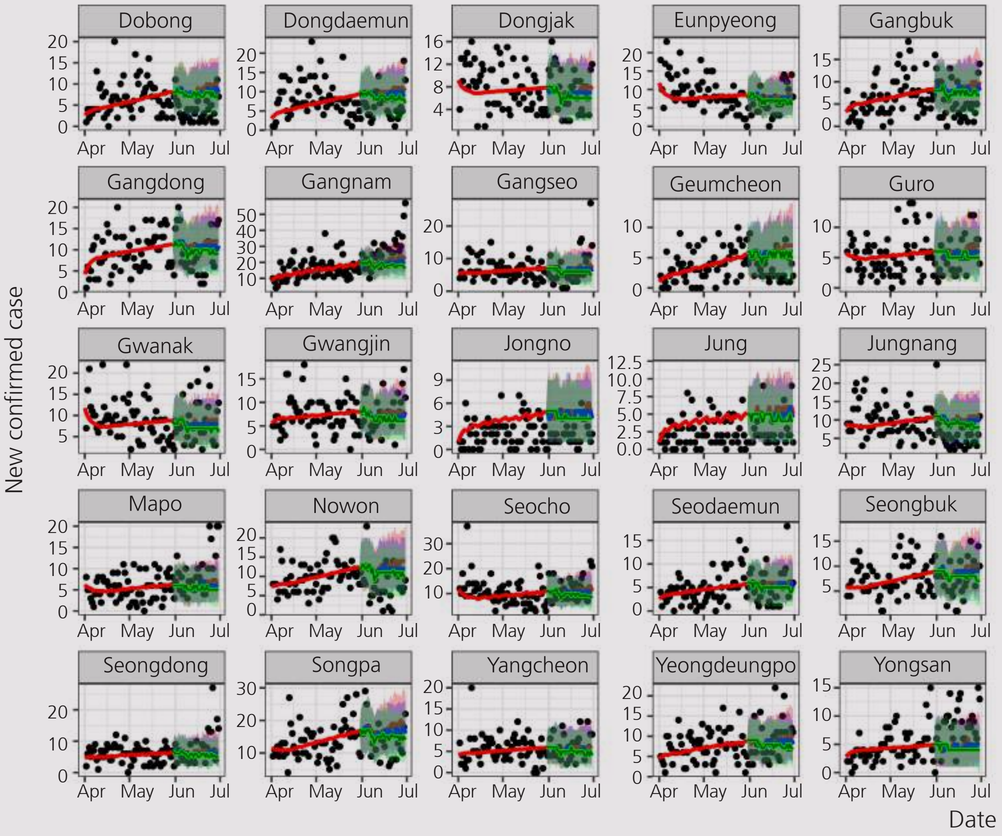
Note: Red lines are without social distancing measures; blue lines are when social distancing measures (at phase 2.5) were implemented; and green lines are when both social distancing measures (at phase 2.5) and non-social gathering over 5 people were implemented. Those effects are more obvious where there are more retail shops and restaurants such as Seocho-gu.

Figure 27 Mobility SEIR simulation results

Table 8 presents the Root-Mean-Square Error (RMSE) of the prediction results. The models with social distancing measures have better prediction power as seen in the RMSE.

Table 08 The prediction result of the SEIR model

Type of non-pharmaceutical interventions	RMSE
None	103.212
Social distancing measures (30% mobility decrease) Social distancing measures plus.	35.931
Non-social gathering (30% mobility decrease plus. shop adjustment coefficient 0.2)	5.018



Note: red lines denote the current vaccination rates, blue lines if the vaccination rates are 5-times higher, and blue lines if the vaccination rates are 10-times higher.

Figure 28 Test results of mobility+SEIR model simulation

3.3 Test of the model

Those predicted results are tested by data after April 2021. The social distancing measure was relaxed to phase 2.0 from 15 February 2021 while continuing non-social gathering capped at five people. Hence, usual mobility ($w_{ij}^{(t)}$) is used and 0.8 is applied to the retail shop adjustment coefficient, for the tests. In addition, the effect of COVID-19 vaccine is also reflected in Figure 28 as the vaccine started from late February 2021. As seen in Figure 28, the model shows a good fit with the real confirmed cases.

As vaccination rates are not different across Seoul, the effect of vaccination is simulated in entire Seoul (see Figure 29). As of 30 June 2021, new confirmed cases are presumed to continue at 240 a day. However, with the 5-times higher vaccination rates, the daily new cases can decrease to 210. With the 10-times higher vaccination rates, it can be decreased to 174. In this simulation model, an 100% increase in vaccination rate leads to a decrease of the daily new cases by 6.

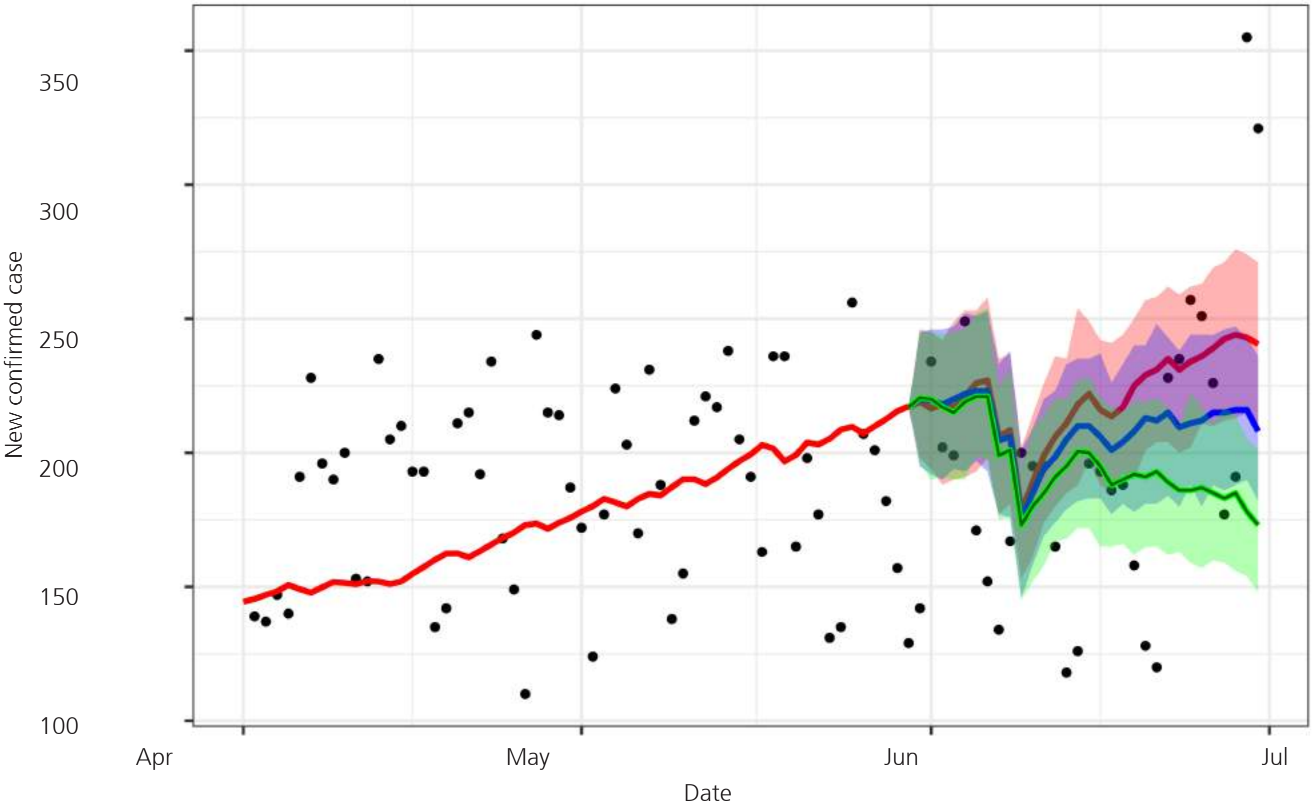


Figure 29 Simulation: the effect of vaccination in Seoul

4. Analysis III: The effects of real-time information through text messages

4.1 Introduction

One of the South Korean approaches was to provide updated information promptly through mobile phone text messages including the outbreak and locations. This section analyzes how effective were text messages in encouraging citizens to do social distancing by MBD. If effective, it investigates the demographic cohorts who better responded to the information from the text messages. In addition, it discovers which information was effective in the text messages.

There have been scholarly efforts to investigate the effectiveness of information delivery through disaster alert messages and the SNS in multiple disciplines including public health and economics. Azizi et al. (2020)

have investigated the process of spreading information about the virus between individuals with reference to a network theory. They pointed out it was an important policy agenda to figure out how to provide information to vulnerable groups to the infection. Mendolia et al. (2021) estimated the effect of information delivery about regional confirmed cases analyzing Google Human Mobility data. They concluded that approximately 15% of the reduction in mobility was attributable to information transfer during the pandemic while the rest was a direct outcome of social distancing measures implemented by the government. Banerjee et al. (2020) conducted a large-scale experiment with 25 million people in India. A 2.5-minute video message from Professor Banerjee, who was a Nobel Prize awardee, was randomly sent, which resulted in a higher level of compliance for social distancing, and the information was voluntarily shared in their local communities. This result demonstrated simple information transfer could lead to changes in actions as stressed in the nudge theory in behavioral economics. However, Garpin et al. (2020) alerted excessive information exposure can cause another public health threat such as anxiety. This research implies the significance of the ways and the frequency of information delivery.

4.2 Disaster alert text messages about COVID-19

Text messages about COVID-19 are pre-processed for text data mining. Text messages are unstandardized data that requires transformation into figures for analysis. Details about the text messages used for analysis are presented below:

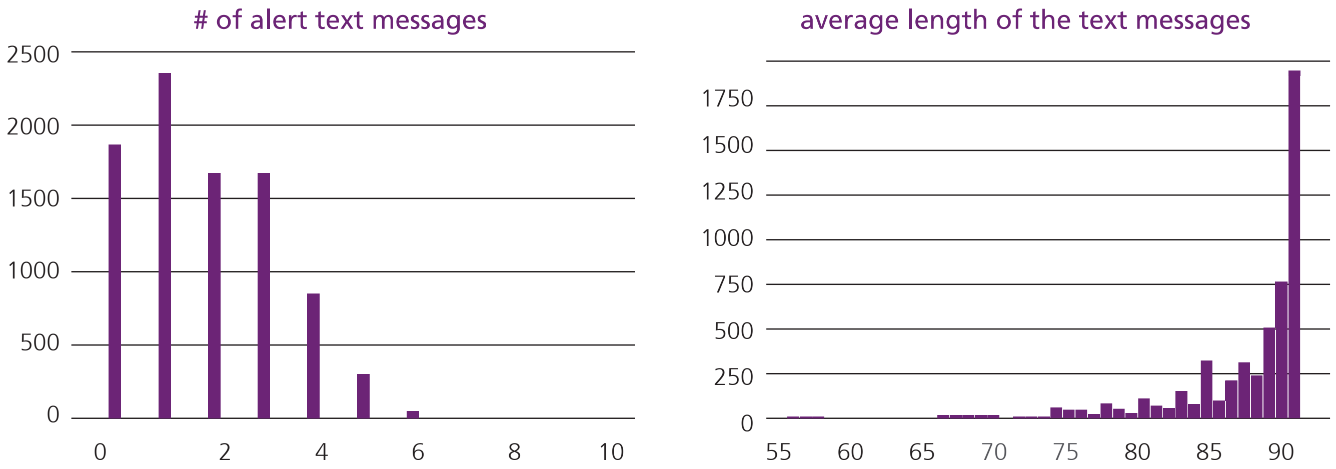
- Source: Disaster text message API from the Public Data Portal
- Data: from 1 January 2020 to 9 November 2020
- Scope of data: All text messages sent by the Seoul Metropolitan Government

	dat	rgn	cnt	len	doc
0	2020-01-23	137	1	91	[행정안전부] 신종코로나바이러스감염증 예방을 위해 손씻기, 기침예절, 마스크착용 ...
1	2020-01-24	137	0	0	
2	2020-01-25	137	0	0	
3	2020-01-26	137	0	0	
4	2020-01-27	137	1	86	[서울시] 신종코로나바이러스감염증 예방을 위해 마스크착용, 손 씻기 등 수칙을 준수하...
...	...	...	...	...	...
7295	2020-11-05	161	1	91	[중대본] 마스크착용이 11.13일부터 의무화 됩니다. ▲코와 입 완전 덮기 ▲만...
7296	2020-11-06	161	1	91	[중대본] 모임에서 식사시간은 코로나 전파위험이 매우 높을때 입니다. “먹고 마실땐 말...
7297	2020-11-07	161	1	91	[중대본] 산행·운동 모임에서 집단감염이 발생하고 있습니다. ▲마스크 상시착용 ▲신...
7298	2020-11-08	161	1	62	[중대본] 주말 종교활동 시 마스크 착용, 출입자 관리, 거리두기와 함께 방역수칙...
7299	2020-11-09	161	1	91	[중대본] 많은 사람이 방문하는 다중이용시설에서는 감염위험이 높습니다. 시설·업소를 ...

Figure 30 Examples of text messages

Table 09 Descriptive statistics of COVID-19 alert text messages

	The number of text messages a day	The length of the message
Average	1.947	87.545
Median	2.0	89.5


# of alert text messages

average length of the text messages

Figure 31 Key features of COVID-19 alert text messages

The unit of analysis is a text message sent by the municipality daily. The total observations become 7,300 (= 292 days x 25 municipalities).

The descriptive statistics are presented in Table 9 and graphed in Figure 31. Figure 32 visualizes the number of COVID-19 alert text messages sent by 25 municipalities. The lighter color was, the more text messages were.

Then, the text messages went through stemming, a process to generalize different words within the text based on pre-defined rules. This process used the KKMA tool developed by the Intelligent Data Systems. Most words were identified through this tool. Stemming was applied only to nouns (in Korean).

The Term Frequency-Inverse Document Frequency (TF-IDF) is a way to analyze the importance of search outcomes and the similarity of documents on search engines. Different weights are applied to each word to remove rarely used words and frequently used words. TF(d,t) means the number of a word 't' appeared in a document 'd'. IDF(t) is an inverse frequency of the document with the word 't'.
TF-IDF(d,t) = TF(d,t) x IDF(t)
Frequent words make IDF smaller and rare words make TF smaller. Important information has a high TF-IDF value. By the TF-IDF, COVID-19 text messages can be digitized in a matrix as seen in Figure 33.
While mean TF-IDF(w) depicts general information, max TF-IDF(w) shows specific information such as hotspots and infection chains.

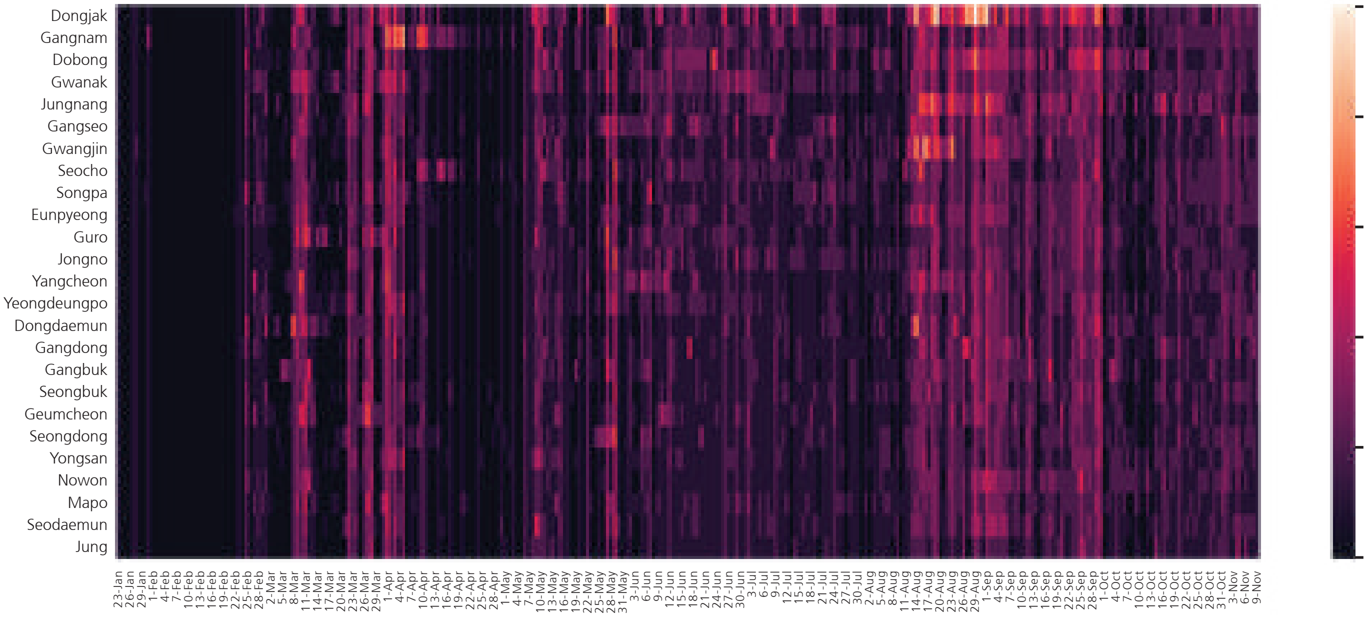
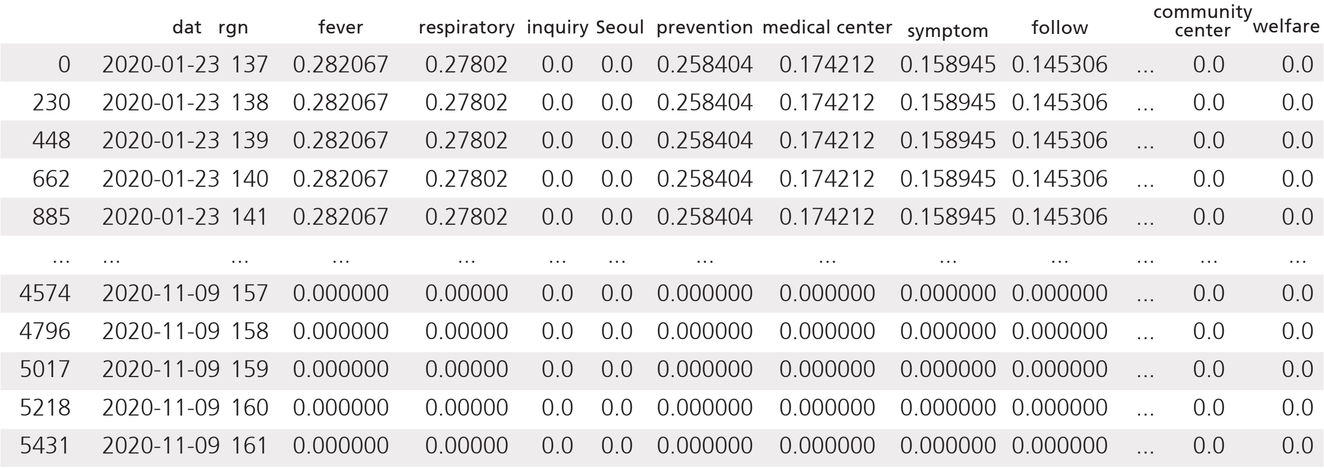


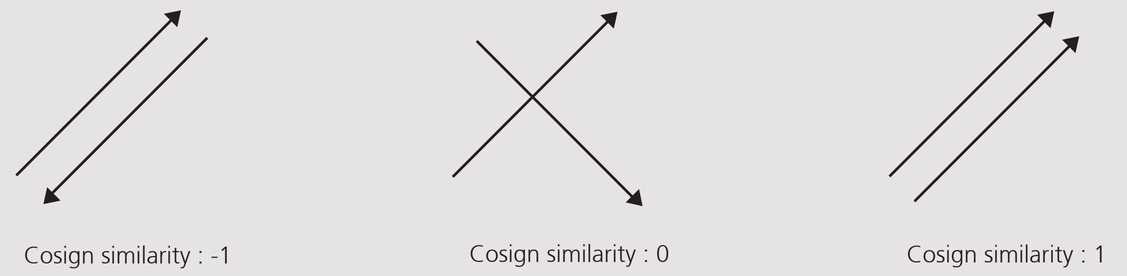
Figure 32 A heatmap of text messages sent by the municipality



	dat	rgn	fever	respiratory	inquiry	Seoul	prevention	medical center	symptom	follow		community center	welfare
0	2020-01-23	137	0.282067	0.27802	0.0	0.0	0.258404	0.174212	0.158945	0.145306	...	0.0	0.0
230	2020-01-23	138	0.282067	0.27802	0.0	0.0	0.258404	0.174212	0.158945	0.145306	...	0.0	0.0
448	2020-01-23	139	0.282067	0.27802	0.0	0.0	0.258404	0.174212	0.158945	0.145306	...	0.0	0.0
662	2020-01-23	140	0.282067	0.27802	0.0	0.0	0.258404	0.174212	0.158945	0.145306	...	0.0	0.0
885	2020-01-23	141	0.282067	0.27802	0.0	0.0	0.258404	0.174212	0.158945	0.145306	...	0.0	0.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...
4574	2020-11-09	157	0.000000	0.00000	0.0	0.0	0.000000	0.000000	0.000000	0.000000	...	0.0	0.0
4796	2020-11-09	158	0.000000	0.00000	0.0	0.0	0.000000	0.000000	0.000000	0.000000	...	0.0	0.0
5017	2020-11-09	159	0.000000	0.00000	0.0	0.0	0.000000	0.000000	0.000000	0.000000	...	0.0	0.0
5218	2020-11-09	160	0.000000	0.00000	0.0	0.0	0.000000	0.000000	0.000000	0.000000	...	0.0	0.0
5431	2020-11-09	161	0.000000	0.00000	0.0	0.0	0.000000	0.000000	0.000000	0.000000	...	0.0	0.0

Figure 33 Digitized text messages by TF-IDF

With the digitized text message matrix, the cosine similarity (cossim) can be computed by measuring the distance between the two vectors of text messages. The cosine similarity provides both time-specific information (novelty) and location-specific information (remoteness) (see Figure 34).



Definition of cosign similarity between vector A and B.

$$\mathrm{cossim}(A, B) = \frac{A - B}{\|A\| - \|B\|} = \frac{\sum_{i=1}^{n} A_i \times B_i}{\sqrt{\sum_{i=1}^{n} (A_i)^2} \times \sqrt{\sum_{i=1}^{n} (B_i)^2}}$$

Figure 34 Cosine similarity

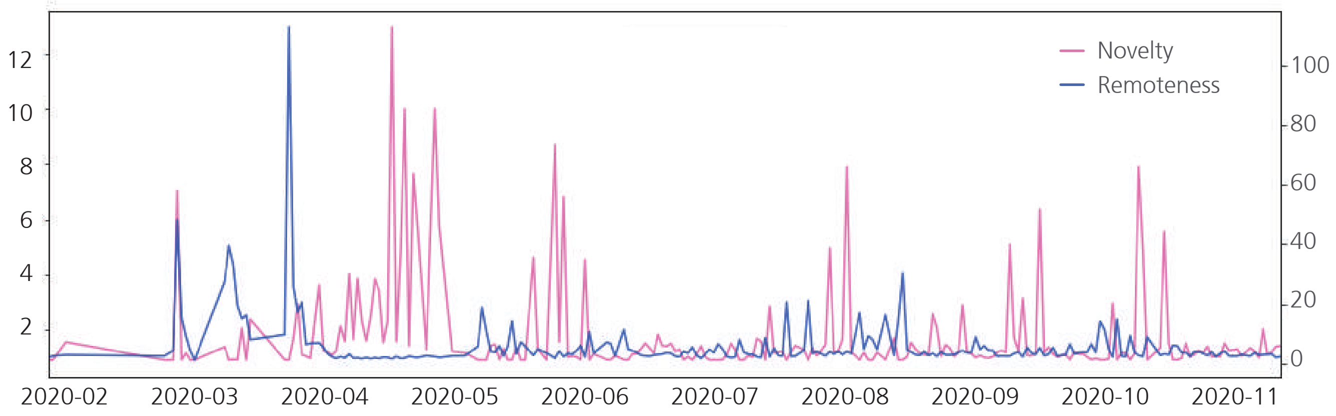


Figure 35 Trends of novelty and remoteness in text messages sent by Gangnam-gu

These two measurements are graphed with Gangnam-gu (Figure 35). The remoteness indicator was high in mid-April 2020. Along with a high number of text messages, information became specific.

A difference-in-differences event study (DID) is employed to analyze the effect of COVID-19 text messages. The DID is an econometric tool in evaluating the effects of the pre- and post-treatment periods. Here the dependent variable is mobility expressed with the number of people comparing the pre-text and the post-text message.

$$Y_{j,t} = \alpha_j + \tau_t + \sum_{k \neq -1} \delta_k \mathbb{I}\{t - E_j = k\} + \varepsilon_{j,t}$$

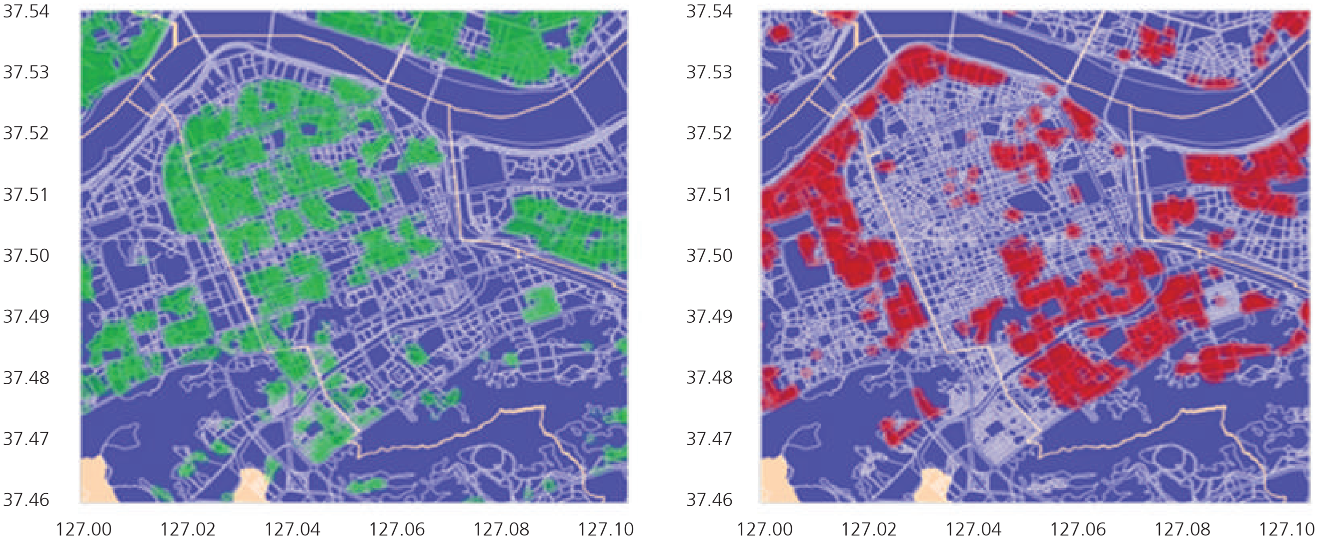
Where α is a fixed effect of municipalities, τ is a fixed effect of time, and ε is an error term.

This modeling is to test the question “Did the number of people (or handsets) decrease after the COVID-19 alert text message?”

To count on the number of people outside the home, the location of MBD and land-use data are combined (Figure 36).

General residential area

High-rise residential area



Commercial business district

Road

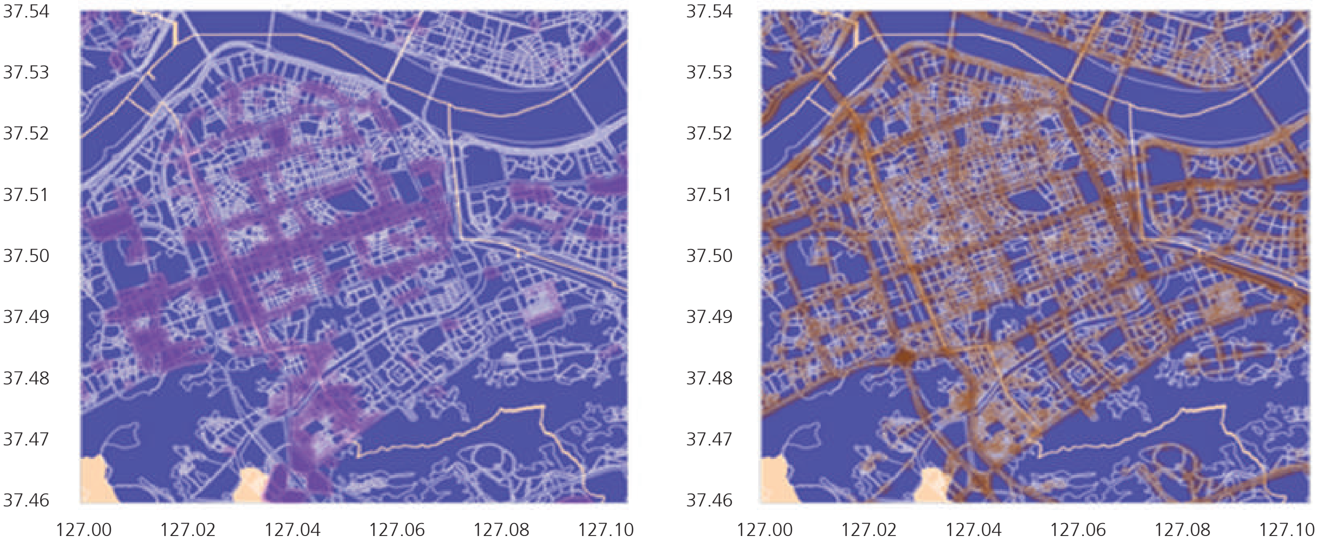


Figure 36 Locations of handsets by land-use

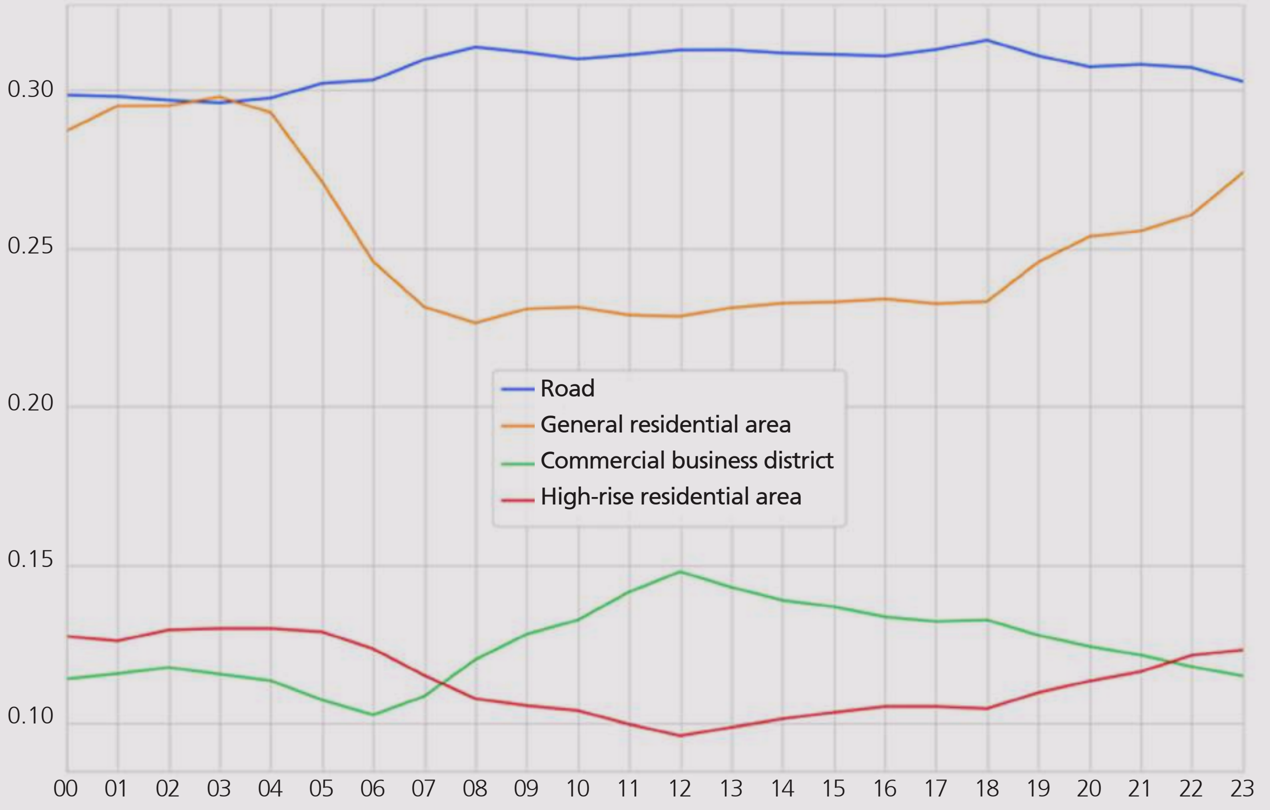


Figure 37 The trends of handsets by land use (%)

The location of handsets is categorized into four land-uses: (1) road, (2) residential area, (3) high-rise residential area, and (4) commercial use.

Figure 37 confirms the trend that the number of handsets decreases during the daytime in residential areas, while it increases on the roads and in commercial zones. The handset data by land use is combined with the COVID-19 text message data.

The DID analysis should follow the following assumptions. These assumptions are visualized in Figure 38.

- There should be a control group and an experiment group in text messages. The former should receive the text message while the latter should not.
- The common trend assumption should hold meaning the trend pre-treatment and post-treatment should be consistent.

Table 10 Data matching

Common Index		KT data	
Variable	Meaning	Variable	Meaning
rgn	Municipality (gu)	ucb	Land use zoning
date	Date	sex	Sex
tm	Time	age	Age
		mob	Real-time population
Disaster alert text message data			
Variable	meaning	Variable	meaning
cnt	The number of words	len	The length of text
demo	Demographic information	Path	Path of patient information
webp	Webpage information	mass	Cluster information
novel	Time-specificity	remote	Region-specificity

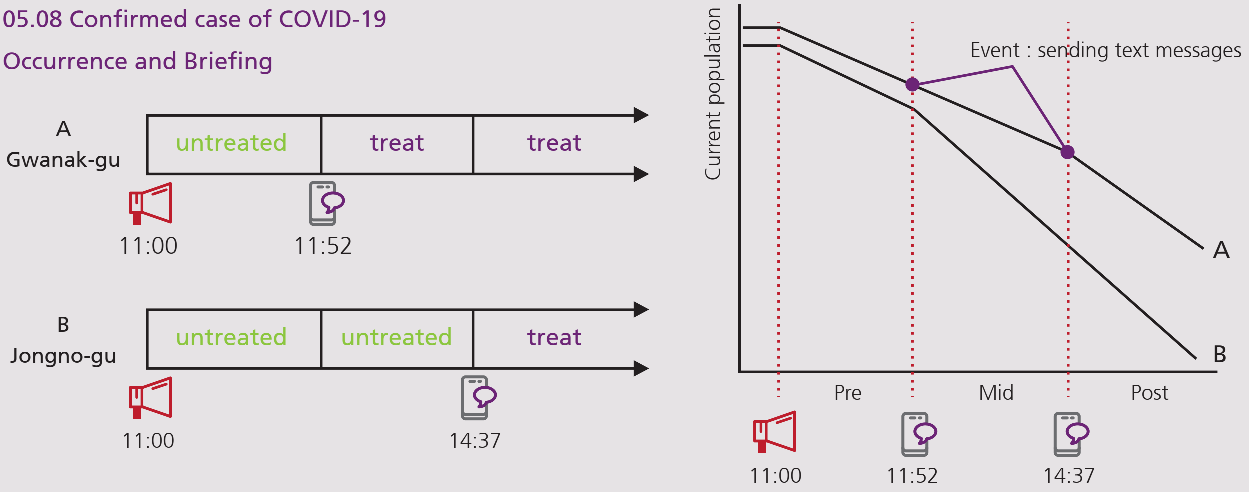


Figure 38 A diagram for DID estimation

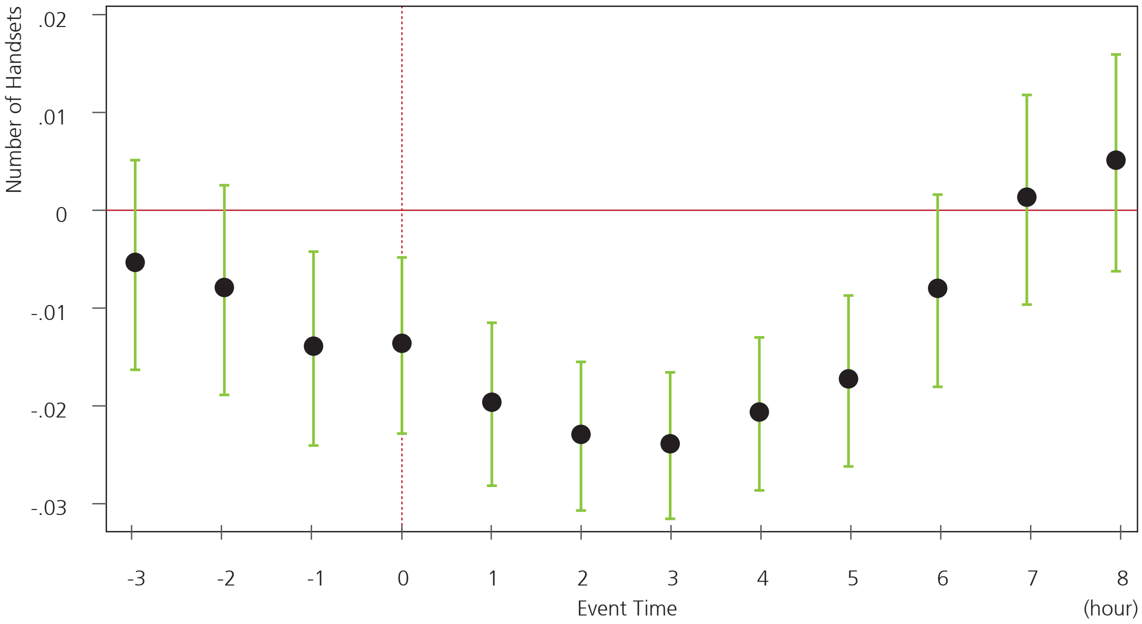


Figure 39 The DID estimation

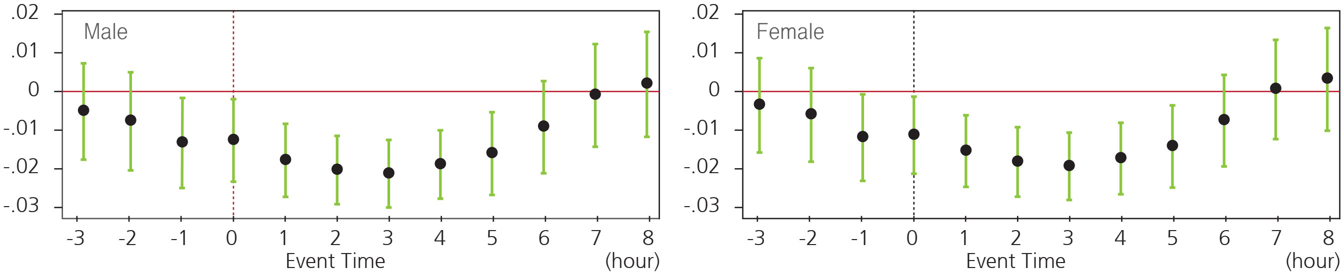


Figure 40 The DID estimation result by gender

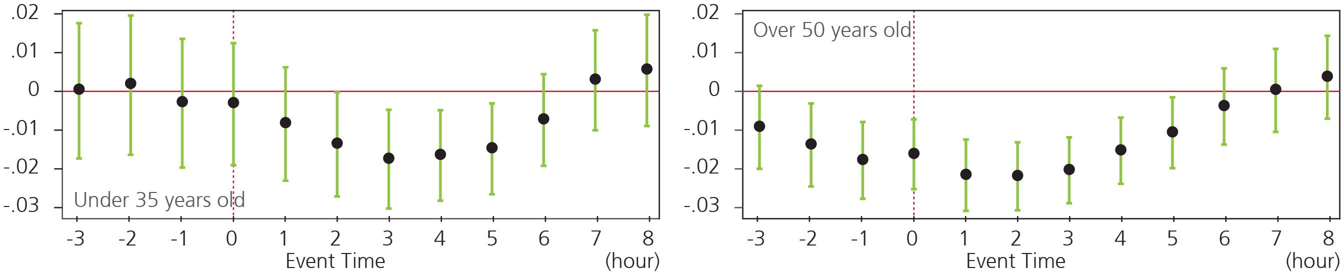


Figure 41 The DID estimation result by age group

Figure 39 is the result of the DID estimation. The vertical axis is the estimated coefficient showing the number of handsets while the horizontal axis is the time in hours after a text message is sent. The vertical green lines are the 95% confidence interval and the black dots in the middle are the estimated coefficients. The result statistically reveals that text messages have reduced the number of handsets outside residential areas for approximately 6 hours. Those text messages decreased the number of handsets by up to 2%. In addition, it was observed that the mobility was decreased 1-2 hours prior to the text messages because those text messages were not the unique source of information. Some people received the same information from another source.

As seen in Figure 40, there was only a marginal difference between males and females in responding to the COVID-19 alert text messages. However, it was clear that older groups responded to the text messages more actively than younger groups (Figure 41). Once the text message was received, the under 35-age group responded, but the over-50 age group decreased their mobility 3 hours before the text message. They may have received the COVID-19 alert information from news and other sources before the text message.

The text message with repeated information did not make any change in mobility. However, information within the text message generated different outcomes in mobility changes (Figure 42). Specific information about hotspots and clusters decreased mobility by almost 10%. The text messages with demographic information about the new confirmed cases did not decrease mobility. New and specific information was effective in reducing mobility as seen in novelty.

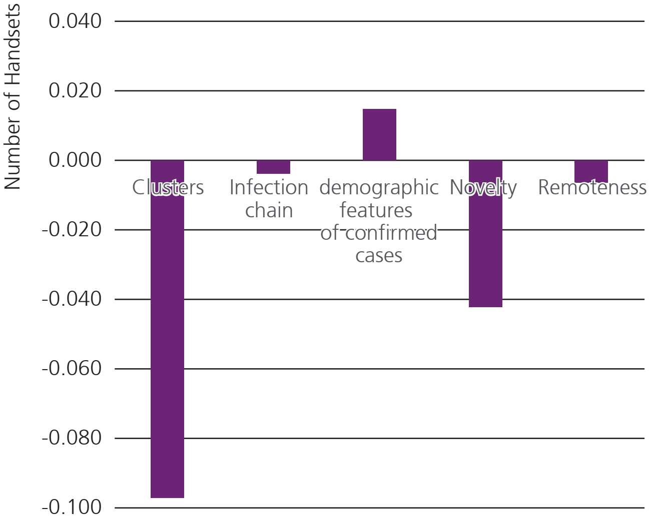


Figure 42 The effect of information within COVID-19 text messages

COVID-19 PCR test at the Sangam World Cup Stadium in Seoul (c) Hyungwoong Chang, December 2021

Chapter 4.
Epidemiologically smart city management

1. Implications of simulations on urban management
2 Epidemiological management in smart cities

1. Implications of simulations on urban management

As analyzed in this report, South Korea has built up the capability to generate, collect, synthesize, and analyze real-time data through automated analysis systems and visualization for policy practitioners and decision-makers in the public health department. Those analysis tools can be incorporated with the Decision Support System (DSS) that can analyze tailored data in each phase for decision- makers and epidemiological investigators beyond collecting, storing, and distributing data. The contact-based dataset and the O-D matrices are examples that can be included in the DSS. In this report, MBD is from SKT for O-D tables or KT for text message analysis, but integrated data including other telecommunication companies, such as LG UPLUS, will strengthen the reliability of this approach. There have been suggestions to make use of MBD for the DSS in other countries as well (Ghayvat et al., 2021).

The DSS based on MBD can identify exposure sites and close contacts of the confirmed cases without delays. Once a new confirmed case is reported, the MBD can sort out the locations that the new case had stayed for more than 15 minutes. A warning text message can be sent only to the targeted mobile phone holders who stayed with the new case within 50 meters for more than 15 minutes. With the visualization of hotspots through the simulation of the virus spread, the DSS can be used for virus control at an early stage. The current epidemiological investigation includes a possibility for delays in necessary data collection for initial responses and, therefore, the containment of the virus at an early stage is difficult. Manual check-ins and interviews based on memory are extremely time-consuming. The delays of the epidemiological investigation result in further outbreaks and increases in mystery cases. Then, social distancing measures are tightened for virus containment, which worsens the level of stress and financial losses. The MBD-embedded DSS can reduce the time for epidemiological investigation from the current pace of 4-5 days to one day.

Due to the automatically stored data, contact tracing can trace back to 14 days. In addition, the COVID-19 alert text messages can enhance the reliability because these messages are sent only to those who had stayed within 50 meters from the confirmed case. From the findings of this research, alert text messages are effective when they contain new and specific information. Numerous repeated text messages may fail to attract attention from the receivers. The finding also points to the timely lagged text messages behind other news media sources. The MBD-embedded DSS will enable the alert text messages to be sent promptly once risks are identified.

The epidemiological smart city management may draw on all available sources including MBD, SNS, transport cards, credit cards, CCTVs, and other sensors after anonymizing the data. These data can be used in various ways including simulations for the virus spread and alert text messages. The management model should be established in metro- politan areas, such as Seoul, where there are high risks.

The metropolitan areas are the center for the virus spread as well as the most strategic location for virus containment. The metropolitan areas have more decent housing, infrastructure, social and medical services than other areas (Neiderud, 2015). In all phases from preparation, the government system should closely work together with urban and regional planners for the

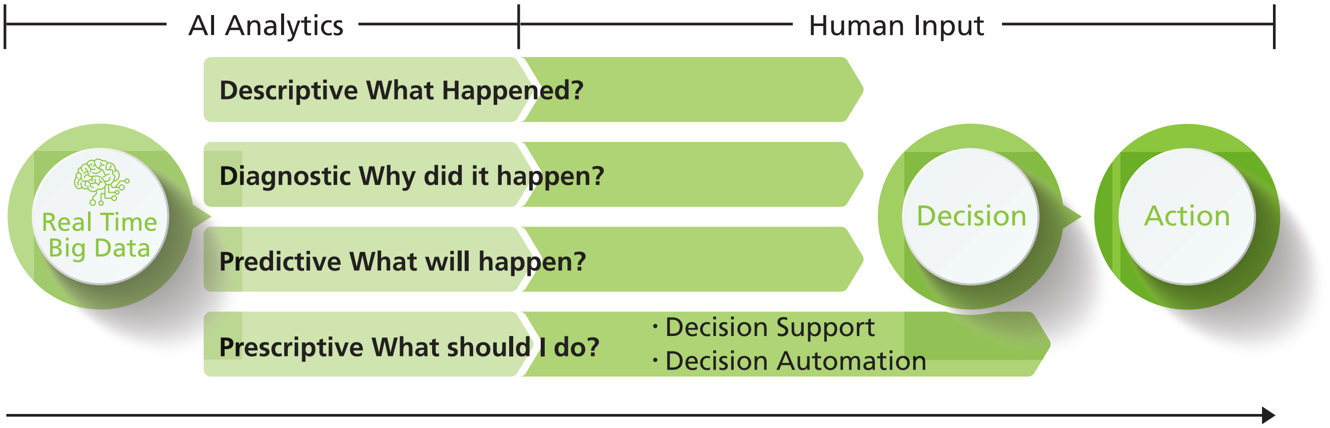


Figure 43 Real-time planning and decision makings by big data

Source: Al Nuaimi et al. (2015) and Sung (2016, 2020)

comprehensive control of the virus (Matthew and McDonald, 2006). In addition, MBD can be integrated with the management system as a critical source of information (see Figure 43).

In the phase of the outbreak and the spread, the use of ICT is of significance. Early alerts, accurate information about the location and the chains of the outbreak, and the responses to them play an important role in mitigating anxiety. The fear from unsourced information can spread causing behavioral biases, socio-economic costs, and social discrimination. The integrated mobile platform can provide accurate information directly to the citizens by which unnecessary social costs and chaos can be mitigated. Until most citizens are fully vaccinated, non-pharmaceutical interventions may be required for which the early alert system should be established. In times of infectious disease threats, the capacity of planning, design, and management for defensible cities should be strengthened (Sung, 2020).

Infectious diseases, such as COVID-19, are worsened in high-density environments where frequent contacts are inevitable. While retaining the advantages from agglomeration in metropolitan areas, how to overcome the threats from the infectious disease is the key to epidemiological smart cities. Urban consolidation for compact city making and the encouragement for public transit have been sustainable planning practices. However, these approaches might be limited in preventing infectious diseases for the following three reasons. First, there are frequent indoor activities in crowded multi-use facilities such as department stores, hospitals, indoor entertainment facilities, terminals, clubs, and pubs. Secondly, to enjoy the urban lifestyle, there are great threats from crowded and closed in-vehicle activities in public transport such as trains, metro carriages, and buses. Thirdly, there are crowded outdoor activities in public spaces such as streets and parks where there are inevitable contacts in metropolitan areas. Although outdoor environments have lower risks to infection, these aggravate the health threat.

These threats need to be managed for which the active use of ICT offers an opportunity. For instance, to overcome high-density environments, government policy should support contactless activities such as working from home, remote meetings, online shopping, and online medical services. Also, the government should actively consider the introduction of flexible working hours, personal mobility, and demand-responsive public transport management. Not all cities are vulnerable to the infectious disease, but the failure of urban management results in vulnerability to the disease within the city.

2 Epidemiological management in smart cities

The pandemic has seemed to become endemic. Continued strict social distancing measures will be a barrier to resuming the usual lifestyle. It seems unachievable to completely eradiate COVID-19 in the near future. Smart epidemiological management is required to enable ordinary life without strict social distancing measures. A big data-based smart epidemiological management model is here proposed to respond to the spread of new infectious diseases by establishing a three-stage management system (Figure 44). In the first stage, before the new infectious disease enters the country, risks should be measured. At the early stage of the new infectious disease, close contacts and the pattern of spread should be analyzed. At the stage of local transmission, simulation should be performed to contain the virus. The quality of epidemiological management can be enhanced by employing smart solutions and technology in the stage of planning/preparation, responses, recovery, and adaptation (see Table 11). This approach will support the prediction of virus spreading patterns, facilitate integrated actions in a timely manner, slow down the spread of the virus, ease

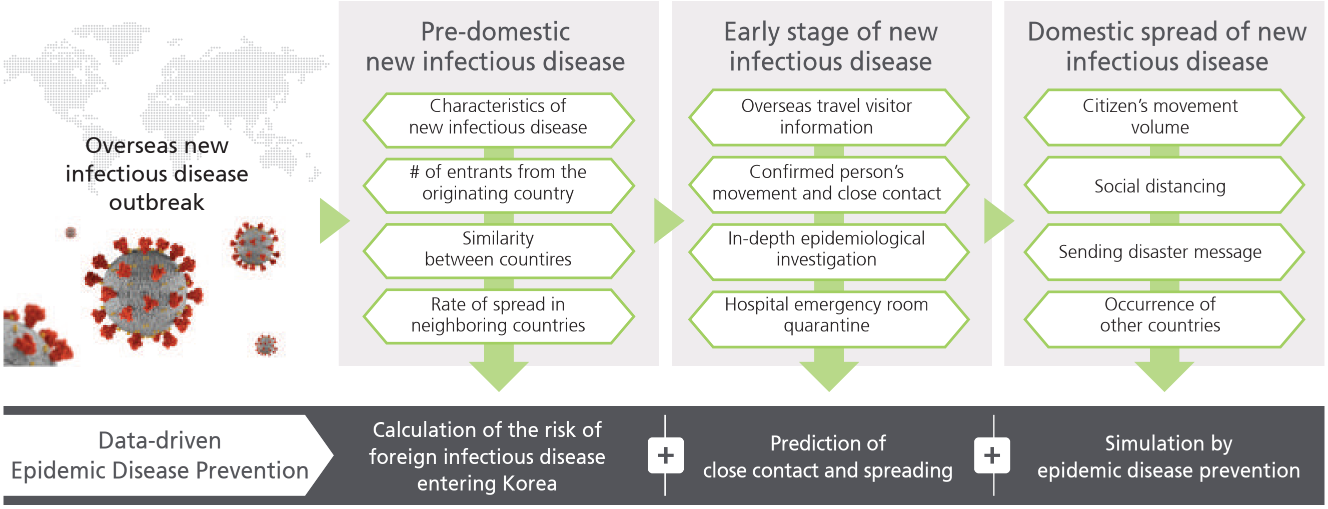


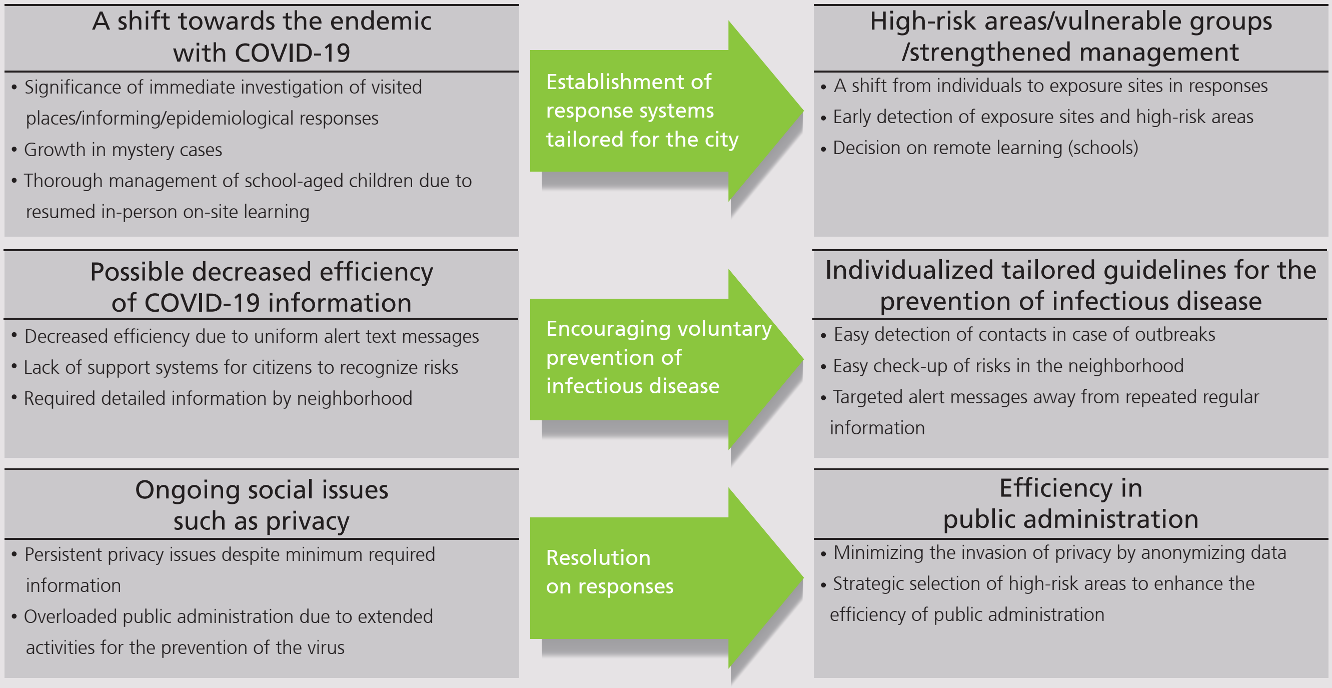
Figure 44 Directions for a data-driven smart epidemiological management model

Table 11 A smart epidemiological management model

	Immediate actions <--------------------------->	Long-term actions
Resilience	Smart decision-making support system - Early information transfer, real-time prediction, and monitoring	Smart spatial planning and management - Planning and management for epidemiological protection
Planning / Preparation	- Smart technology for prediction and the detection of hotspots	- Collaboration and integrated planning - Smart city infrastructure
Response	- Preventative measures against the spread of virus - Tracing and tracking contracted individuals - Transparent communication and limiting false news	- Preventative measures
Recovery	- Support for overloaded staff	- Alternative means to continue key functions
Adaptation	- Speeding up digitalization	- A shift to digitalization - Lessons for optimal urban management

Source: Adapted from Sharifi et al. (2021)

workloads in overloaded health management sectors, and improve the capacity of the cities. While citizens enjoy an ordinary lifestyle, continued monitoring and management efforts are required in the circumstances with COVID-19. This research proposes targeted detailed epidemiological approaches (see Figure 45). MBD enables to detect close contacts and hotspots through simulations. Thus, it is highly recommended to introduce this approach. In South Korea, the verification of identity when booking for COVID-19 vaccination can be done by mobile phones due to the collaboration of the KDCA with telecommunication companies and internet search engines in September 2021. Therefore, MBD can provide further detailed information by the vaccination status – first dose, second dose, and unvaccinated. This approach is developed based on the dataset in the format of international standard agreements. Hence, it can be also introduced to other cities. This research has developed a method to condense the MBD to 20% or a maximum of 2% of the previous movement data in the capital region, where half of the Korean population is concentrated and over 70% of infection occurred, which support the identification of infection chains. This approach can be applied to other metropolitan areas in different scales such as local government areas and neighborhoods. In addition, fine-scale geographical information can be further integrated to improve the quality of analysis, and therefore the efficiency of epidemiological management.



A shift towards the endemic with COVID-19

- Significance of immediate investigation of visited places/informing/epidemiological responses
- Growth in mystery cases
- Thorough management of school-aged children due to resumed in-person on-site learning

Establishment of response systems tailored for the city

High-risk areas/vulnerable groups /strengthened management

- A shift from individuals to exposure sites in responses
- Early detection of exposure sites and high-risk areas
- Decision on remote learning (schools)

Possible decreased efficiency of COVID-19 information

- Decreased efficiency due to uniform alert text messages
- Lack of support systems for citizens to recognize risks
- Required detailed information by neighborhood

Encouraging voluntary prevention of infectious disease

Individualized tailored guidelines for the prevention of infectious disease

- Easy detection of contacts in case of outbreaks
- Easy check-up of risks in the neighborhood
- Targeted alert messages away from repeated regular information

Ongoing social issues such as privacy

- Persistent privacy issues despite minimum required information
- Overloaded public administration due to extended activities for the prevention of the virus

Resolution on responses

Efficiency in public administration

- Minimizing the invasion of privacy by anonymizing data
- Strategic selection of high-risk areas to enhance the efficiency of public administration

Figure 45 Directions for smart epidemiological management and public services

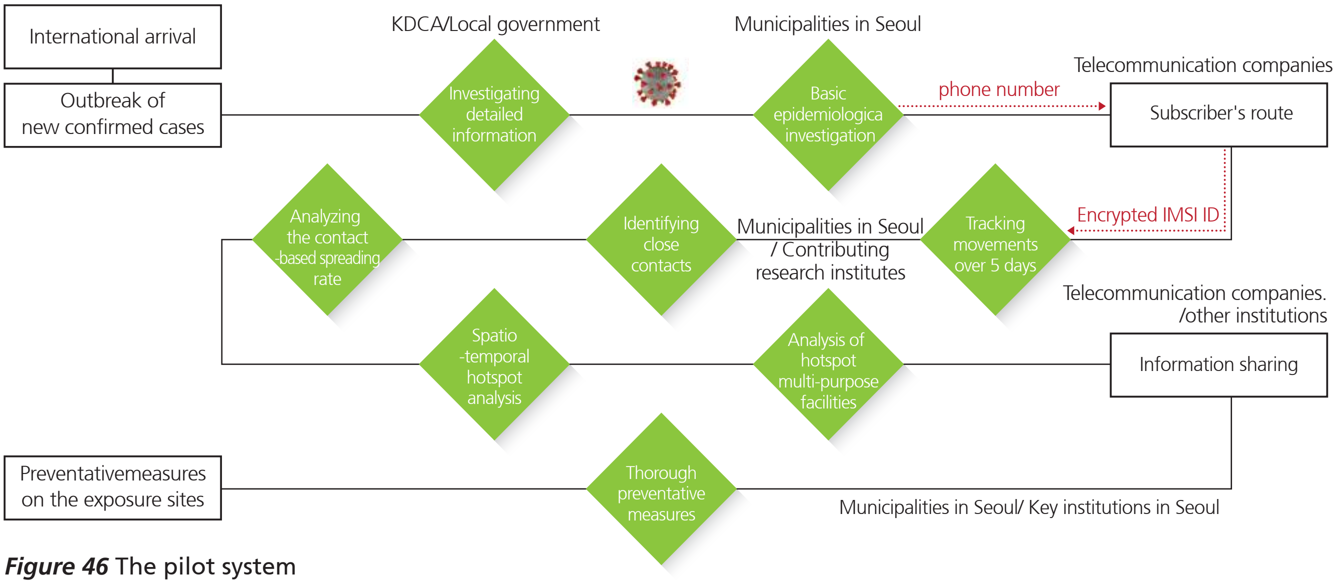


Figure 46 The pilot system

Chapter 5. International case studies and strategies for international collaboration

Parking lot of Seoul Public Sharing Bicycle Ttareungyi(따릉이) near DMC, Sangam, Seoul (c) Hyungwoong Chang, December 2021

1. Case Study 1: Jakarta, Indonesia
2. Case Study 2: Kuala Lumpur, Malaysia
3. Case study 3: Bogota, Colombia
4. Case Study 4: Lima
5. Case Study 5: Accra
6. Case Study 6: Addis Ababa, Ethiopia
7. Strategies for international collaboration

This chapter reviews COVID-19 responses in six metropolitan areas in developing countries. Two cities each in Asia, South America, and Africa are selected for case studies. The objective of the case studies is to find out the role of ICT in handling the pandemic and the potential for the active adoption of MBD. Table 12 presents the case study cities.

Table 12 The selection of case studies

Continent	City	Country
Asia	(1) Jakarta	Indonesia
	(2) Kuala Lumpur	Malaysia
South America	(3) Bogotá	Colombia
	(4) Lima	Peru
Africa	(5) Accra	Ghana
	(6) Addis Abba	Ethiopia

1. Case Study 1: Jakarta, Indonesia

1.1 Overview

Jakarta, the capital city of Indonesia, is one of the largest metropolitan areas in Southeast Asia, situated on Java Island. Jakarta has a population of more than 10 million and has the highest population density (13,000 people/km2). Jakarta experienced rapid population growth from 2000 to 2010 at 1.42% per annum, from 2010 to 2020, at 0.92% per annum (BPS DKI Jakarta, 2021). Indonesian ICT sectors saw a gradual growth from the early 2010s. However, the market has expanded dramatically due to the COVID-19 pandemic recently. It is believed that the use of ICTs would have a significant impact on the national economy, generating 3.7 million new jobs within the country (Ariansyah et al., 2019). The Jokowi Administration launched a digital economy infrastructure project.

The allocation of 30.5 trillion RP (US$ 2.1 billion) was included in the 2021 state budget for ICT development (Jakarta Post, 2020). The Jokowi Administration endeavors to enhance public services in the education, health, and government sectors. Since 2017, the estimated value for the ICT sector has passed $1.35 billion with projects such as digitizing public broadcasting networks, building e-government infrastructure, and the national crime information system (Ariansyah et al., 2019). Later, the Indonesian government focused on the Making Indonesia 4.0 roadmap and infrastructure for digital economies. ICTs in Jakarta are relatively more advanced than other provinces in Indonesia (Ariansyah et al., 2019). The use of smart devices has been increasing in Jakarta. The recent survey released by the Indonesian

Internet Service Provider Association (APJII) reported that the internet penetration in Jakarta was 85%, compared to the national average at 73.7% in 2021 (KOMPAS, 2021). This growth was much faster than the 2017 forecast (Statista, 2017). The estimated number of internet users in Indonesia was 175.4 million people in January 2020, more than half of the total population (Datareportal.com, 2020).

4G network services have been improved significantly in Indonesia. Jakarta also experienced a 7.7% average increase of 4G network service availability between Q3 2018 and Q3 2020 (Opensignal, 2020).

The mobile phone subscription reached 63.5% in Indonesia and over 73% in Jakarta in 2019 (Statista, 2020).

The internet speed has been increased significantly in all regions of Indonesia. Jakarta also experienced a 46.0% of increase over the last two years partly due to the Palapa Ring Project (Opensignal, 2020).

The Jakarta Smart City project, launched in 2014, is to handle urban problems by integrating ICTs for public service management. The Jakarta Smart City project aims to contribute to Smart Governance, Smart Economy, Smart People, Smart Mobility, Smart Environment, and Smart Living.

In addition, Smart City 4.0 Ecosystem Platform has been developed to advance the current Jakarta Smart City project, encouraging the participation of citizens and communities in city-building with a focus on innovative cities and happiness (Nugraha, 2020).

Figure 47 Smart City 4.0 Framework for Jakarta

Source: Jakarta Smart City Portal (2021)

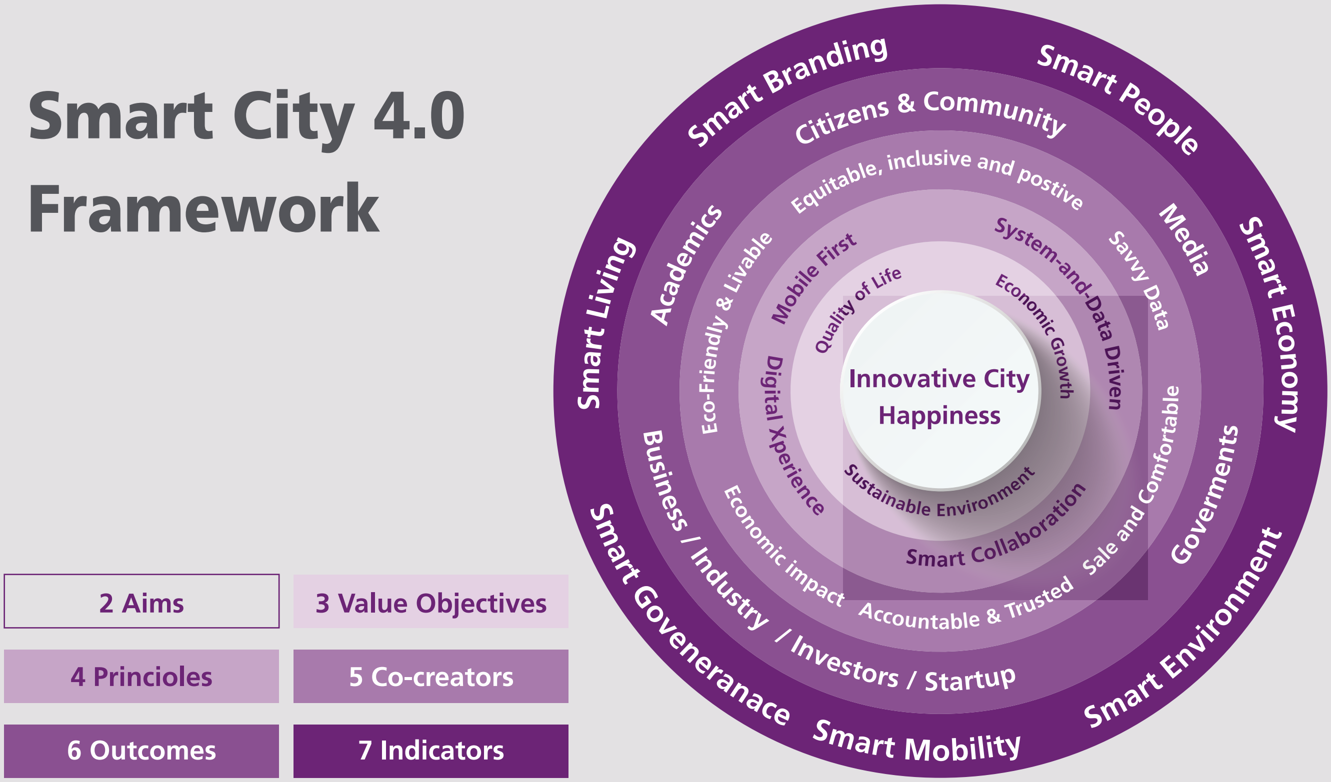


Figure 48 Smart City 4.0 Framework for Jakarta

Source: Jakarta Smart City Portal (2021)

1.2 COVID-19 and public policy in Jakarta

The public health emergency status was announced on 31 March 2020 through Presidential Decree No. 11/Year 2020 of Indonesia (Syafri et al., 2020). It was two weeks after the World Health Organization declared COVID-19 as a pandemic on 11 March 2020 (WHO, 2020) and four weeks after detecting Indonesia's first confirmed case. Along with the announcement, the Large-Scale Social Restrictions (PSBB) policy was established to prevent the spread of COVID-19 by the national government, being applied to Jakarta as well.

Jakarta has encountered four peaks from March 2020 to August 2021 among which the third wave was the largest (Figure 49). Those outbreaks were related to large-scale travels from Jakarta to participate in religious services and visit families and friends for holidays. Before the vaccine approval, the most popular intervention in Jakarta and any other cities in the world for COVID-19 were the non-pharmaceutical measures, such as face masks, social distancing, contact tracing, quarantining, and maintaining personal hygiene (Aldila et al., 2021).

The Regional Head Election in September 2020 was postponed to December 2020, as the election may result in further community transmissions. The postponed election resulted in widespread of the virus in many different parts of the nation, causing fatalities, especially in remote areas. The PSBB in Jakarta was extended to 17 January 2021, and 3T (Testing, Tracing, and Treatment) measures were strictly applied. It was reported that almost half of the residents (about 4.7 million people) may have contracted COVID-19 in Jakarta (CNN World, 2021). There are only 141 hospitals with 20,197 beds, and 51 special purpose hospitals with 3,460 beds. This is very insufficient to support the population of Jakarta. The responses from local hospitals for the COVID-19 outbreak were slow. Those hospitals were overwhelmed by new patients and death victims. The Government of Jakarta hurried to build new hospitals and isolation facilities to respond to a rapid increase of confirmed cases, but the new hospital was not enough to take care of COVID-19 patients. Hospitals in Jakarta reached 90% of the occupancy rate when Jakarta had 50,000 patients a day by the highly infectious Delta-variant.

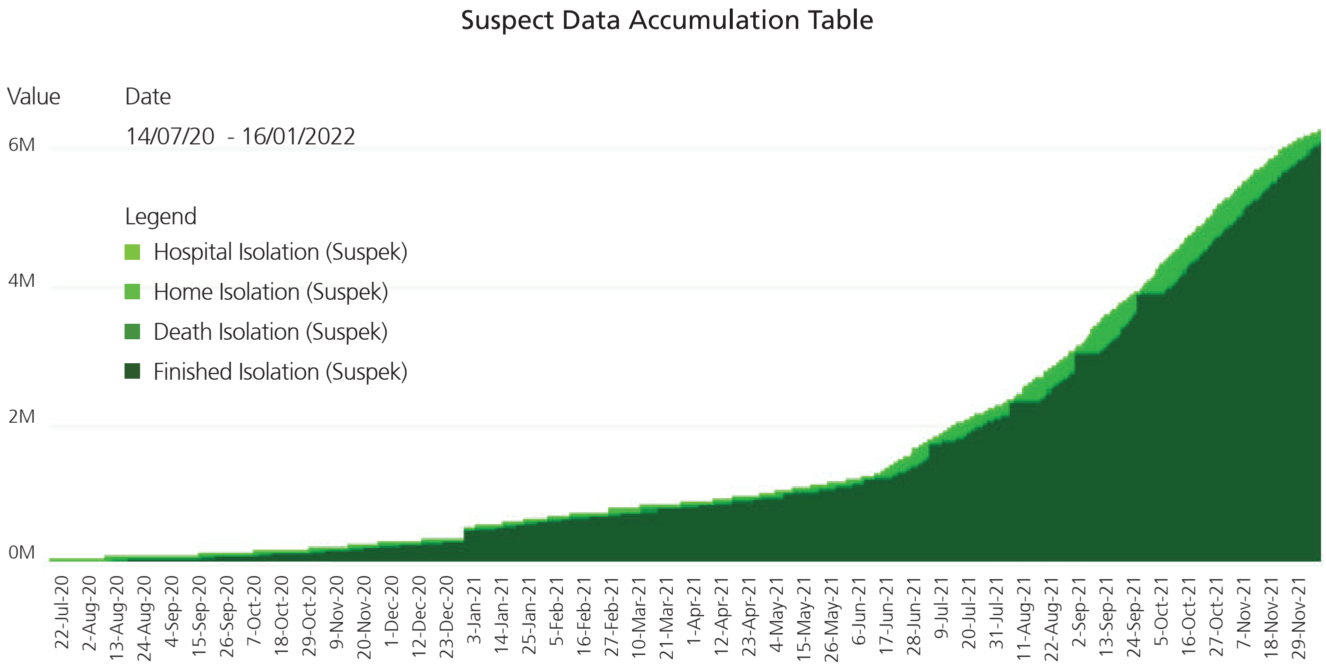


Figure 49 Statistics of the confirmed case (daily and accumulated) for Jakarta*

Source: Open Data Jakarta, http://data.jakarta.go.id/

1.3. ICT-oriented responses to COVID-19

The primary response by the Jakarta and the Indonesian government has been the large-scale social distraction (Pembatasan Sosial Berskala Besar, PSBB). PSBB provided a guideline for activities in an area suspected of being affected by COVID-19 to prevent possible spread. PSBB was based on Government Regulation No. 21/2020. The PSBB has been applied more strictly in Jakarta due to its high population size and density. Offices, religious places, shopping malls and restaurants were closed across Jakarta and Java Island. Jakarta was the first province to activate the PSBB measures on 10 April 2020, followed by cities in the JABODETABEK metropolitan area.

The Community Activities Restrictions Enforcement (Pemberlakuan Pembatasan Kegiatan Masyarakat, PPKM) was implemented by the Indonesian government. The first PPKM policy was introduced in February 2021, followed by Emergency PPKM in June 2021. The PPKM and Emergency PPKM decreased mobility and human interactions in local communities. From 22 June 2021 to 5 July 2021, the extension of PPKM was announced in Jakarta with more restrictions. These enforced restrictions include: 1) applying 75% of working from home, 2) online classes for the education sector, 3) shortened shopping center operating hours, and 4) worship activities at home.

Table 13 the list of limited activities on PSBB

PSBB	1. Schools and workplaces were closed except for the health sector, food, energy, communication, finance and banking, logistics, daily necessities, and strategic industries. 2. Restrictions on religious activities were in place. 3. Limitation of activities in public places/facilities: gathering more than 5 people was prohibited. 4. Limitation of social and cultural activities 5. Limitation of transportation modes: the maximum number of passengers was 50 percent of vehicle capacity. The operational hours of public transportation on the route and infrastructure were limited from 6:00 to 18:00. 6. Limitation of other activities specifically related to defense and security aspects: except in the context of upholding the country's sovereignty, maintaining territorial integrity, and protecting the Indonesian people from threats and harassment.

Negative Pressure ICU
With Ventilator 135 Available
Without Ventilator 26 Available

Non-Negative Pressure ICU
With Ventilator 16 Available
Without Ventilator 23 Available

Isolation Room
Negative Pressure Isolation 351 Available
Non-Negative Pressure Isolation 569 Available

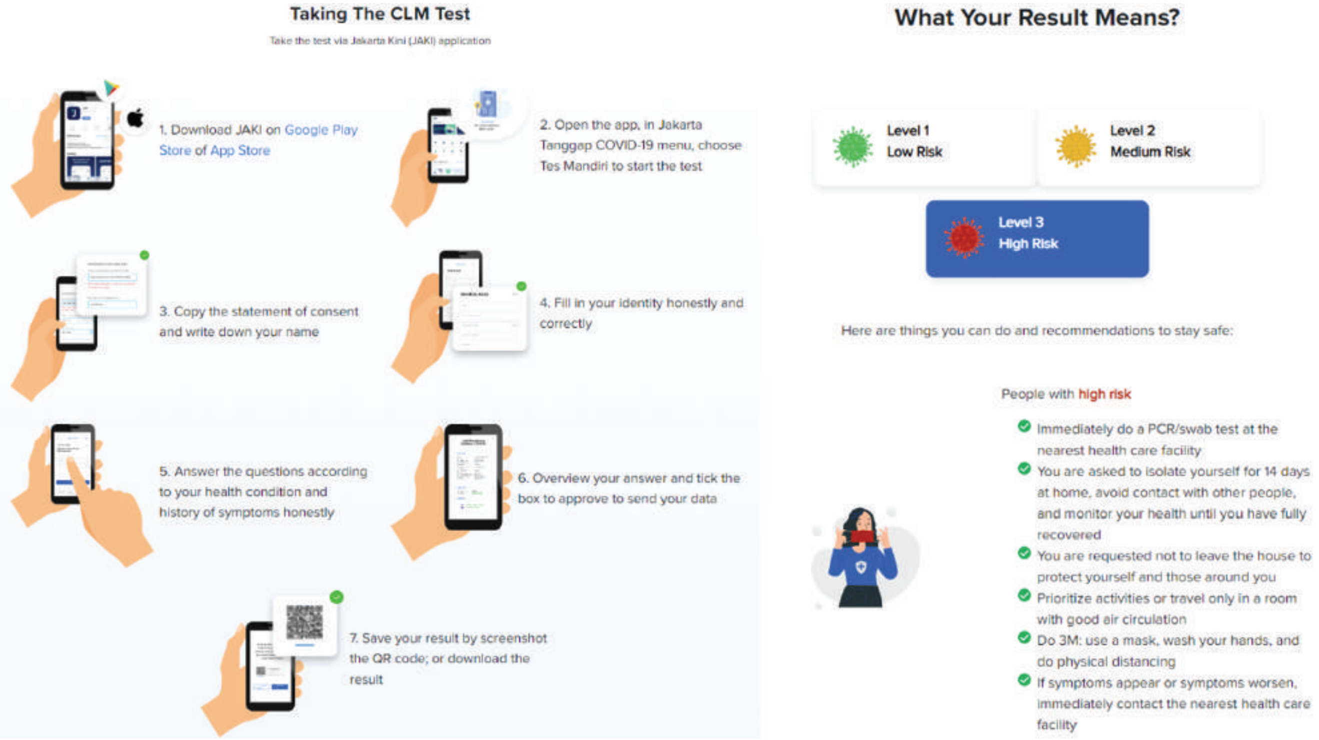
PICU/NICU/Perinatology for COVID-19
PICU Covid-19 5 Available
NICU Covid-19 7 Available
Perinatology Covid-19 24 Available

Figure 50 Live update on COVID-19 referral hospitals in Jakarta

Source: COVID-19 Monitoring System, Jakarta Smart City (2021)

Mobile phone applications and websites were developed. Information about hospital beds at COVID-19 Referral Hospitals is available at JAKI, the Jakarta Smart City Service. The service offered information about the availability of Intensive Care Units (ICU), pediatric ICU rooms for children, and other special-purpose units (Figure 50).

Another approach by Jakarta with the aid of advanced technology was the Corona Likelihood Metric (CLM) Assessment. CLM is a self-screening application based on machine learning technology. The CLM provides information about COVID-19 infection and recommendations to individuals



Taking The CLM Test

Take the test via Jakarta Kini (JAKI) application

1. Download JAKI on Google Play Store of App Store
2. Open the app, in Jakarta Tanggap COVID-19 menu, choose Tes Mandiri to start the test
3. Copy the statement of consent and write down your name
4. Fill in your identity honestly and correctly
5. Answer the questions according to your health condition and history of symptoms honestly
6. Overview your answer and tick the box to approve to send your data
7. Save your result by screenshot the QR code; or download the result

What Your Result Means?

Level 1 Low Risk
Level 2 Medium Risk
Level 3 High Risk

Here are things you can do and recommendations to stay safe:

People with high risk

- ✓ Immediately do a PCR/swab test at the nearest health care facility
- ✓ You are asked to isolate yourself for 14 days at home, avoid contact with other people, and monitor your health until you have fully recovered
- ✓ You are requested not to leave the house to protect yourself and those around you
- ✓ Prioritize activities or travel only in a room with good air circulation
- ✓ Do 3M: use a mask, wash your hands, and do physical distancing
- ✓ If symptoms appear or symptoms worsen, immediately contact the nearest health care facility

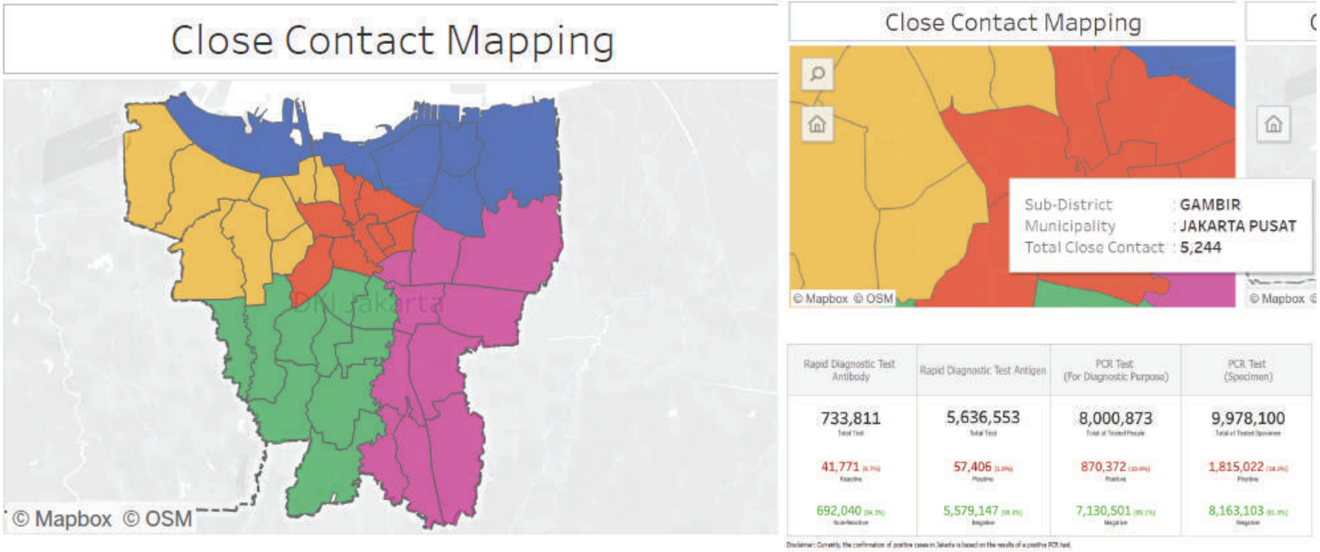
Figure 51 Guidelines to CLM test procedure and test results

Source: https://corona.jakarta.go.id/en/clm

(COVID-19 Monitoring System, 2021). The risk assessment requires general information such as age and sex, COVID-19 symptoms, and travel history (contacts and travel sites).

The Jakarta Smart City project utilized the existing platforms to provide information on COVID-19 through the COVID-19 Monitoring System in the Jakarta Smart City webpage and Jaki (Jakarta Kini). Jakarta's COVID-19 Response provides statistics, interactive maps, social aid programs on a website. Jakarta's COVID-19 Monitoring System was launched in early March 2020 even before the first confirmed case was detected in Indonesia.

JAKI assisted the citizens of Jakarta by providing various information, including flood risk, COVID-19 situation, and other issues in everyday life. Specific to COVID-19, JAKI provided information on a vaccination schedule, COVID-19 self-assessment through the CLM, daily update, and information on the distribution of social assistance. The service is operated by Jakarta Provincial Government, Department of Human Settlements, Spatial Planning, and Land Services.



Sub-District : GAMBIR
Municipality : JAKARTA PUSAT
Total Close Contact : 5,244

Rapid Diagnostic Test Antibody	Rapid Diagnostic Test Antigen	PCR Test (For Diagnostic Purpose)	PCR Test (Specimen)
733,811 Total Test	5,636,553 Total Test	8,000,873 Total of Tested People	9,978,100 Total of Tested Specimen
41,771 Reactive	57,406 Positive	870,372 Positive	1,815,022 Positive
692,040 Non-Reactive	5,579,147 Negative	7,130,501 Negative	8,163,103 Negative

Disclaimer: Currently, the confirmation of positive cases in Jakarta is based on the results of a positive PCR test.

Figure 52 The interactive maps showing active cases in each district

Source: COVID-19 Monitoring System, Jakarta Smart City Service (2021)

1.4 Implications

Social distancing measures were employed to prevent the virus from spreading in a community in Jakarta (Yanti et al., 2020). The national Government of Indonesia insisted on keeping the multi-tiered public activity restrictions (PPKM). However, in conjunction with the advancement in ICTs, the Indonesian government has also paid attention to online resources and platforms. Jakarta developed a platform to provide information about COVID-19.

The COVID-19 Monitoring System launched by the Jakarta Smart City project was useful in providing daily statistics, information on social support, and medical care services, and CLM self-diagnosis. Also, the mobile application, JAKI, was developed to provide up-to-date information and patrol PSBB guidelines. The case study of Jakarta shows the potential of ICTs and big data in implementing public policy for virus containments.

2. Case Study 2: Kuala Lumpur, Malaysia

2.1 Overview

Kuala Lumpur, the capital of Malaysia, was ranked at the top 10 leading technology innovation hubs in the Asia Pacific region (KPMG, 2021). The population of Kuala Lumpur was 8.2 million, accounting for 26% of the Malaysian total, with a population density of 6,890 people/km2 (Department of Statistics Malaysia Official Portal, 2021). Malaysia has undertaken rapid urbanization (UN, 2015). The urban population is expected to increase to 36.2 million by 2050 (UN, 2015). Kuala Lumpur has been facing urban challenges such as traffic congestion, air pollution, urban poverty, and polarization. Migration from regional areas of Malaysia has resulted in high demand for new infrastructure, resulting in the spatial expansion of urban areas (van Grunsven and Benson, 2020).

In digitalization, Malaysia was ranked second place in Southeast Asia after Singapore (Loh et al., 2021). The IT sector was the 5th highest contributor to the Malaysian national economy. ICT sectors have contributed to productivity especially in high value-added industries. The cost of broadband service has been relatively affordable in Malaysia (Kylasapathy et al., 2017).

In Malaysia, the number of internet users has increased significantly since 2010, almost by 1.5 times. According to the Department of Statistics Malaysia (2021), Malaysians' access to mobile phones and computers reached 98.6% and 77.6%, respectively, in 2020. Through internet services, various activities have been supported such as ordering goods and services, seeking health information, participating in online courses, and utilizing internet banking services (TheStar, 2021). In 2015, 83% of the National Government services have been provided via online platforms. Most Malaysians have embraced digitalization with 44 million having a mobile phone (Kylasapathy et al., 2017).

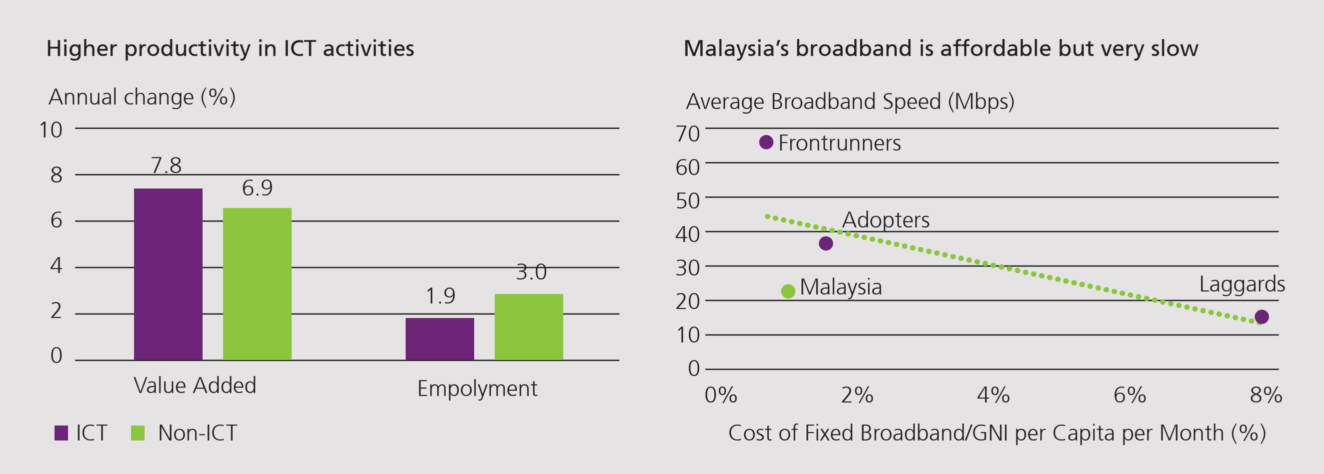


Figure 53 The indicators for representing Malaysia's ICT condition

Source: Kylasapathy et al. (2017)

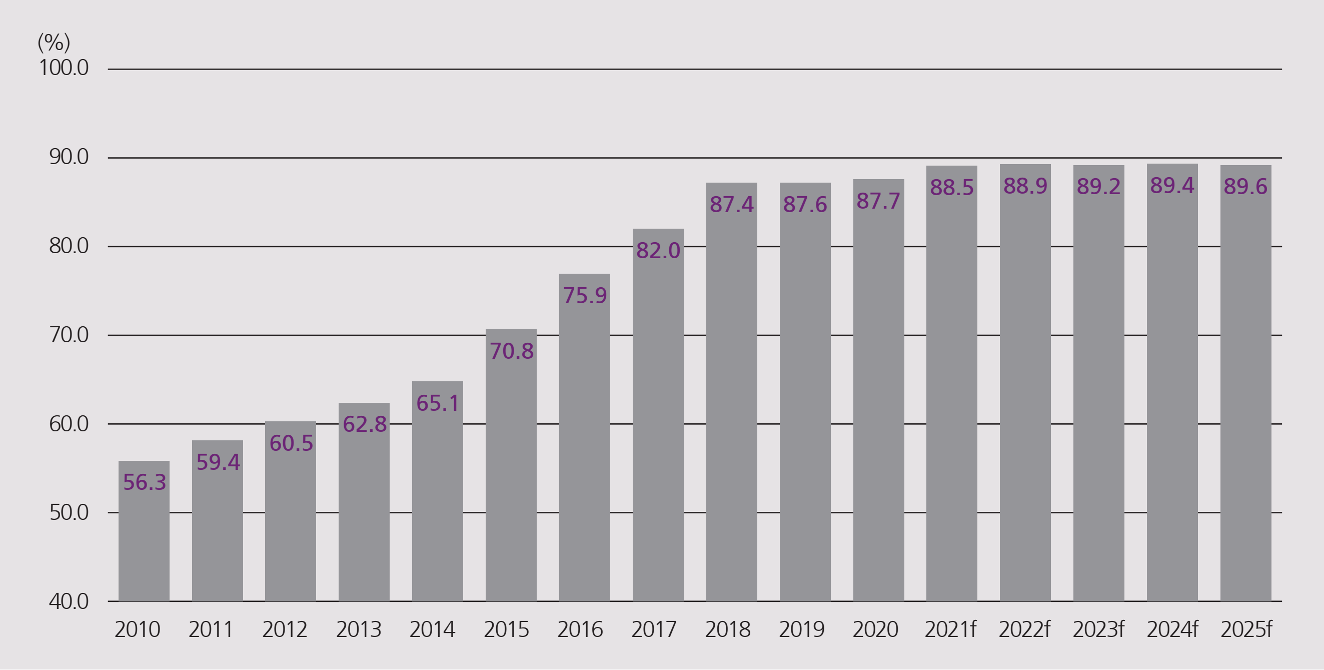


Figure 54 A trend of internet subscription in Malaysia (2010-2025*)

* The expected rate of internet penetration is based on the current situation and policy directions

Source: Statista (2021)

The COVID-19 outbreak further encouraged businesses to rely on digital technology. Malaysia has already had a high number of mobile broadband subscribers along with an increasingly growing mobile phone holders (Gong, 2020). The Malaysian government has developed a plan for digital infrastructure in response to COVID-19. Although there have been complaints about the quality of the internet service, internet networks have been well established even before the pandemic.

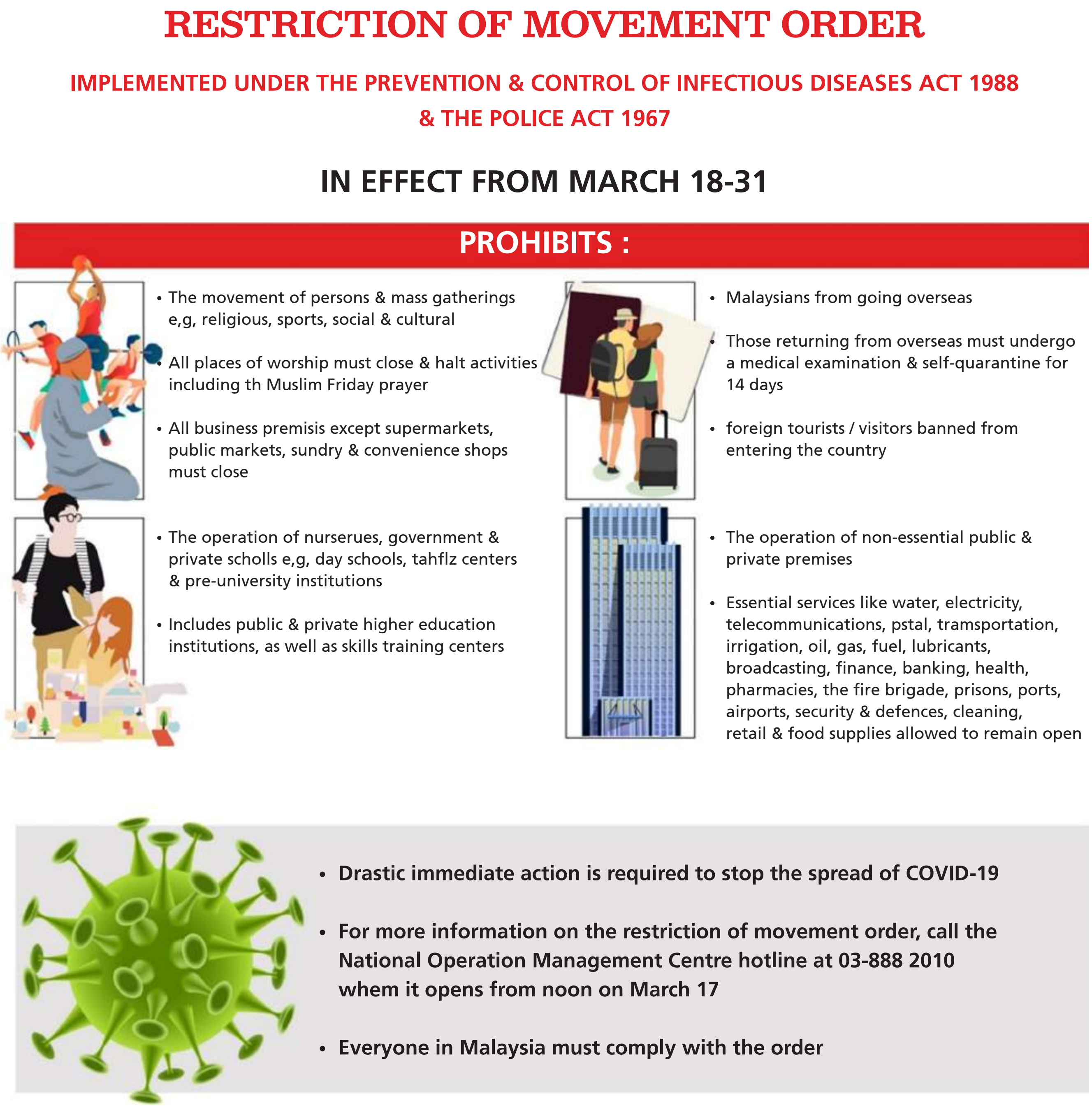
2.2 COVID-19 and public policy in Kuala Lumpur

The first COVID-19 patient was identified on 25 January 2020 in Malaysia. With growing international arrivals, new patients were further identified, and local transmission became pervasive. In response to the outbreak of COVID-19, the Malaysian government implemented a border closure on 16 March 2020, which was the first in Asia.

The Malaysian government implemented strict social distancing measures called the Movement Control Order (MCO). Starting from 18 March 2020, nationwide travel restrictions were in place except for medical visits. Also, interstate travel was banned for two weeks in the beginning.

The government coordinated lockdown measures with religious groups as the MCO coincided with Ramadan. Mass gatherings for religious activities were either restricted or postponed. Strict MCOs over six weeks from 18 March 2020 to 3 May 2020 contributed to curbing the trend. In this period, a total of 5,623 new cases was reported, but at the end of MCO, daily new cases were reduced to less than 100 a day.

After controlling the spread of COVID-19 in the early stage, the Malaysian government relaxed some of the social distancing measures. On 4 May 2020, the Conditional MCO (CMCO) was announced, allowing some businesses to resume their operations if they comply with the Standard Operating Procedures (SOP) with an aim to "restart the economy". Specific and targeted restrictions were implemented, and the information about the change in restrictions was shared through digital media platforms. However, the CMCO raised concerns among state governments, politicians, experts, and the public. Over 420,000 people signed a petition in objection to the CMCO, urging the extension of MCO (WHO, 2020). The CMCO lasted for a month between 4 May 2020 and 9 June 2020.



RESTRICTION OF MOVEMENT ORDER

IMPLEMENTED UNDER THE PREVENTION & CONTROL OF INFECTIOUS DISEASES ACT 1988 & THE POLICE ACT 1967

IN EFFECT FROM MARCH 18-31

PROHIBITS :

- The movement of persons & mass gatherings e,g, religious, sports, social & cultural
- All places of worship must close & halt activities including th Muslim Friday prayer
- All business premisis except supermarkets, public markets, sundry & convenience shops must close
- The operation of nurserues, government & private scholls e,g, day schools, tahflz centers & pre-university institutions
- Includes public & private higher education institutions, as well as skills training centers
- Malaysians from going overseas
- Those returning from overseas must undergo a medical examination & self-quarantine for 14 days
- foreign tourists / visitors banned from entering the country
- The operation of non-essential public & private premises
- Essential services like water, electricity, telecommunications, pstal, transportation, irrigation, oil, gas, fuel, lubricants, broadcasting, finance, banking, health, pharmacies, the fire brigade, prisons, ports, airports, security & defences, cleaning, retail & food supplies allowed to remain open

- **Drastic immediate action is required to stop the spread of COVID-19**
- **For more information on the restriction of movement order, call the National Operation Management Centre hotline at 03-888 2010 whem it opens from noon on March 17**
- **Everyone in Malaysia must comply with the order**

Figure 55 Activities prohibited as a result of MCO

Source: Prime Minister's Office of Malaysia (2021)

Figure 56 New COVID-19 cases reported during MCO

Source: WHO (2021), Coronavirus (COVID-19) Dashboard

After the new daily cases were stabilized by end of May 2020, the CMCO was further relaxed by introducing the Recovery Movement Control Order (RMCO) that was implemented from 10 June 2020 to 31 March 2021. The RMCO allowed interstate travels, morning and night markets, and most social, religious, business, and educational activities to be resumed. While some restrictions were still in place, the objective of the RMCO was to bring back ordinary life. On 7 June 2020, the number of new cases dropped to seven. Local transmission appeared to have been controlled by this point, and the Malaysian government began a stricter screening process on incoming travelers to Malaysia. In addition, incoming travelers were required to provide negative testing results upon entry and quarantine for 14 days and PCR tests. In early August 2020, face masks became mandatory in public transportation and crowded places. The RMCO was initially implemented between 10 June 2020 and 31 August 2020, but it was planned to extend for four months until the end of 2020 as only small-scale outbreaks occurred. However, the number of new cases increased to over 100 a day in September 2000, and around 2,000 a day by the end of 2020. The RMCO was further extended to the end of March 2021. During this period, the highest number of new cases reached 5,700 a day.

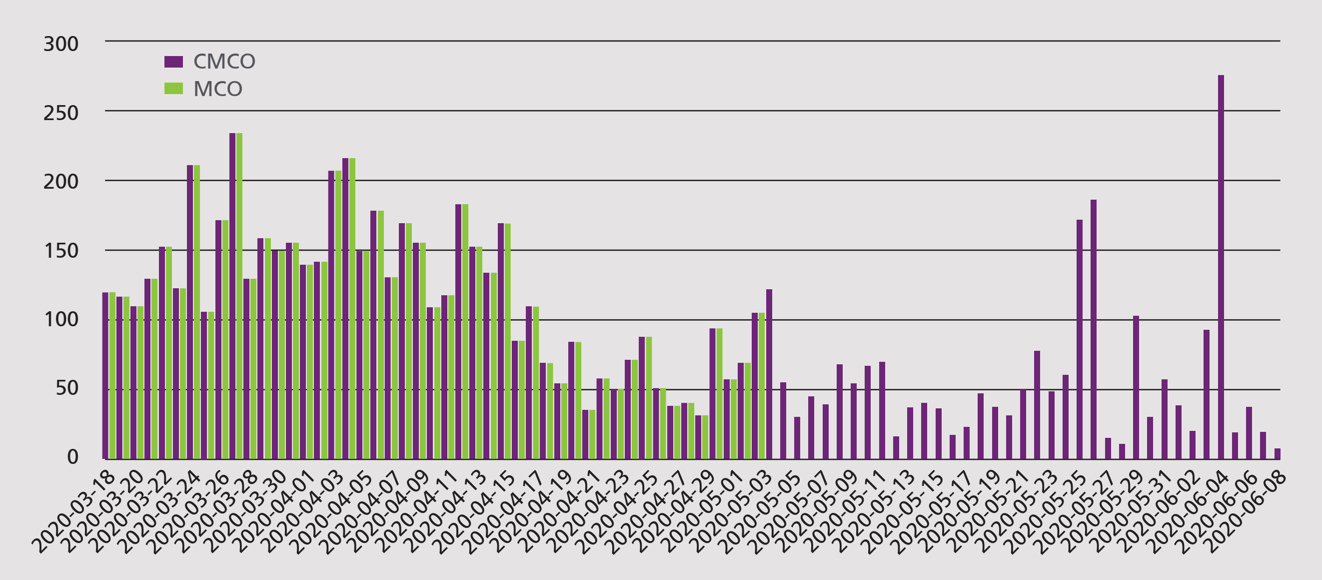


Figure 57 New COVID-19 cases reported during CMCO

Source: WHO (2021), Coronavirus (COVID-19) Dashboard

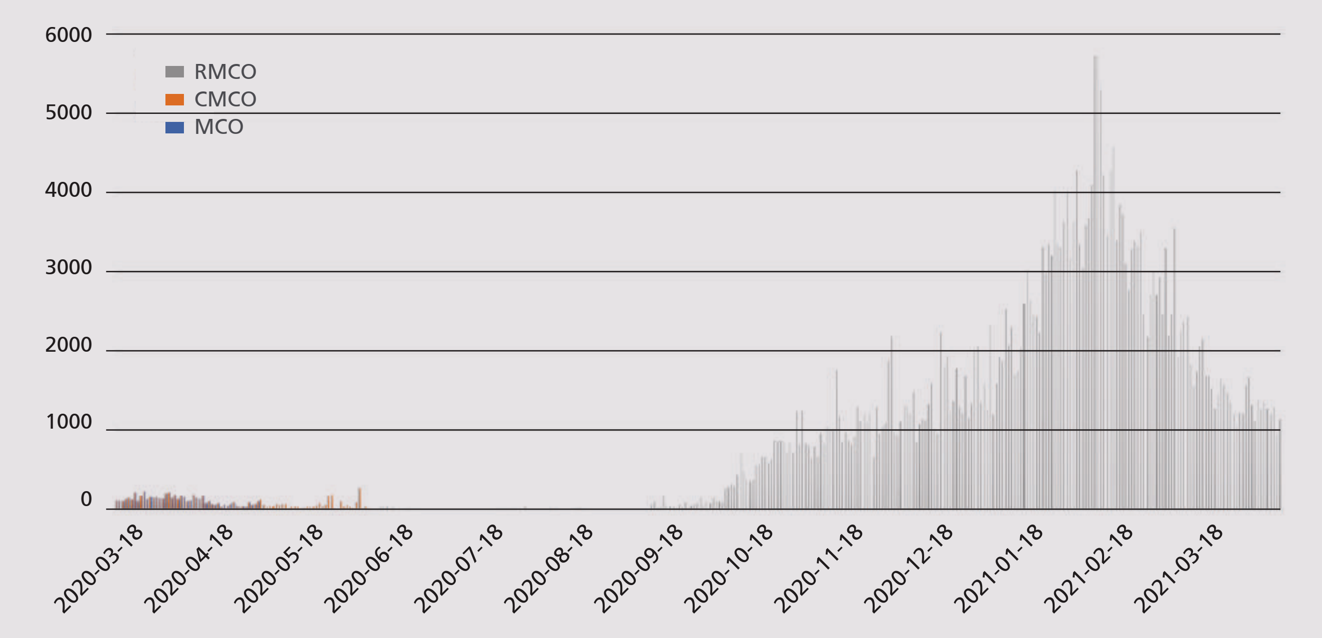


Figure 58 New COVID-19 cases reported during RMCO

Source: WHO (2021), Coronavirus (COVID-19) Dashboard

CONDITIONAL MOVEMENT CONTROL ORDER (CMCO)

STARTING : MAY 4, 2020

PUBLIC TRANSPORT SERVICE OPERATIONS

- All public transport services to resume normal operations
- Users & operators of public transport must comply with government guidelines including
  - Practising social distanceing
  - Practising good personal hygiene
- Passenger numbers will be limited to half of the actual capacity of the public transport

PRIVATE VEHICLE

- Macimun 4 people
- Must be from the same family

BUSINESS

- Most business and industry sectors given permission to resume operations
- Must comply with any SOP prescribed by the government
- Exercise self-regulation to prevent COVID-19 outbreak
- Individuals must avoid going to any public place if there is no reason to be there

Published: 3/5/2020

Figure 59 CMCO infographics

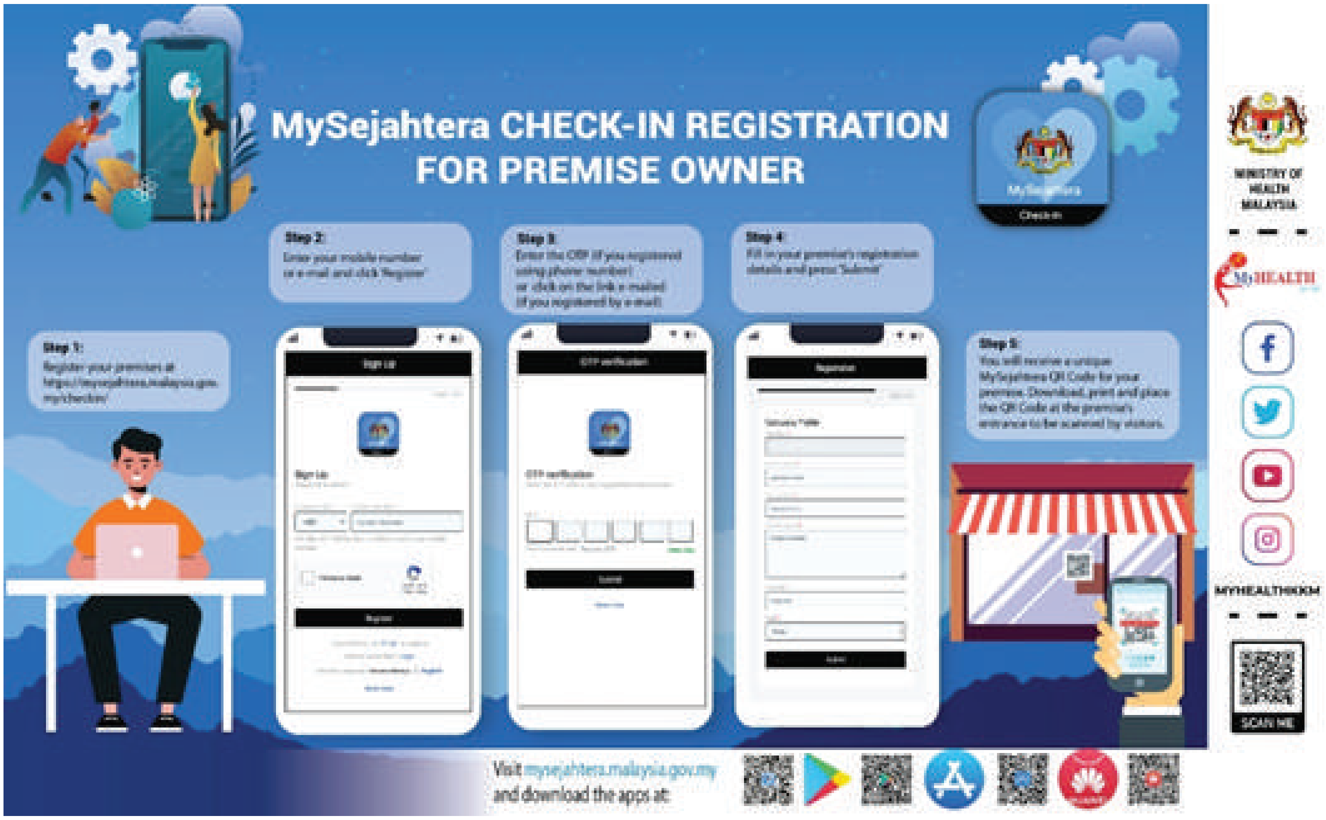
Source: Malaysian Dutch Business Council (2021)

Social distancing and lockdown measures were implemented differently by states. While some states reinstated the MCO, others employed the CMCO. However, the explosive increase in new cases resulted in political unrest. The Malaysian parliament was suspended from January 2021 due to a controversial national emergency declaration, which hampered the setting and execution of coherent and effective measures to handle the situation, combined with other political factors. The nation-wide lockdown was declared in June 2021. Nevertheless, a high number of new cases continued over 5,000. On 15 June 2021, the 4th National Recovery Plan (NRP) was announced. However, after the introduction of the NRP, the number of new cases skyrocketed, peaking at 23,564 cases on 21 August 2021. Also, further political chaos took place as Muhyiddin Yassin, former Prime Minister of Malaysia, resigned on 16 August 2021 after losing majority support in the parliament. He was criticized for his failure to handle the COVID-19 outbreak.

2.3 ICT-oriented responses to COVID-19

Figure 60 Malaysia’s Sunway Medical Centre launches Telemedicine Command Centre

Source: Healthcare IT News (2021)



MySejahtera CHECK-IN REGISTRATION FOR PREMISE OWNER

Step 1: Register your premises at https://mysejahtera.malaysia.gov.my/checkin/

Step 2: Enter your mobile number or e-mail and click 'Register'

Step 3: Enter the OTP (if you registered using phone number) or click on the link e-mailed (if you registered by e-mail)

Step 4: Fill in your premise's registration details and press 'Submit'

Step 5: You will receive a unique MySejahtera QR Code for your premise. Download, print and place the QR Code at the premise's entrance to be scanned by visitors.

Visit mysejahtera.malaysia.gov.my and download the apps at:

Figure 61 MySejahtera application is adopted to track and coordinate patient contacts

Source: Government of Malaysia (2021), https://www.malaysia.gov.my/portal/index

COVID-19 was a wake-up call for the Malaysian public health system. While it was a catastrophic disaster, it was an opportunity to prove that it is possible to make wide-scale changes with innovation and the right coordination from stakeholders. During the pandemic, digital adoption was accelerated, and collaboration between stakeholders was strengthened. MySejahtera is a mobile application developed by the National Security Council, the Health Ministry, the Malaysian Administrative Modernization and Management Planning Unit (MAMPU), and the Malaysian Communications and Multimedia Commission (MCMC). The mobile app provided data for the Malaysian government to monitor and mitigate COVID-19 outbreaks. It allowed its users to monitor their health, look for hot spots, and find treatment immediately if they were diagnosed with COVID-19. In addition, a check-in QR code function was embedded in the app.

The app was constantly updated to provide new functions. For example, a new feature was added providing medical information about the reasons for

Figure 62 MySejahtera introduction page (left) and MySejahtera 's check-in function in use (right)

Source: https://mysejahtera.malaysia.gov.my/intro/

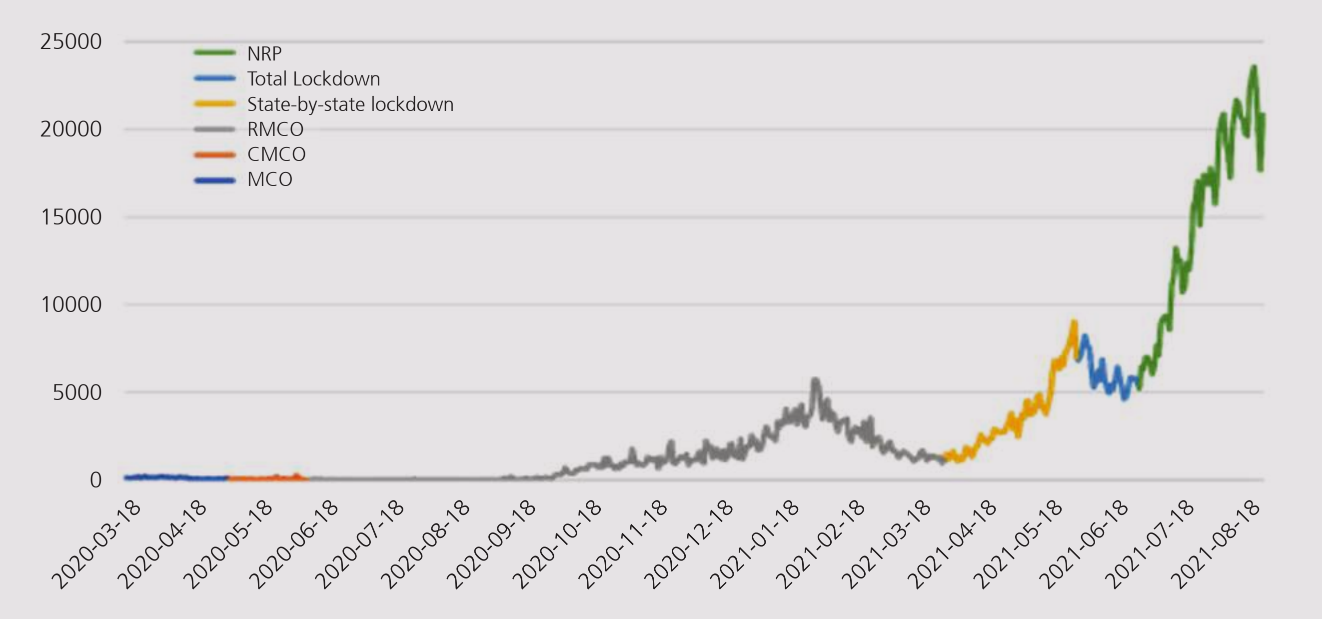


Figure 63 The whole picture of Malaysia's battle against COVID-19

Source: WHO (2021), Coronavirus (COVID-19) Dashboard (un)vaccination. It was also connected to the digital health certificate for vaccinated people. Through constant updates, MySejahtera served as an important platform through which the Malaysian government communicated with the citizens. The app was widely used throughout Malaysia. 1.9 million out of 2.32 million students in the age group between 12 and 17 years registered for COVID-19 vaccination through the MySejahtera app. By December 2020, 24.5 million users, approximately 70% of the Malaysian population, downloaded the MySejahtera app.

2.4 Implications

Malaysia's early responses to COVID-19 were made in a timely manner. It was among the first countries to implement the border closure and a nationwide lockdown, which resulted in low case numbers for the first ten months. Malaysia's medical services and facilities supported the government's responses. However, along with growing case numbers, political unrest followed.

The government's responses were no longer well-coordinated. The development of mobile phone applications demonstrated a high potential that ICT and big data can be possibly employed to handle the outbreak as seen in the high download number and active use of MySejahtera.

3. Case study 3: Bogotá, Colombia

3.1 Overview

The population of Colombia was 48.3 million with the urban population accounting for 77.1% in 2018 (DANE, 2018). After the civil war from the 1960s to the peace agreement in 2016, rural-to-urban migration has increased in Colombia.

Bogotá, the capital of Colombia, is located on the Andean plateau at an elevation of 2,650m above sea level. According to the 2018 National Census, the population of Bogotá was 7,4 million, 15% of the total population of Colombia and 20% of the country's urban population. Rapid urbanization has resulted in critical issues in the land, housing, and infrastructure. Poor quality housing appeared without essential facilities such as a kitchen and access to basic infrastructure. Informal settlements have been continuously established since the 1950s. Along with growing informal settlements, the quality and quantity of infrastructure are inadequate due to the geographical location on the plateau and the long-lasted civil war. In fact, Bogotá was ranked third after Moscow (Russia) and Mumbai (India) in the list of the world's worst cities with heavy traffic congestion in 2020 by the World Economic Forum. Despite ongoing discussions, the new metro construction project has not yet been implemented worsening traffic congestion in the city.

Colombia's ICT development is not advanced by international standards. Colombia was ranked at 84 out of 176 countries in the ICT Development Index at 5.36. Iceland (8.98), the Republic of Korea (8.85), and Switzerland (8.74) were on the top on the list. Colombia's ICT development falls behind other South American countries such as Uruguay (7.16), Argentina (6.79), Chile (6.57), and Brazil (6.12). Nevertheless, the use of the internet and mobile devices has increased steadily in Colombia. While only 43.8% of Colombian households had internet access in 2018 according to the 2018 National Census. However, the number of fixed internet connections increased by 273,668 in 2021, a 51% increase compared to 2020. 4G networks are popular in Colombia servicing 75% of mobile internet access, 32.9 million mobile internet access, and 69.4 million mobile phone lines.

Figure 64 A geography of Colombia

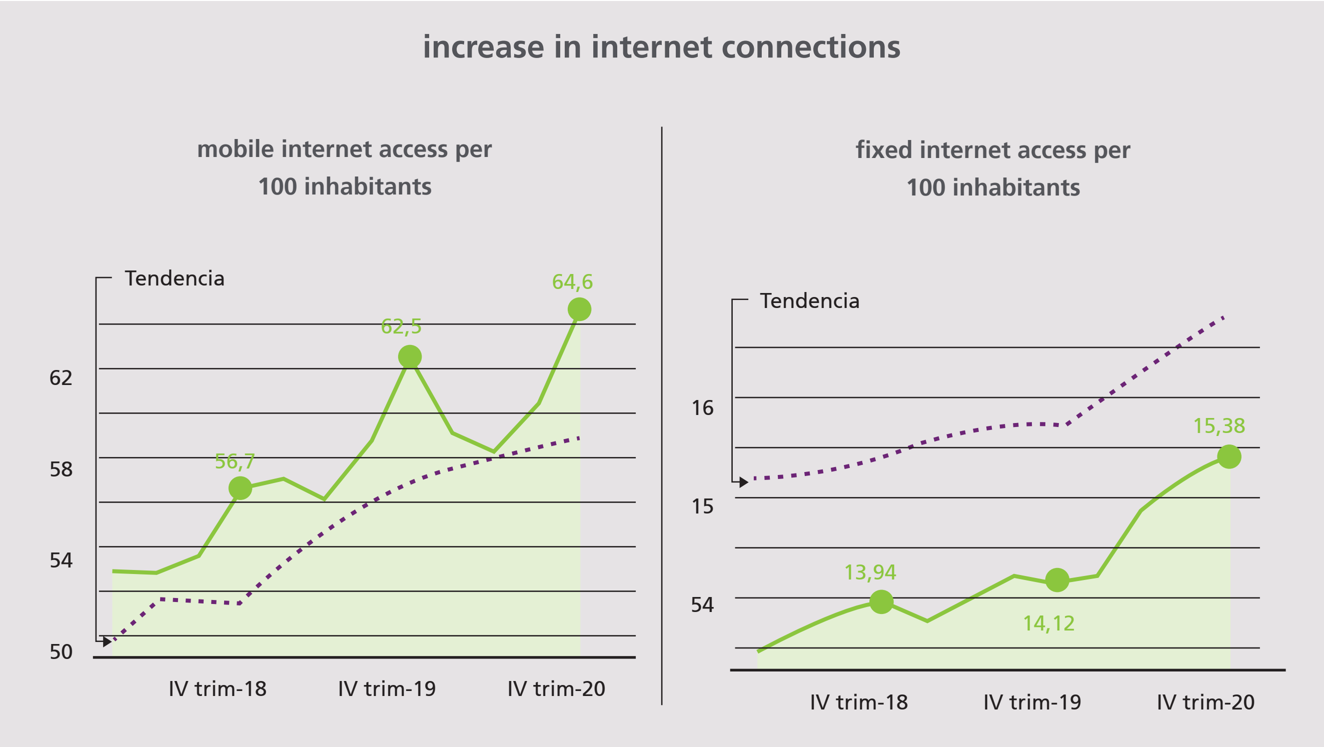


Figure 65 Increase in internet connections

Source: LR Republica (2021)

The Colombian government aims to improve the quality of internet access. Hogares Conectados (Connected Homes Program) aims to connect almost 500,000 low-income households with affordable fixed internet rates such as $US 2.2 or $US 4.9 per month. The Ministry of ICT (MinTIC) aims to increase household internet connections to 70% by the end of the term of the current President Iván Duque or August 2022. Also, the Data Monitoring and Analytics Center of the Ministry of ICT (DataTIC) was established on 13 July 2021. In 2021, 60.8 million mobile devices and the internet were registered on the line, and the number of mobile devices such as mobile phones, tablets, and laptops, exceeded 119% of the total population. However, the actual number of internet users was 34.7 million, or 68% of the total population, which means that three in ten people still do not have access to the internet. Due to the lockdown, the use of mobile devices and the internet increased significantly. According to Karen Abudinen, Minister of ICT, fixed internet access in Colombia increased by 320% in 2020 (LR Republica, 2021). Bogotá is advanced in the use of ICT compared to other Colombian regions. 75.5% of the residents in

Bogotá had internet access while the national average was 43.8% according to the 2018 census. In 2021, Bogotá had the highest number of fixed Internet connections with 2,1 million (ICT Ministry, 2021). In addition, the average speed of the fixed Internet increased significantly to 39.4 Mbps while Bogotá has the highest average download speed at 51.7 Mbps in 2021.

3.2 COVID-19 and public policy in Bogotá

The first confirmed case appeared on 6 March 2020. A 19-year-old woman returning from Milan, Italy, had respiratory symptoms. After the first case, the number of cases and death increased significantly. The cumulative number of confirmed cases and deaths was 4.9 million and 124 thousand, respectively, by August 2021. The scale of the COVID-19 patients was the third-largest in Latin American and the Caribbean after Brazil and Argentina.

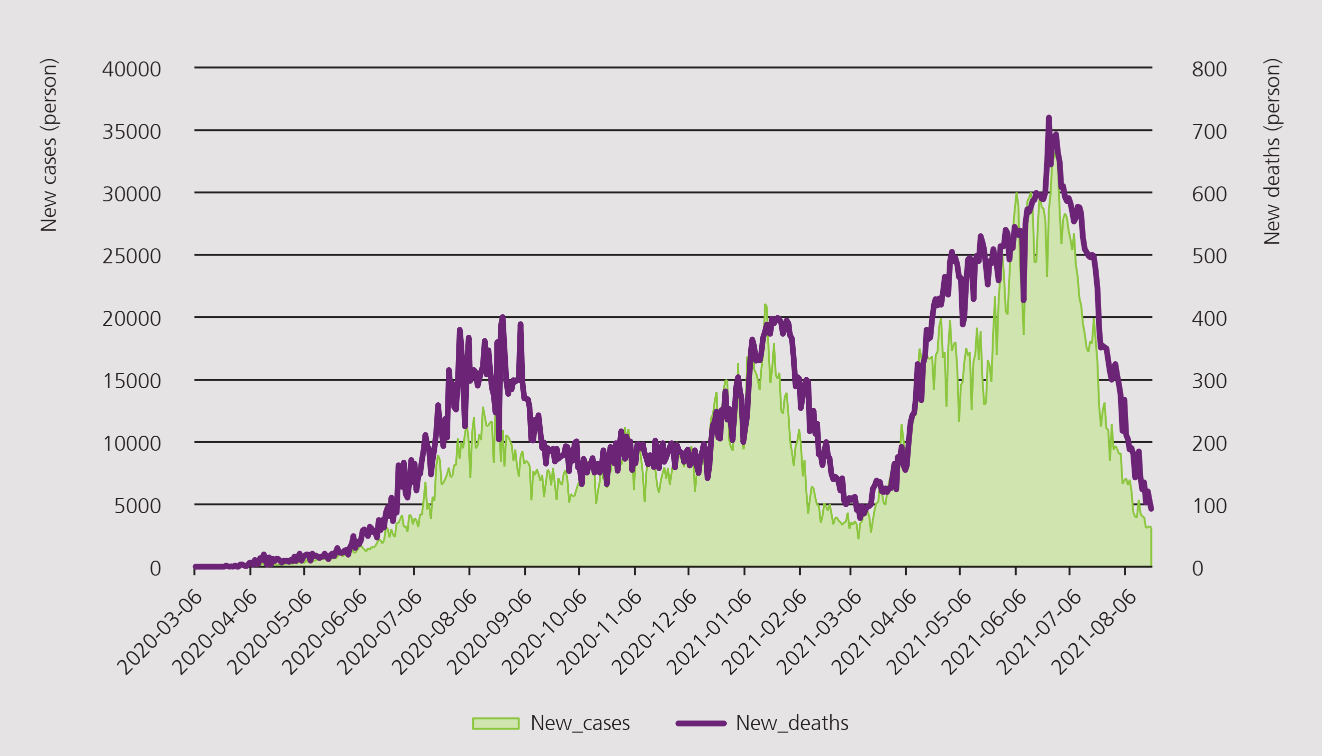


Figure 66 Number of new cases and deaths in Colombia (March 2020 - August 2021)

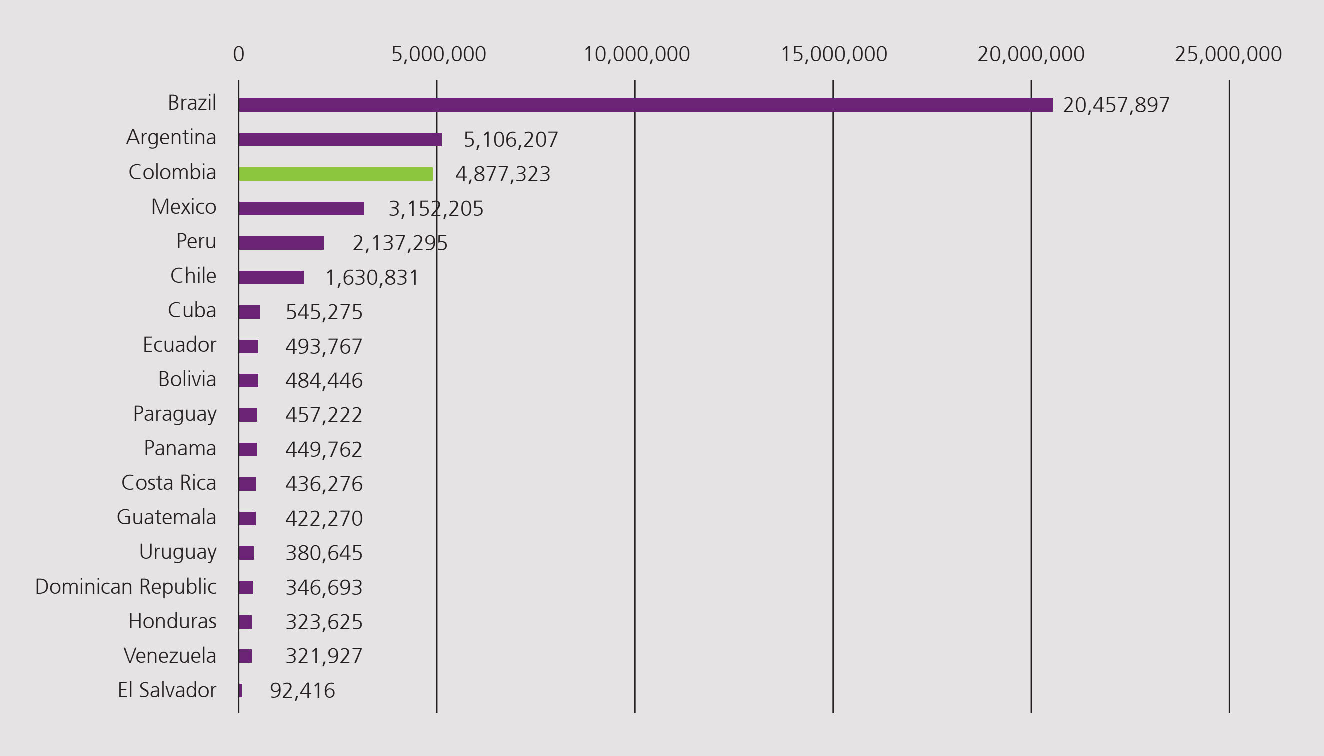


Figure 67 Trends of the COVID-19 confirmed cases in Latin America and the Caribbean by August 2021

Source: Statista, https://www.statista.com/statistics/1101643/latin-america-caribbean-coronavirus-cases/

The Colombian government declared the "economic, social and ecological emergency of the country" On 17 March 2020 and implemented strong quarantine measures at a national level. For instance, national self-quarantine, preventive isolation for the elderly over 70 years old, and the suspension of landings for international flights were continuously extended from March 2020 to August 2020. The Colombian government announced more than 70 decrees on economic and social matters in response to the COVID-19 outbreak.

The Test, Trace, and Sustainable Selective Quarantine Program, PRASS, commenced through Presidential Decree No. 1374 in September 2020 to slow down the spread of COVID-19. PRASS was designed to facilitate tests and contact tracing for the three groups:

(1) those who have respiratory symptoms or suspected patients
(2) those who are at risk and in vulnerable groups such as medical personnel, officials, high mobility, large businesses, and social workers (such as prisons or nursing homes)
(3) contacts of confirmed or suspected death to COVID-19

PASOS PARA RASTREO

PRESENTARSE

1 Presentarse y obtener la informacion basica del caso

1. Confirmation case report and collection of confirmed patient information

Dereminar el perfodo infeccioso para el caso

2 INDAGAR

2. Identify the period of infection for each confirmed person

IDENTIFICAR CONTACTOS

3 Preguntarle al caso sobre contactos durante el periodo infecciono, y determinar clasificacion de riesgo

3. Investigate contacts of confirmed cases during the period and classify risk groups

Proporcionar instrucciones de aislamiento al caso, ientificar riesgos y ofrecer apoyo

4 ALSLAR

4. Implementing Selective Quarantine

INICIAR EL RASTREO DE CONTACTO

5 Llamar a los contactos del caso e informarles sobre su exposicion, preguntarles sobre sintomas y darles instrucciones sobre la cuarentena

5. Start contact tracking

Hacerle seguimiento al caso y a sus contactos hasta que el aislamiento o la cuarenta terminen

6 IMPLEMENTAR SEGUIMIENTOS REGULARES

6. Implementation of monitoring of confirmed cases and contacts (until quarantine ends)

Figure 68 Tracking procedure in the PRASS strategy

Source: Ministry of Health

One of the most important elements of the PRASS is the National Tracking Contact Center (CCNR). There were about 1,800 trackers who made a maximum of 140,000 calls a day from 8:00 am to 8:00 pm every day. CCNR facilitated early isolation. In the first month of the CCNR operation between 15 October 2020 and 18 November 2020, the CCNR attended 444,741 calls about probable cases of infection.

3.3 ICT-oriented responses to COVID-19

CoronApp is a mobile phone application that users self-report their symptoms if unwell. CoronApp exchanges Bluetooth signals with nearby phones that run the same application. The government can make a map that shows outbreaks in the area. However, the

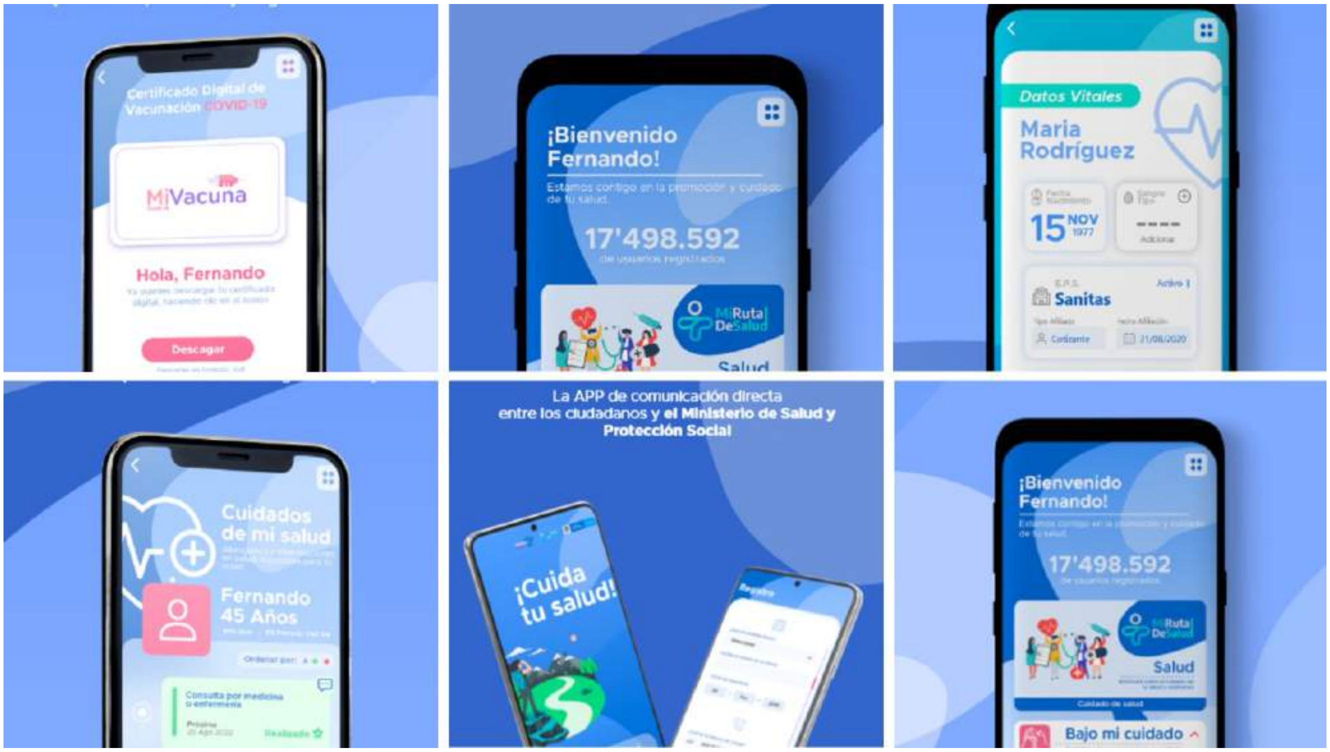


Figure 69 CoronApp-Colombia

Source: The Bogota Post (2020)

tracking function stopped due to low mobile internet access and connectivity, technical faults in Bluetooth recognition, and low reliability. Rather, CoronApp provided a function to self-report symptoms, display official data on COVID-19, and connect with the COVID-19 information call (192).

SegCovid19 is a web application that enables health monitoring with the function to report suspected deaths to COVID-19 and carry out the remote autopsy in accordance with the protocol by the Ministry of Health.

3.4. Implications

While Colombia has not built advanced ICT, internet connections and mobile phones have been increasingly adopted, in particular, in the capital city, Bogotá. With the wide spreading infection, the government established a strategy for tests and self-reporting. Those primary approaches were assisted by mobile phone applications such as CoronApp and SegCovid19. Information was publicly shared with the residents through those online platforms. The case study of Bogotá also shows the significance of ICT and mobile phone platforms.

Tableros de control SegCovid19

Este sitio contiene la información oficial del Ministerio de Salud y Protección Social sobre la pandemia por SARS-CoV-2 (COVID-19)

Fuentes: SEGCOVID y REPS.

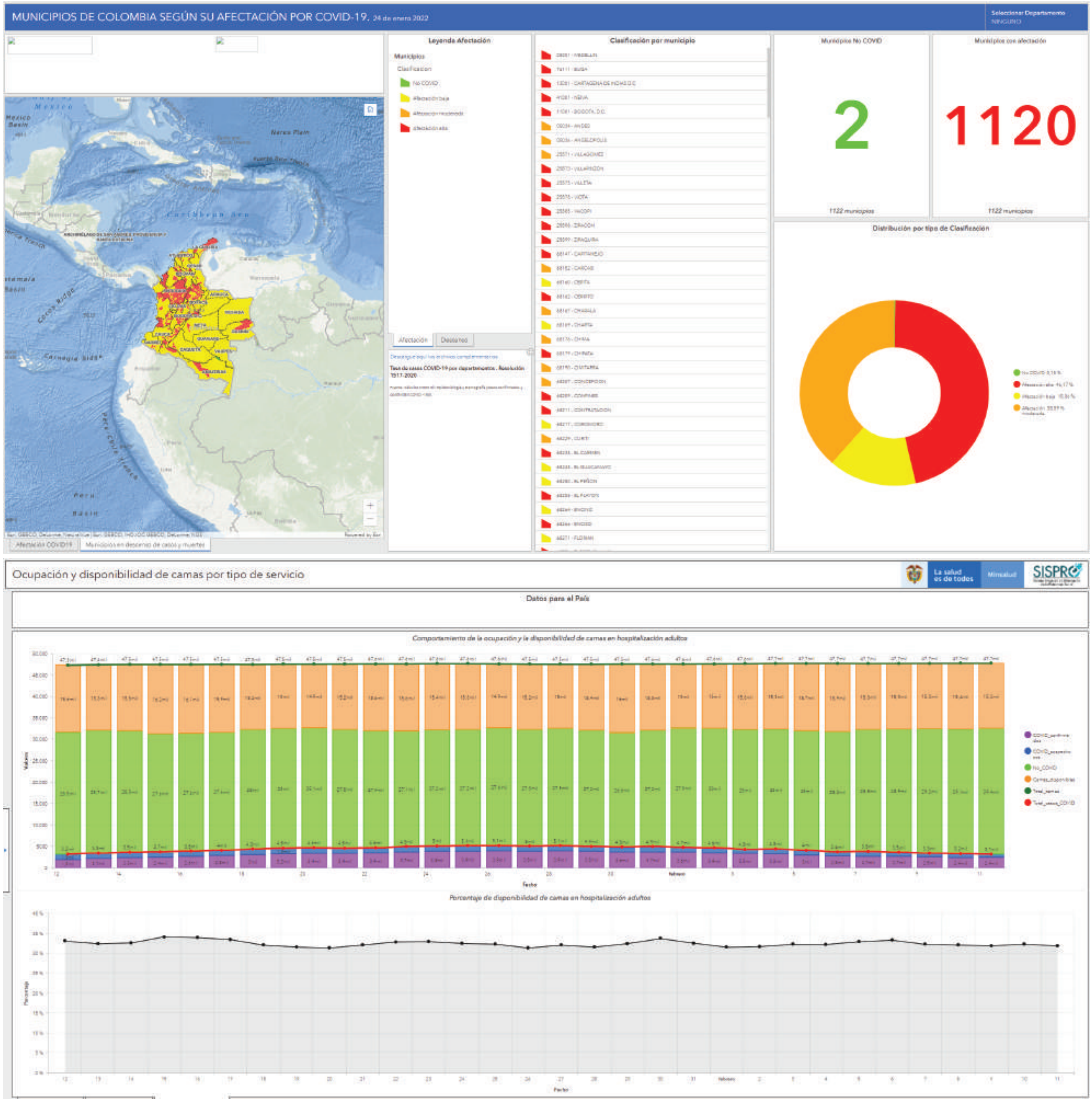


Figure 70 SegCovid19 web application

Source: Ministry of Health

4. Case Study 4: Lima, Peru

4.1 Overview

The population of Peru was 31.2 million and 79.3% of them lived in urban areas according to the 2018 Census. The urban population increased by 17.3% between 2007 and 2017, equivalent to an annual increase of 1.6% on average over the ten years (INEI). Lima, the capital of Peru, had a population density of 3,697 people/km2. Most residents in the province of Lima had access to basic services. For instance, 95.9% of them were connected to a public network for water, 94.7% to a sewer system, and 99.7% to electricity.

Peru has faced an urban planning challenge due to limited fiscal capacity. According to the National Registry of Municipalities of 2018, only 47% of the 196 provinces made the Territorial Conditioning Plan, and only 43% of the 1678 district municipalities had the Urban Development Plan. According to the Ministry of Housing, Construction, and Sanitation, only 9.5% of the projects in the urban development plan were executed in 2017. Approximately 70% of the workforces in Peru work in informal sectors. Although the government decided to support those who lost their jobs due to the pandemic, immediate actions were difficult because only 38% of Peruvian adults had a bank account.

Peru was ranked at 96th out of 176 countries in the ICT Development Index at 4.85. In 2017, only 33.5% of the households owned a computer, and 26.4% had internet access. However, smartphones have become the main means to access the internet. 73.4% of the Peruvians accessed the internet through their mobile phone (or smartphone) in 2018 (Flores-Cueto et al., 2020). The significance of smart devices was on the increase in access to the internet (Table 14). In Lima, 96.4% of the households had at least one mobile phone.

Table 14 Tendency of use internet device in Peru

Type of device	1st quarter of 2017	1st quarter of 2018	3rd quarter of 2018	3rd quarter of 2019
Computer	56.5	45.4	45.5	38.5
Laptop	23.5	21.4	22.1	20.5
Mobile phone	66.2	73.4	81.8	82.6
Tablet	4.6	3.5	4.1	3.6
Smart TV	0.4	0.7	1.6	3.6

Table 15 Cases and mortality by country (2021. 8. 22. Updated)

Country	Confirmed	Deaths	Case-Fatality	Deaths/100k Pop.
Peru	2,140,062	197,752	0.092	608.27
Hungary	810,781	30,046	0.037	307.53
Bosnia and Herzegovina	209,073	9,722	0.047	294.52
Czechia	1,677,378	30,384	0.018	284.77
Brazil	20,556,487	574,209	0.028	272.07
North Macedonia	167,991	5,654	0.034	271.38
Montenegro	109,340	1,666	0.015	267.79
San Marino	5,231	90	0.017	265.8
Bulgaria	440,911	18,467	0.042	264.73
Colombia	4,886,897	124,121	0.025	246.57
Argentina	5,130,852	110,217	0.021	245.26
Moldova	264,283	6,356	0.024	239.16
Slovakia	393,977	12,547	0.032	230.05
Paraguay	457,612	15,550	0.034	220.74
Belgium	1,163,726	25,320	0.022	220.48
Italy	4,478,691	128,728	0.029	213.49
Slovenia	263,303	4,438	0.017	212.55
Croatia	369,392	8,298	0.022	204.01
Poland	2,886,513	75,316	0.026	198.35
Mexico	3,217,415	252,927	0.079	198.26
United Kingdom	6,491,529	131,909	0.02	197.37
Chile	1,633,153	36,605	0.022	193.15
Tunisia	638,072	22,457	0.035	192.03
United States	37,673,118	628,303	0.017	191.42
Ecuador	495,115	31,985	0.065	184.1
Georgia	510,941	6,723	0.013	180.71
Romania	1,090,408	34,403	0.032	177.73
Spain	4,770,453	83,136	0.017	176.6
Uruguay	384,026	6,016	0.016	173.79
Portugal	1,017,308	17,630	0.017	171.67
France	6,682,952	113,472	0.017	169.21
Andorra	14,988	129	0.009	167.22
Panama	451,984	7,003	0.015	164.91
Lithuania	293,342	4,481	0.015	160.79
Armenia	237,249	4,737	0.02	160.16
Bolivia	486,394	18,296	0.038	158.91

Source: Coronavirus Resource Center, https://coronavirus.jhu.edu/data/mortality

4.2 COVID-19 and public policy in Lima

Peru was deadly affected by COVID-19. The mortality rate was the highest as seen in the death toll per 100,000(100K) people (Table 15). By 22 August 2021, the cumulative number of deaths reached almost 200,000, a mortality rate of 9.3%. The death rate of 608.27 per 100k population was almost double of the second-highest country, Hungary.

Lima had an infection rate of 4.66 per 100 people in 2020, higher than the national average, 3.34 per 100 in Peru in 2020. People in the age group between 30 and 59 were the most highly contracted by COVID-19, accounting for 57% of the confirmed cases, followed by young adults (18 – 29 years old) (20%), and 60 or older (17%).

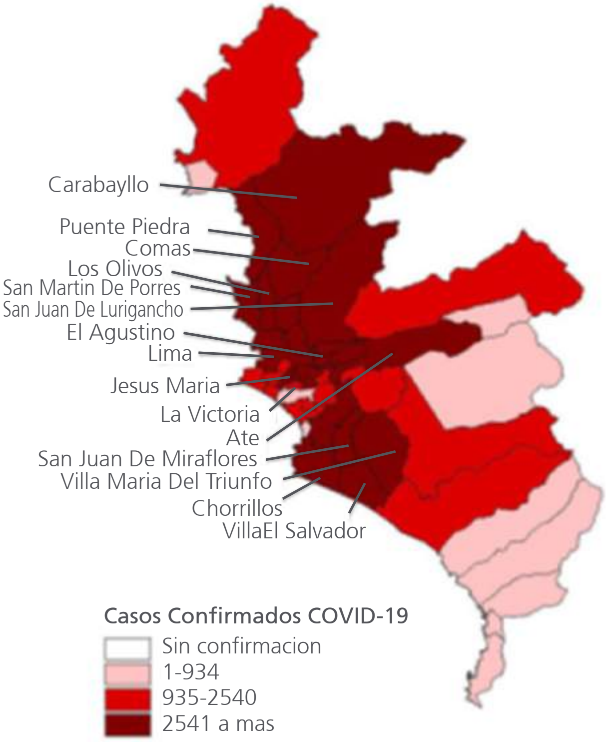


Figure 71 Confirmed cases of COVID-19 in Lima metropolitan area

Source: Ministry of Health (2021. 08. 02 presentation material)

According to the Ministry of Health on 2 August 2021, 11.9% of the residents in the Lima metropolitan area were infected by COVID-19. The most affected districts were San Juan de Lurigancho, Lima, San Martín de Porres, Comas, Ate, Villa El Salvador, Jesús María, San Juan de Miraflores, Villa María el Triunfo, Los Olivos, El Agustina and Los Olivos as seen in Figure 71. In the Lima metropolitan area, more than 80,000 deaths to COVID-19 were recorded by December 2020, which was a fatality rate of 9.4%.

On 19 February 2021, the Government of Peru extended the COVID-19 health emergency for another 180 days from 7 March 2021 to 2 September 2021. The Government of Peru indicated re-evaluation of the public health measures would be made every three weeks. All regions were categorized into Moderate, High, Very High, or Extreme to implement varying restrictions. Night curfew was implemented and quarantine on Sundays was enforced for extremely risky regions. Double facemasks were required to visit shopping centers, markets, supermarkets, department stores, and other crowded places.

The Peruvian government implemented tax policies such as tax cuts and extensions to payment deadlines. In addition, on 13 March 2020, the drug tariff was temporarily abolished through Supreme Court Decree N° 051-2020-EF. By the end of 2020 about $86.7 billion (357 billion Peruvian Sol) had been spent to provide financial and food support for low-income households, provide grants for local governments, and purchase tablets for low-income teachers and students (Ministry of Economy and Finance).

4.3. ICT-oriented responses to COVID-19

A multisectoral working group "*Te Cuido Peru* (or Peru takes care of you)" led by the Ministry of Defense, was established with an aim of detecting, isolating, and assisting the infected people and their close contacts to mitigate the virus transmission. This project was further strengthened by Supreme Decree No. 013-2020-DE (released on 26 December 2020) to establish the "Operation Tayta" strategy. Operation Tayta aimed at attending to the most vulnerable population such as the 60+ age group and people with chronic diseases. Operation Tayta was implemented by emergence response teams made up of doctors, nurses, and health technicians and assisted by the Ministries of Defense and the Interior, and the Military Force, and the National Police. Their actions were coordinated by regional and local authorities. Since the launch on 1 June 2021, Operation Tayta conducted tests with 11,527 adults with pre-existing health conditions. Among them, 4,066 (or 35.3%) were positive to COVID-19. These detected patients received early medical treatment and preventive medication for free. To ensure their home quarantine, they were given food support for 15 days.

Figure 72 Contents of Working Group "Te Cuido Peru"

Source: Peruvian government homepage

The working group Te Cuido Peru was composed of seven contents:

(1) Digital Platform: The digital platform of *Te Cuido Peru* was based on the database and information from the Ministry of Health, health-related departments such as ESSALUD, military health services, and private sectors that collect and/or process COVID-19 data. The Digital Platform allowed the geolocation of the patients and their families enabling updates and monitoring.

(2) Detection teams: the detection team is composed of 250 Rapid Response Teams (ERR) from the Ministry of Health and related departments with support from the Military Forces and the National Police. Each ERR included a medical doctor, a technician, and a driver with a vehicle. The detection team received information on suspicious cases handled by the different call centers and the application "Peru in your hands".

(3) Medical follow-up team and mental support: The team conducted clinical monitoring of the infected people and their families to assess the development of the disease. The team offered mental health care due to potentially high levels of stresses generated by prolonged isolation.

(4) Isolation: *Te Cuido Peru* provides a place for 15 days of isolation for the patients who could not isolate themselves and their families.

(5) Food support: The National Civil Defense Institute (INDECI) was responsible for providing food for the people under quarantine. Food distribution was based on geolocated data collected through a digital platform.

(7) Surveillance team: A monitoring team consisting of military and police personnel was trained to monitor and patrol the quarantine.

(8) Assistance in the treatment of deaths: Support of military and police personnel was provided to assist in the management of deaths outside medical facilities in accordance with the guidelines by the Ministry of Health.

Figure 73 Digital Platform of "Te Cuido Peru"

Source: Andina (2020)

The Peruvian government launched three main digital initiatives:

(1) the mobile application Perú en tus manos to monitor the COVID-19 cases.

(2) the platform for self-evaluation.

(3) the platform developed by the National Institute of Health to provide consultation for new confirmed cases.

The application Peru en tus manos was launched as a part of the digital strategy designed by the Working Group "*Te Cuido Peru*". The app was managed by the Digital Government Secretary with three main objectives:

(1) to alert citizens of risky areas with affection information.

(2) to assist self-diagnosis.

(3) to provide updated information about COVID-19. The app was available for Android, Huawei, and Apple operating systems and had been downloaded more than one million times before 14 May 2021, approximately 3% of the total population.

Figure 74 Peru en tus manos application

Source: https://elcomercio.pe/tecnologia/actualidad/coronavirus-peru-en-tus-manos-covid-19-aplicacion-minsa-guia-para-usar-la-app-que-muestra-las-zonas-de-riesgo-de-covid-19-en-el-peru-noticia/?ref=ecr

Registration was required to access this application for which personal detail such as the social security number and mobile phone number was mandatory. The app collected location information. For instance, Bluetooth recordings were used to identify the location of the user for tracking contacts.

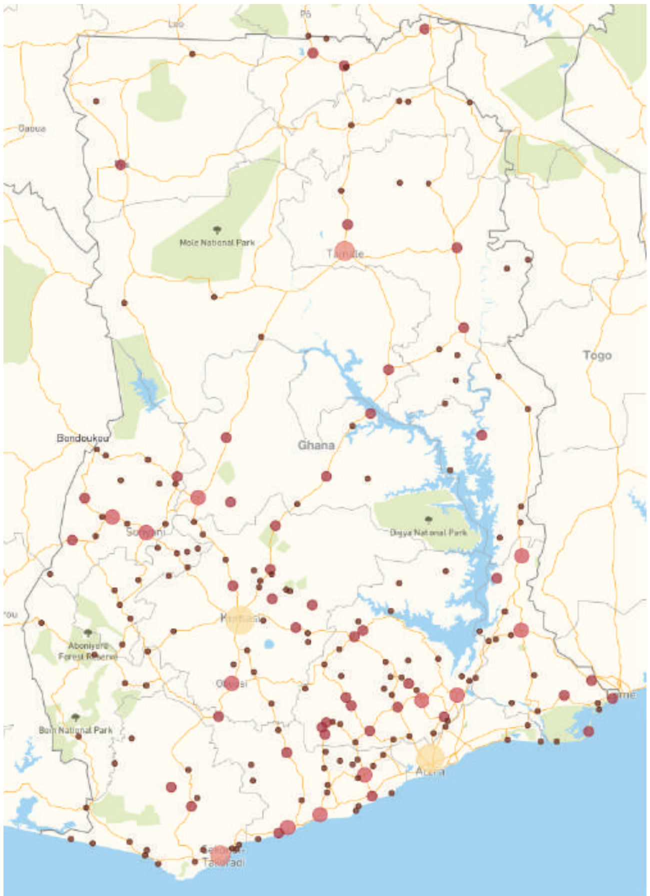
4.4 Implications

Lima, as the capital of Peru, had a high number of infections and the number of death tolls was also high. The government implemented social lockdown measures and provided support for quarantine. Those government actions were assisted by mobile phone applications, such as Peru en tus manos, by providing updated information and tracking functions. The case study of Lima shows the applicability of big data approaches in handling the health threat.

5. Case Study 5: Accra, Ghana

5.1 Overview

Accra is the capital of Ghana with half of the residents living in urban areas. It accounted for more than a quarter of the national total currently with 4.5 million people while the second-largest Ghanaian city, Kumasi had 2.8 million people. These largest two urban areas have had a population density of 3,700 people/km^2 in Accra and 5,000 people /km^2 in Kumasi. The population of Accra is on the exponential rise (AFRICAPOLIS),



●	Above 3M	1	4.5M
●	1-3M	1	2.8M
●	300 000 - 1M	2	1M
●	100 000 - 300 000	11	1.5M
●	30 000 - 100 000	44	2.1M
•	10 000- 30 000	150	2.4M

Figure 75 Urban agglomerations in Ghana in 2015

Source: Africapolis, www.africapolis.org

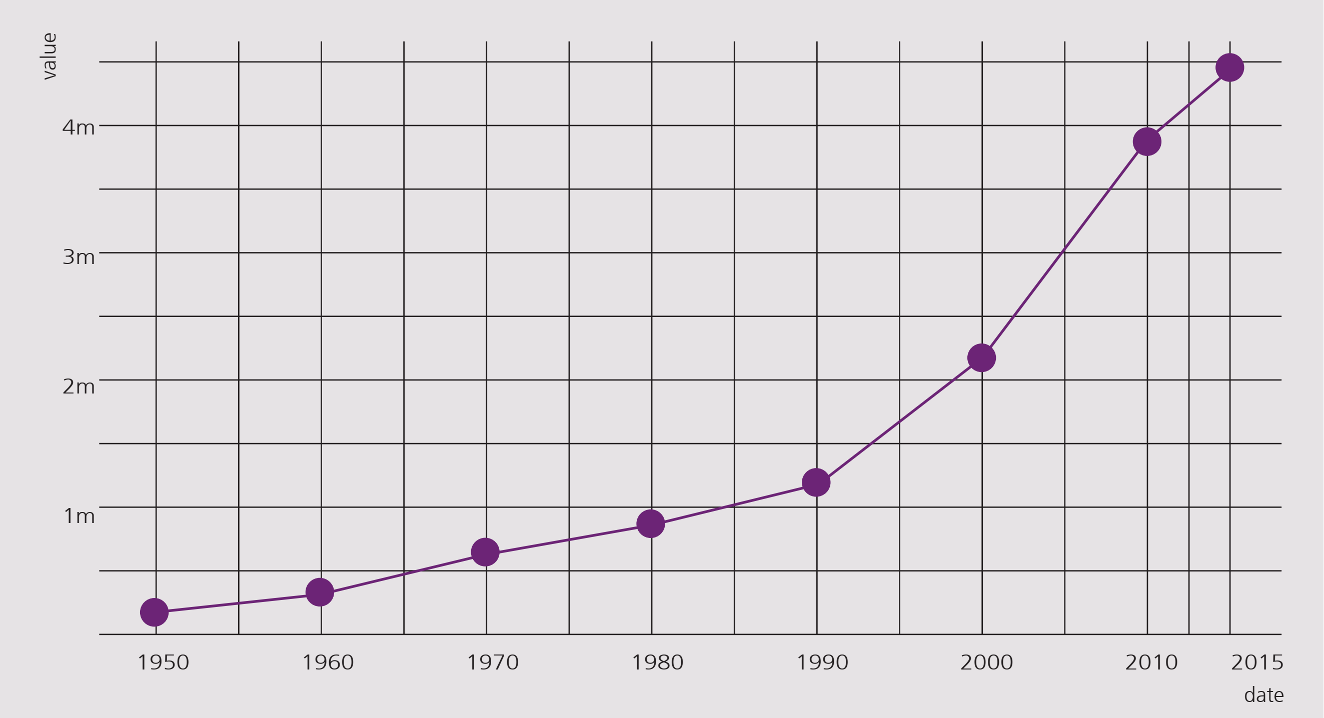
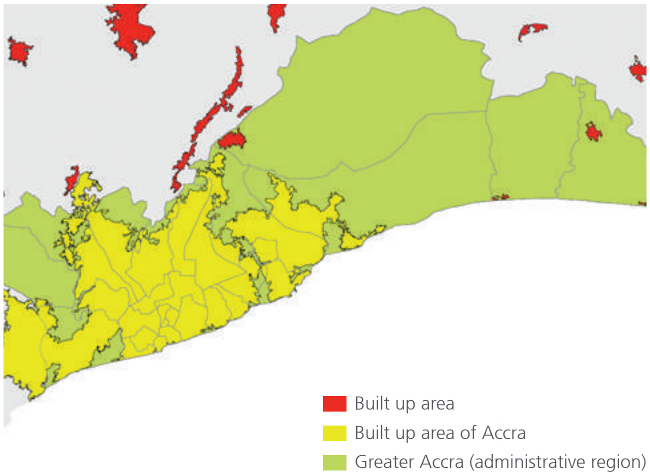


Figure 76 Population growth in Accra between 1950 – 2015

Source: Africapolis, www.africapolis.org



Internet use and mobile cellular subscription have been growing in Ghana according to the World Bank Open Data. While per 100 people mobile phone subscribers were less than one in 2000, but it increased up to 134.3 by 2019.

In an extensive survey, Accra showed a high rate of mobile phone ownership. Table 16 shows the ratio of mobile phone holders in Accra and its districts. In 2019, 98% of the respondents replied that they had a mobile phone. While the high rate was observed in almost all districts, it was obvious across all age groups (Demographic Health Survey).

Figure 77 Built-up area and Administrative area in Accra

Source: Africapolis and Database of Global Administrative Areas (GADM), www.gadm.org

Table 16 Mobile phone ownership

Name of district	2008	2014	2016	2019
Accra	88.6% (5230)	96.2% (4101)	96.6% (2210)	97.9% (1947)
Ablekuma Central Municipal	83.3% (413)	98.1% (426)	99.5% (188)	95.1% (102)
Ablekuma North Municipal	90.1% (545)	98.2% (282)	100% (269)	100% (274)
Ablekuma West Municipal	93.1% (233)	94.6% (74)	98.8% (84)	100% (279)
Accra Metropolis	85.2% (297)	84% (125)	97.6% (84)	
Ada West	70.9% (134)	92.6% (122)		
Adenta Municipal		96% (101)	100% (103)	
Ashaiman Municipal	91.1% (327)	98.8% (162)	99.4% (162)	89% (73)
Ayawaso Central Municipal	82.1% (134)		98.7% (77)	
Ayawaso East Municipal	80.6% (196)	98.1% (206)	95.3% (86)	90.5% (84)
Ayawaso North Municipal	100% (69)	100% (90)		93.9% (66)
Ayawaso West	89.9% (99)	96.6% (88)		95% (80)
Ga Central Municipal	91.5% (106)	94.9% (79)	100% (103)	100% (99)
Ga East	98.1% (206)	97.4% (195)		98.1% (107)
Ga North Municipal	88.3% (196)		100% (116)	
Ga South Municipal	52.4% (82)			
Ga West Municipal	98.9% (92)	95.8% (380)		100% (127)
Korle Klottey Municipal			90.5% (63)	
Kpone Katamanso	90.9% (110)	93.7% (63)		
Krowor Municipal	98.9% (87)	100% (62)		100% (95)
La Dade-Kotopon	98.4% (252)	96.9% (320)	94.8% (77)	94.9% (78)
La-Nkwantanang-Madina	95.2% (210)	100% (86)	100% (112)	98.5% (65)
Ledzokuku Municipal	91.1% (325)	92.7% (164)	98.7% (75)	
Ningo/Prampram	35% (120)	85.6% (90)	75.3% (77)	
Okaikwei North Municipal	91.3% (184)	97% (237)	100% (101)	100% (89)
Shai Osudoku		85.9% (149)		
Tema Metropolitan	95.1% (550)	100% (144)	82.6% (92)	98.2% (219)
Tema West Municipal		100% (96)		
Weija Gbawe Municipal	90.9% (263)	98.3% (360)	94.1% (341)	100% (110)
Outside of Accra	47.8% (41291)	82% (39844)	88.4% (20850)	92.8% (21766)

Source: Demographic Health Survey, https://dhsprogram.com/

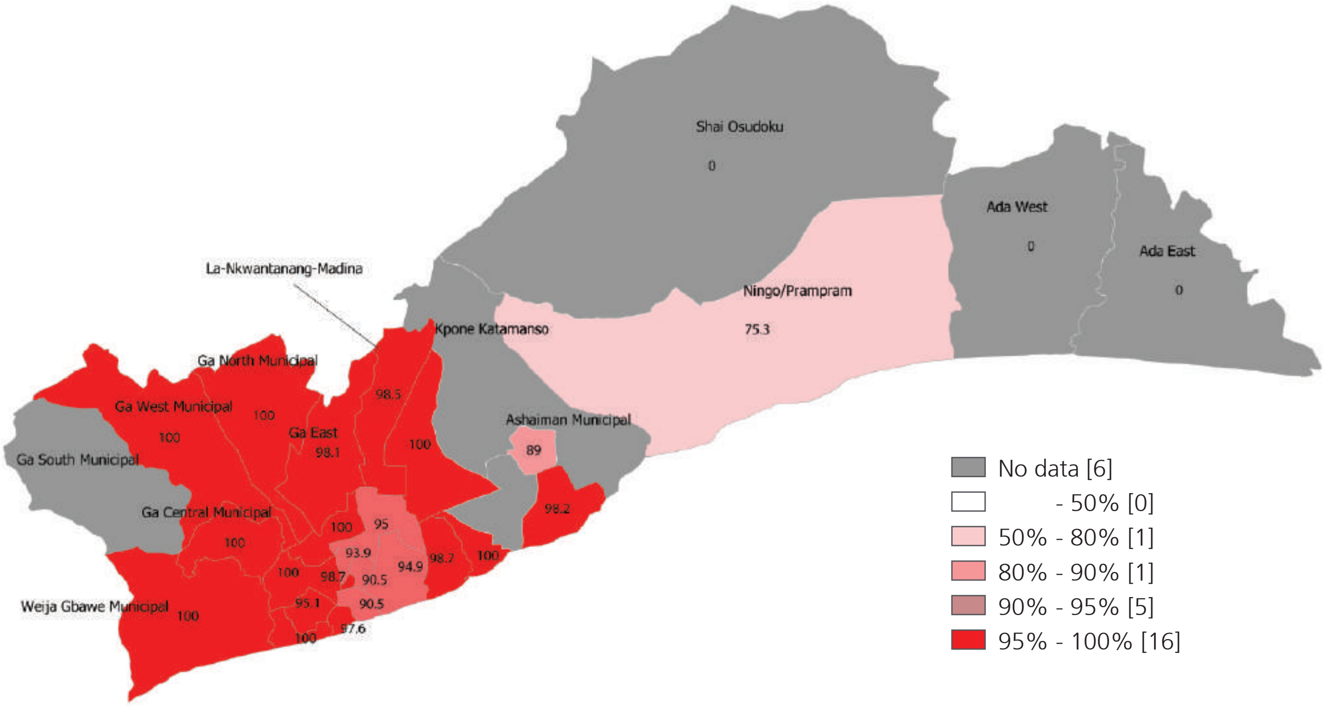


Figure 78 A map of mobile phone ownership in Accra

Source: Demographic Health Survey,

https://dhsprogram.com/

5.2. COVID-19 and public policy in Accra

In the emergency press briefing on 12 March 2020, the Minister of Health Kwaku Agyemang-Manu announced Ghana's first two confirmed cases in Accra. By the end of March 2020, there had been 152 confirmed cases, 5 deaths, and 22 recovered patients. A partial lockdown was implemented in the two largest cities – Accra and Kumasi. These cities were the most deadly affected by COVID-19. There were restrictions on human mobility and police and military teams patrolled in major roads. Only essential workers such as healthcare, media, food vendors, restaurants, security agencies were allowed to move in these towns at the very beginning of the COIVD-19 outbreak.

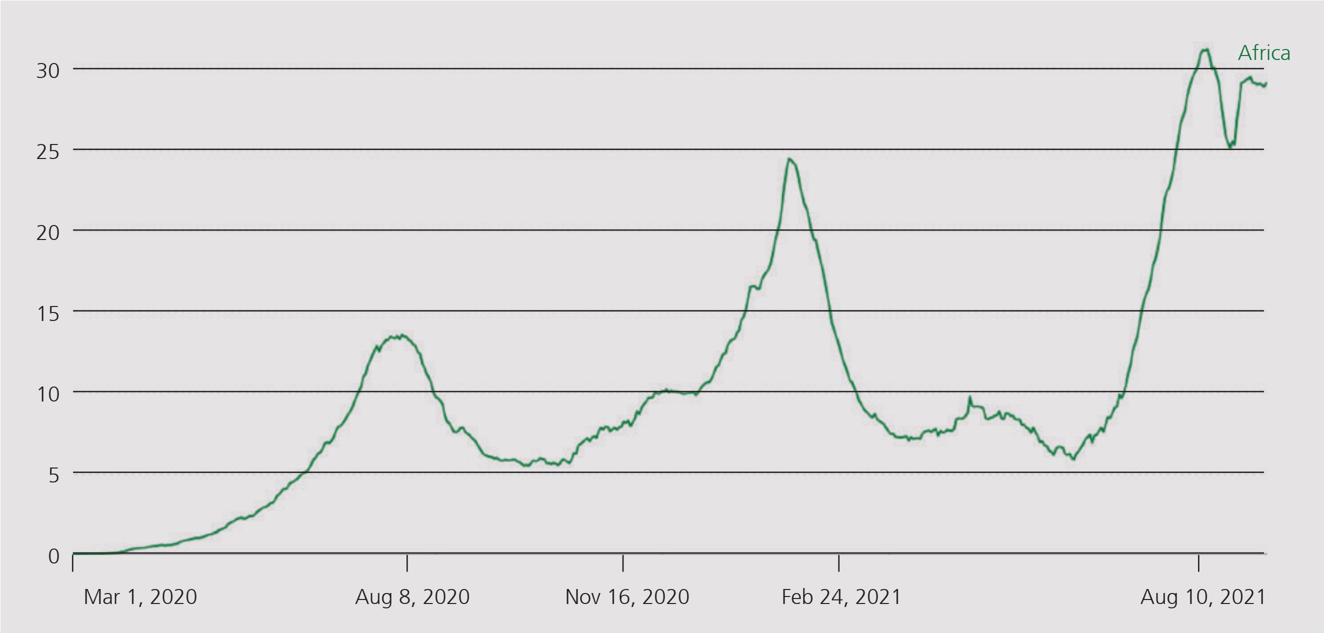


Figure 79 Daily new confirmed COVID-19 cases per million people - Shown is the rolling 7-day average. The number of confirmed cases is lower than the number of actual cases; the main reason for that is limited testing.

Source: Our World in Data retrieved 13 August 2021

The first peak of COVID-19 started from June 2020. Despite the sudden increase in covid confirmed cases, restrictions were relaxed on religious services and schools. Religious services were allowed to commence from 5 June 2020 with the mandatory use of masks and capped at 100 people. The President announced that final year students at junior high schools, senior high schools, and universities could return to school from mid-June 2020. According to the new Executive Instrument, E.I. 164, signed by the President on 15 June 2020, those who refused to wear a face mask in public space could face jail terms up to 10 years or a fine up to GHS 60,000 (US$10,320) or both. The government deployed over 200 people to monitor COVID-19 cases in senior high schools and the government distributed 50,000 PCR testing kits across Ghana. The government spent US$35 million on testing suspected cases.

The second peak took place from February 2021. Neither mass gatherings nor sporting activities were allowed. The government provided 10 million sanitizers to school children. Beaches, nightclubs, cinemas, and pubs were closed, and the President urged workplaces to run on a shift system.

The third peak appeared from July 2021. President Nana Akufo-Addo banned church activities and large gatherings during the Easter celebration. Travels to high-risk countries were regulated to stop or postpone.

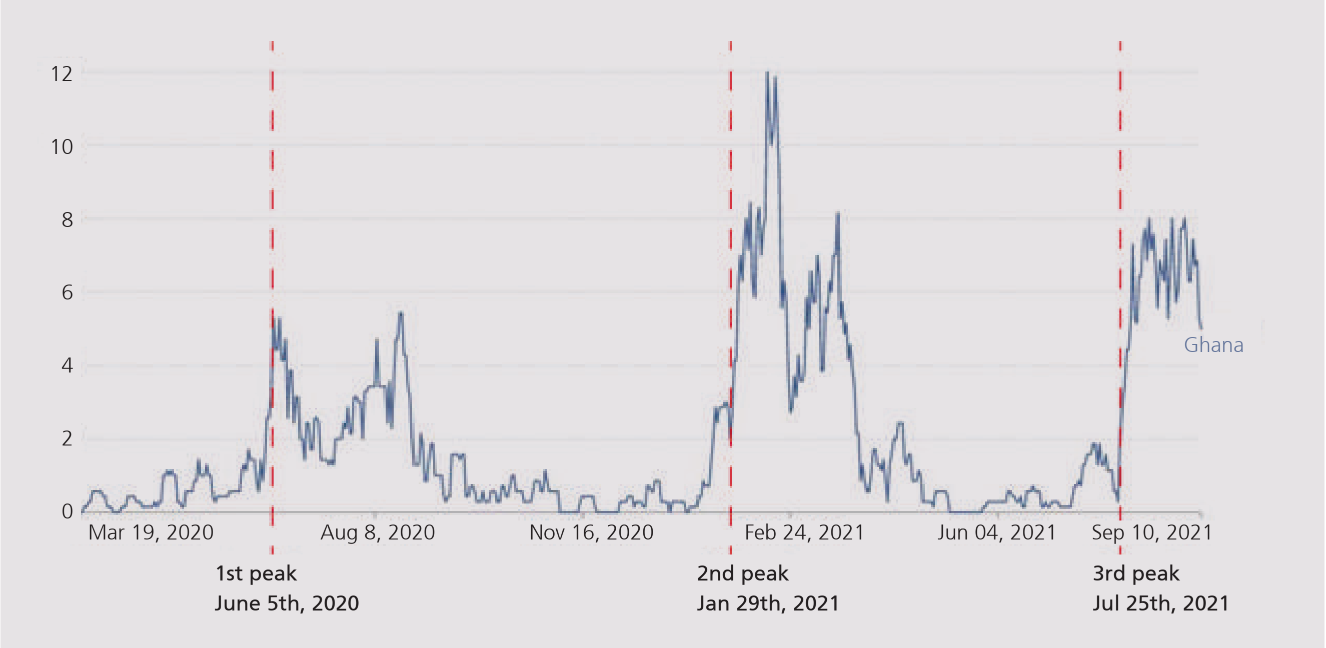
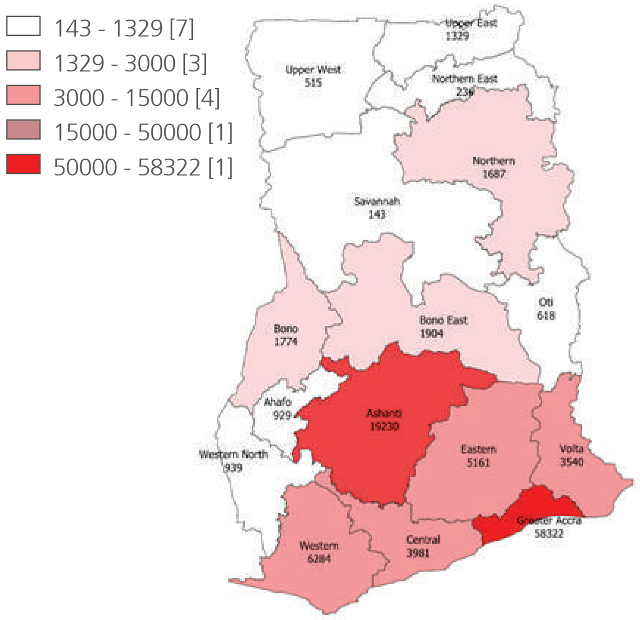


Figure 80 Daily new confirmed COVID-19 deaths, 7-day moving average.

Note: Limited testing and challenges in the attribution of the cause of death mean that the number of confirmed deaths may not be an accurate count of the true number of deaths from COVID-19.



Confirmed cases were highly concentrated in Accra. Nationwide the vaccination rate remained low, less than 3% by July 2021.

In response to COVID-19 outbreaks, the GH¢100 billion Ghana CARES “Obaatanpa” program was launched. It was a 3.5-year comprehensive program to mitigate the pandemic, return the country to a sustained path of robust growth, and create a stronger, more resilient, and transformed economy.

Figure 81 Cumulative Cases per Region

Source: Ghana Health Service - Ministry of Health,
https://www.moh.gov.gh/ghana-health-service/

In April 2020, at the onset of the pandemic, the Government announced a package of economic stimulus measures called the Coronavirus Alleviation Program (CAP).

Key initiatives included:

- GH¢579.5 million for COVID-19 Emergency Preparedness and Response Plan (EPRP)
- GH¢200 million relief for provision of water and sanitation for households for three months
- GH¢1,028 million as a three-month subsidy for electricity use in households and businesses
- GH¢54 million for distribution of hot meals and food packages; GH¢ 323 million as relief (e.g. PPEs, tax waiver, allowances, transportation and COVID insurance) for frontline health workers
- GH¢600 million for Micro, Small and Medium-Sized Enterprises (MSMEs) via the Coronavirus Alleviation Program - Business Support Scheme (CAPBuSS) to be supplemented by up to GH¢400 million in bank lending
- the announcement to build 101 new hospitals in districts that lack such facilities, 7 regional hospitals for the newly created regions, rehabilitation of the Effia-Nkwanta Regional Hospital, and 2 psychiatric hospitals (Agenda 111). In addition, three infectious diseases centers will be constructed in each of the 3 ecological zones of the country.

The Ghana Cares Program – Stabilization - was implemented in the period Jul 2020 – Dec 2020. It offered a temporary reduction in the cost of basic services extending the provision of free water for additional 3 months and free electricity for customers on the lifeline tariff for additional 6 months. It also ensured food security expanding support from 1.2 million to 1.5 million for farmers (e.g, fertilizer, seeds, and extension service) under the Planting for Food and Jobs Program. It also supported farmers through the Rearing for Food and Jobs Program (RFJ).

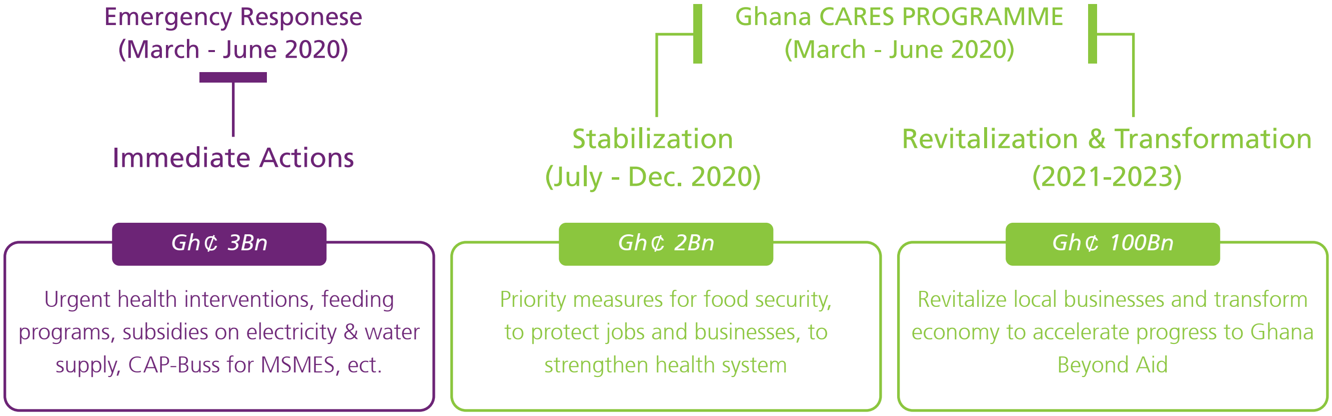


Figure 82 Overview of Ghana's Response to COVID-19 pandemic

The Ghana Cares Program was to strengthen the health system by building new 100-bed district hospitals, seven new regional hospitals, rehabilitation of Effia-Nkwanta regional hospital (Takoradi), and two new psychiatric hospitals. In addition, 3 infectious diseases centers would be built in each of the three ecological zones of the country.

The Ghana Cares Program – Revitalization & Transformation was proposed for 2021 – 2023. The Ghanaian government wanted to accelerate the implementation of the Ghana Beyond Aid agenda by providing support to private sectors in targeted sectors.

This program was to support light manufacturing and enhance the efficiency of public sectors including the following seven initiatives.

1. To support commercial farming and attract educated youth into agriculture
2. To build Ghana's light manufacturing sectors
3. To develop engineering/machine tools and ICT/digital economy industries
4. To facilitate fast track digitization
5. To develop Ghana's housing and construction industry
6. To Establish Ghana as a regional hub
7. To review and optimize government flagship programs

Source: Ministry of Finance Ghana (2020)

Table 17 Lockdown policy in Ghana

Year	Date (mm/dd)	Measures	Duration
2020	03/30 - 04/18	Require not leaving home with some exceptions	19 days
2021	02/23 – 03-29	Recommend not leaving the house	One month
2021	04/21 -	Recommend not leaving the house	4 months (ongoing)

Table 18 International border control

Year	Date (mm/dd)	Measures	Duration
2020	01/24 – 03/16	Screen arrivals	2 months
2020	03/17 – 03/21	Quarantine arrivals from some or all regions	4 days
2020	03/22 – 08/31	Ban arrivals from all regions	5 months
2020 -2021	09/01 – 03/06	Screen arrivals	6 months
2021	03/07 – 05/02	Ban arrivals from all regions	2 months
2021	05/03 -	Screen arrivals	5 months (ongoing)

5.3 ICT-oriented responses to COVID-19

In 2016, the Global Epidemic Prevention Platform (GEPP) was developed when Korea Telecom (KT) proposed that global telecoms could use big data to prevent contagions at the UN General Assembly. Using roaming data, this platform provided information on visits to contaminated areas to the Centers for Disease Control and Prevention. The platform began in Kenya in 2018 and gradually expanded to Ghana and Malaysia with the use of a Google App . As part of the COVID-19 response, it tracked movements of travelers, sent warning messages to people who have visited infectious areas, and allowed the government to collect and monitor data (KT, 2020)

GEPP - ① International Mobility Tracing

Roaming-driven data analysis allows a national health authority to identify the movement of those who traveled disease-prone countires and to send SMS alerts to improve the travelers' risk awareness.

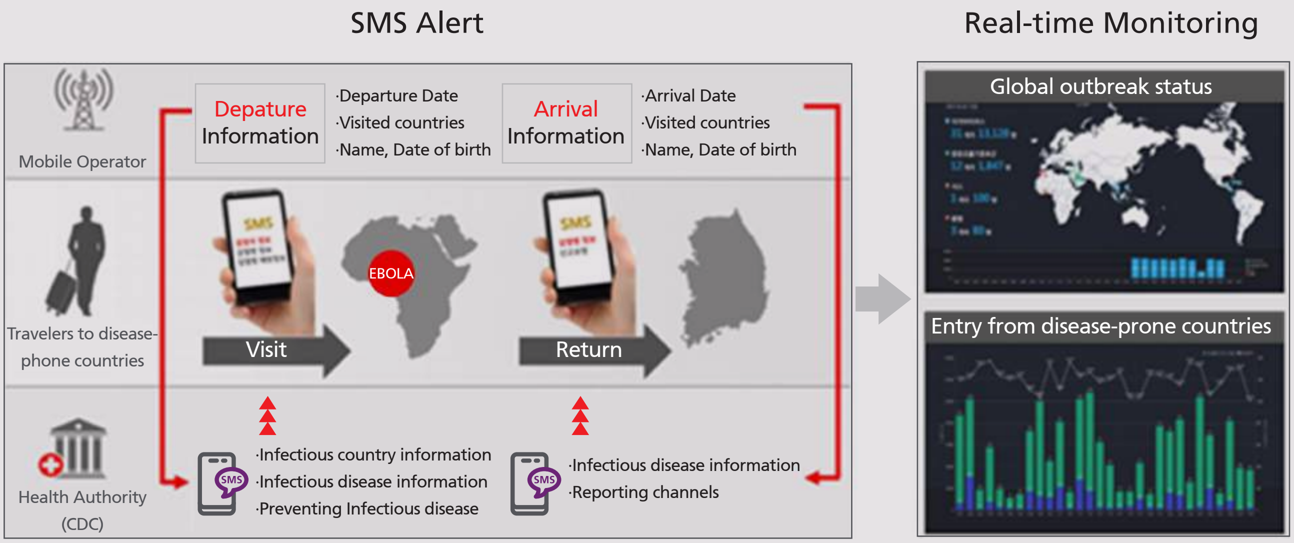
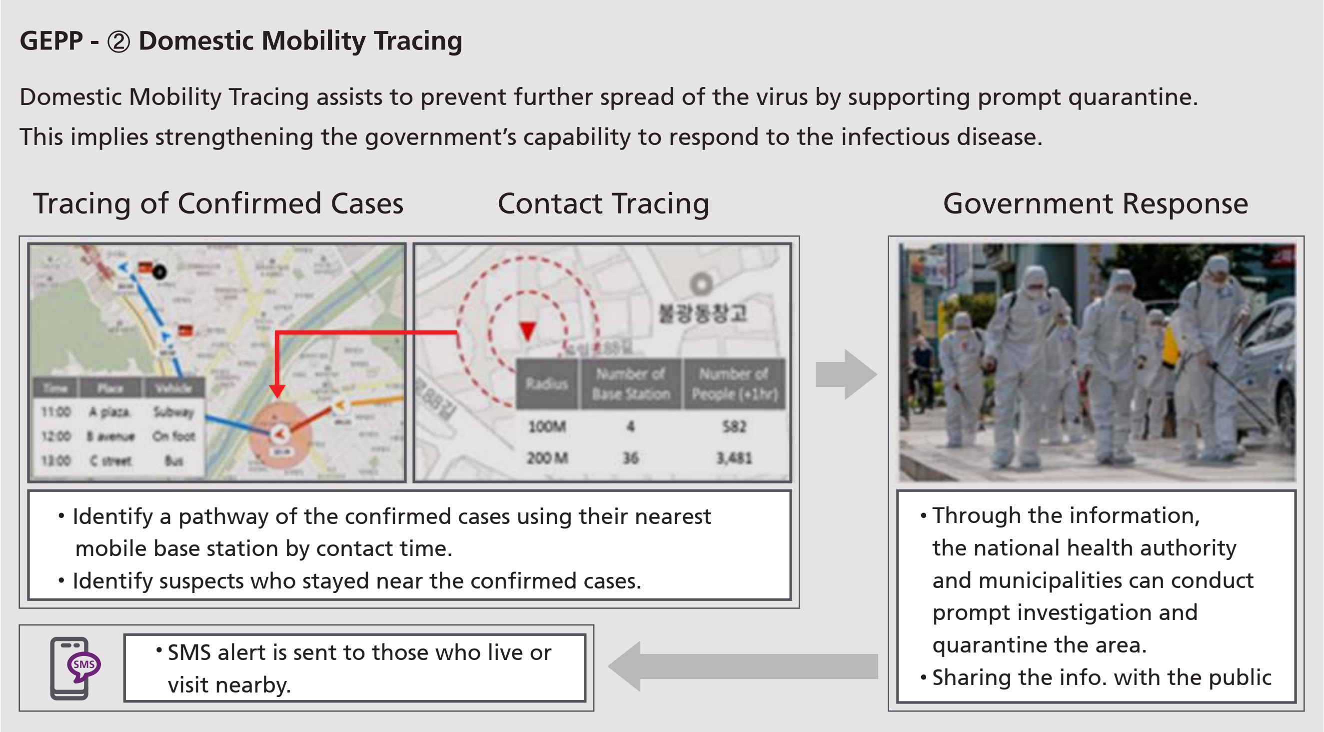


Figure 83 Global Epidemic Prevention Platform - International mobility training

https://play.google.com/store/apps/details?id=com.kt.gepp.and&hl=en&gl=US



GEPP - ② Domestic Mobility Tracing

Domestic Mobility Tracing assists to prevent further spread of the virus by supporting prompt quarantine. This implies strengthening the government's capability to respond to the infectious disease.

Tracing of Confirmed Cases

Time	Place	Vehicle
11:00	A plaza	Subway
12:00	B avenue	On foot
13:00	C street	Bus

Contact Tracing

Radius	Number of Base Station	Number of People (+1hr)
100M	4	582
200 M	36	3,481

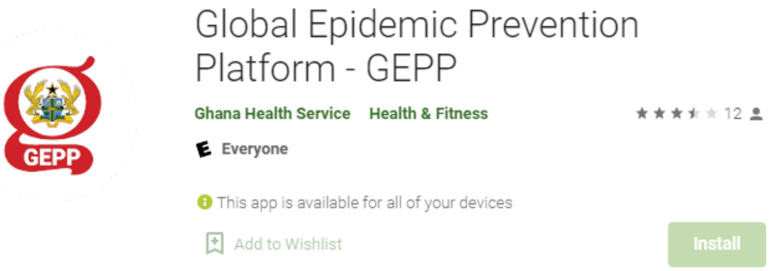
- Identify a pathway of the confirmed cases using their nearest mobile base station by contact time.
- Identify suspects who stayed near the confirmed cases.

Government Response

- Through the information, the national health authority and municipalities can conduct prompt investigation and quarantine the area.
- Sharing the info. with the public

- SMS alert is sent to those who live or visit nearby.

Figure 84 Global Epidemic Prevention Platform - Domestic Mobility Tracing



Global Epidemic Prevention Platfrom - GEPP

Ghana Health Service Health & Fitness

★★★★★ 12

Everyone

This app is available for all of your devices

Figure 85 Global Epidemic Prevention Platform on google playstore

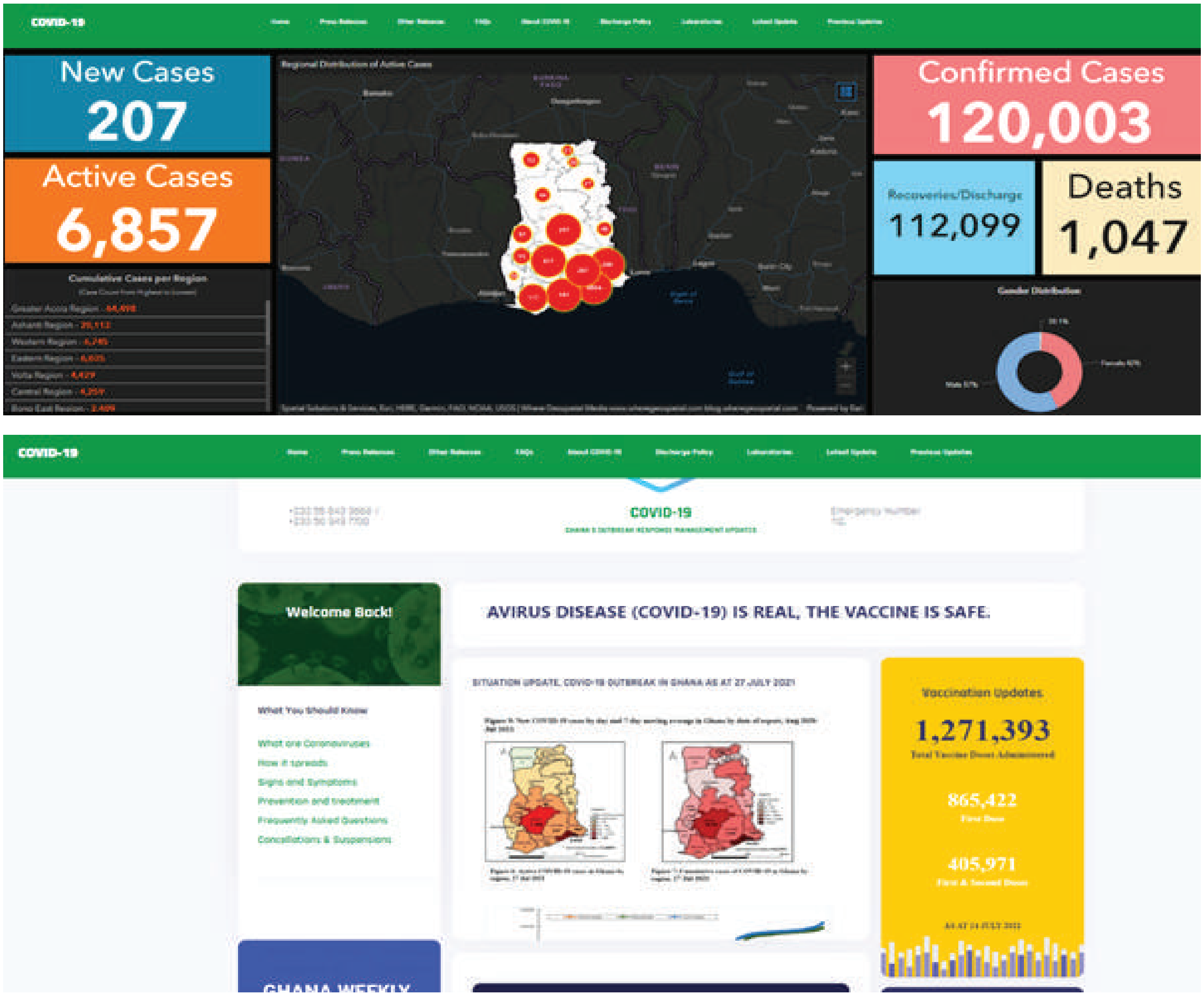


Figure 86 Ghana's COVID-19 Response website – interactive map and dashboard

5.4 Implications

Accra's mobile phone ownership has been matured reaching 98%. This appeared to almost all age groups. Vaccines were not available for ordinary citizens, but information about COVID-19 was shared through websites and the mobile phone app was developed for contact tracing purposes. Although the use of it was not as high as the Korean example in this report, the case study of Accra shows there is potential to make use of big data in infectious disease management.

6. Case Study 6: Addis Ababa, Ethiopia

6.1 Overview

Ethiopia is the third-largest African country after Nigeria and Egypt. Ethiopia has approximately 24 million urban residents, 27% of the total Ethiopian population and recent urban growth is noteworthy. Despite rapid economic growth as seen in the doubled GDP per capita between 2010 and 2015 and marked population growth at 2% per annum, Ethiopians have been vulnerable to environmental shocks such as drought. Addis Ababa is the capital of Ethiopia with 3.7 million inhabitants.

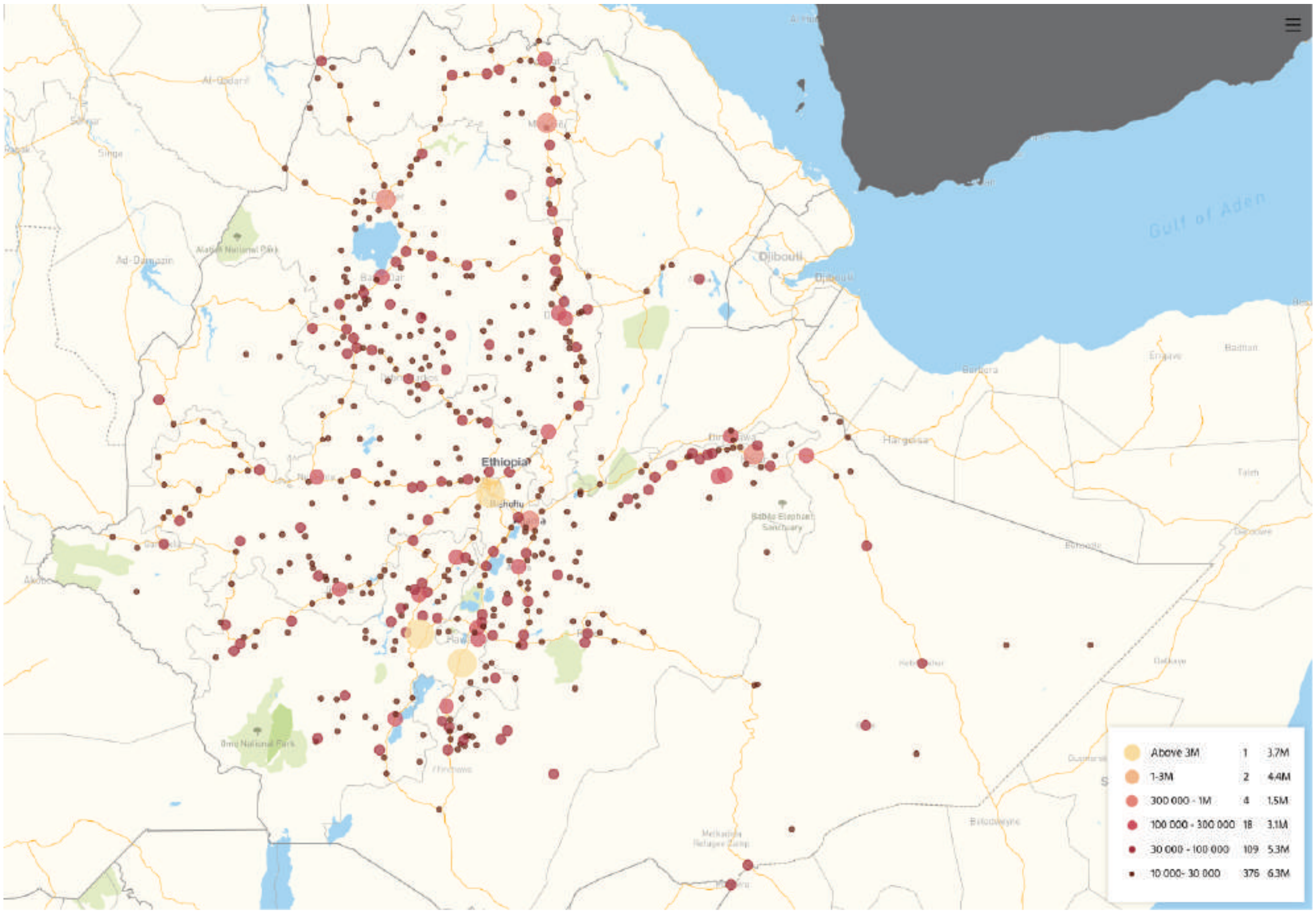


Figure 87 Urban agglomerations in Ethiopia

Source: Africapolis, https://africapolis.org/en/country-report/Ethiopia

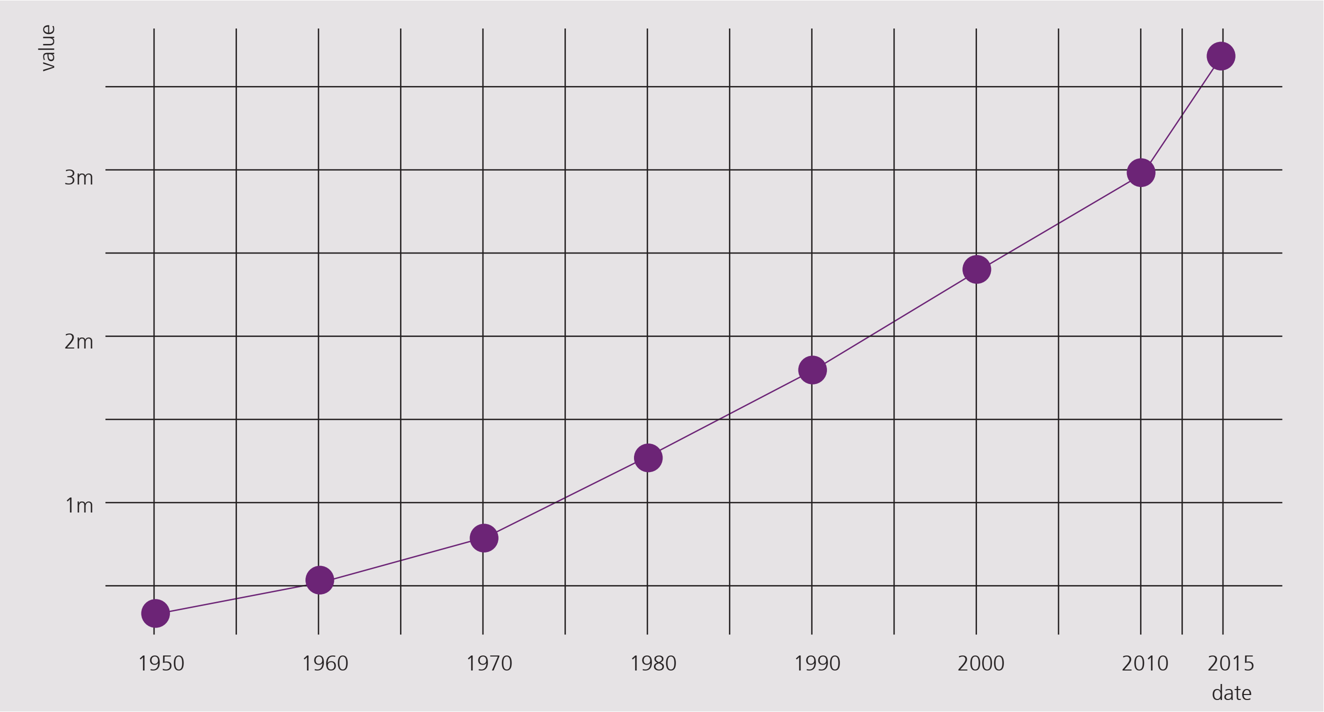
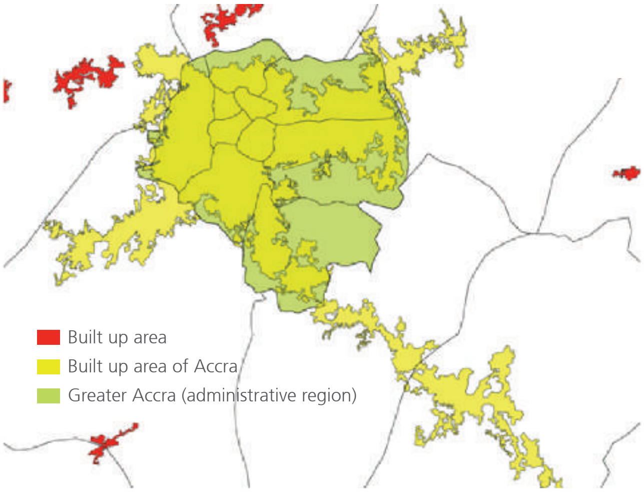


Figure 88 Population growth in Addis Ababa between 1950 – 2015

Source: Africapolis, www.africapolis.org



In Addis Ababa, 98% of the residents had a mobile phone in 2016, an increase from 91% in 2010. Compared to the regions (59%), Addis Ababa has shown high reliance on mobile phones demonstrating the potential to employ big data approaches. The high mobile phone ownership appeared across all districts and all age groups within Addis Ababa.

Figure 89 Built-up area and administrative area in Addis Ababa

Source: Africapolis and Database of Global Administrative Areas (GADM), www.gadm.org

Table 19 Mobile phone ownership in Addis Ababa

Name of district	2010	2016
Addis Ababa	90.5% (5808)	98% (5639)
Addis Ketema	93.5% (509)	97.7% (725)
Akaki - Kalit	88.9% (578)	98.5% (328)
Arada	92.8% (540)	92.2% (372)
Bole	90% (598)	99.4% (466)
Gulele	95.1% (710)	99.1% (643)
Kirkos	93.3% (534)	99.7% (300)
Kolfe - Keran	85.5% (768)	97.6% (859)
Lideta	94.3% (300)	97.3% (262)
Nefas Silk	86.3% (571)	97.5% (673)
Yeka	88.7% (700)	99.1% (1011)
Outside of Addis Ababa	24.9% (71915)	59.1% (69585)

Source: Demographic Health Survey, https://dhsprogram.com/

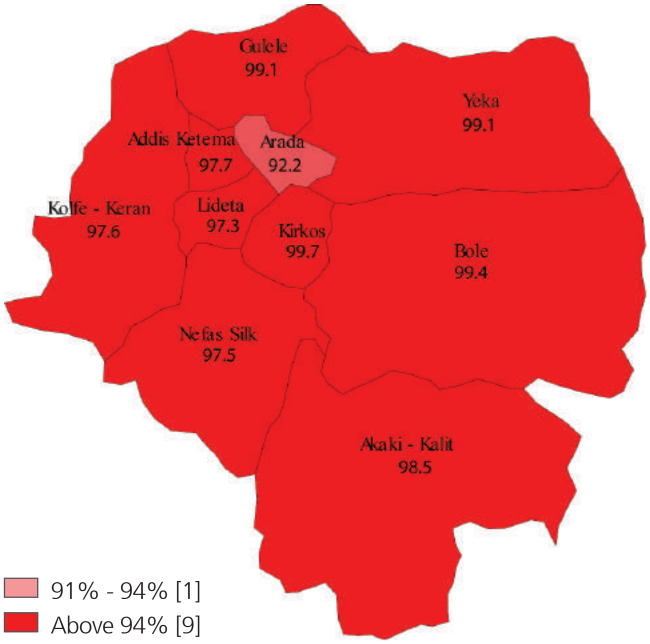


Figure 90 Ratio of people who answered yes to "Has a mobile telephone" in 2016.

Source: Demographic Health Survey, https://dhsprogram.com/

6.2. COVID-19 and public policy in Addis Ababa

Since the first COVID-19 case was reported on 13 March 2020, contact tracing and social distancing measures have been in place. However, despite the growing case numbers, Ethiopia did not implement travel bans. The confirmed cases were highly concentrated in Addis Ababa. While the reported confirmed cases were not as high as in Latin American countries, the vaccination rate remained very low, less than 2% by August 2021.

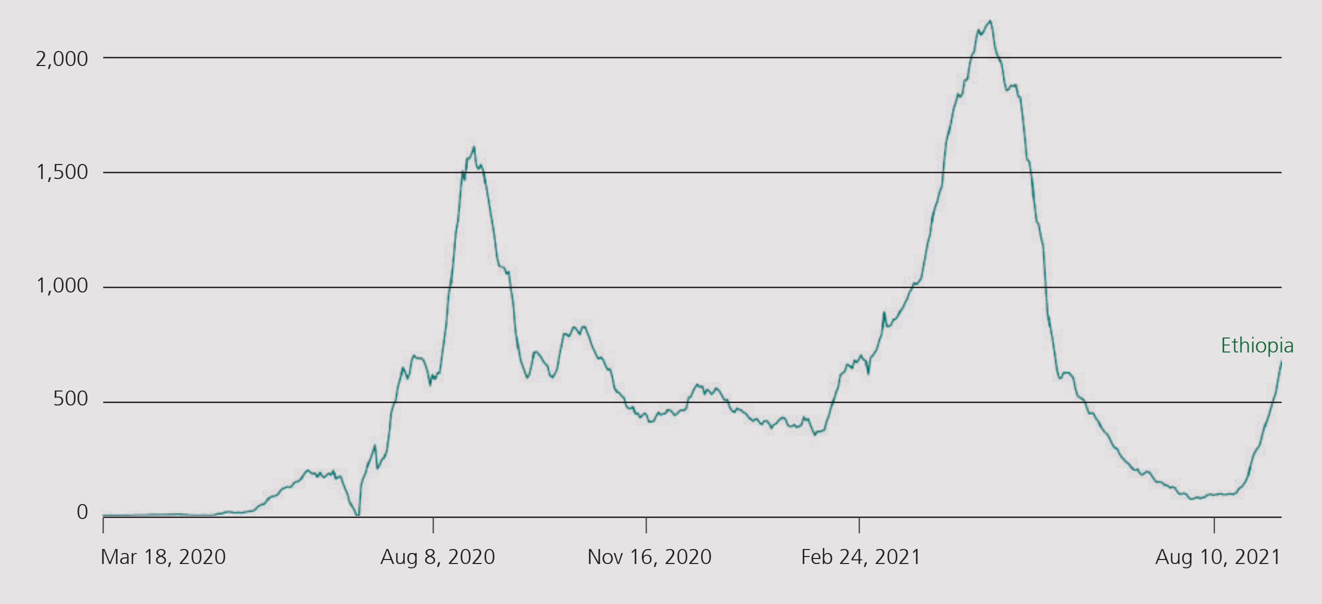


Figure 91 Daily new confirmed COVID-19 cases, 7-day moving average.

Note: The number of confirmed cases is lower than the number of actual cases; the main reason for that is limited

Source: Our World in Data retrieved on 13 August 2021

The first peak appeared from April 2020. The Ethiopian government declared a 5-month State of Emergency including the following measures (Embassy of the Federal Democratic Republic of Ethiopia, 2020):

- The banning of all public gatherings of more than four people. The ban was applied to all religious, governmental, non-governmental, commercial, political, and social gatherings. In the gatherings with a group of four, 2-meter social distancing was required.
- All movements at land borders, except for the flow of cargo and essential goods, were banned.
- In-person schooling was banned.
- Sporting activities were prohibited.
- Playgrounds for children were closed.

The second peak started from April 2021. Social distancing measures included as follows (GARDAWORLD, 2021):

- Public gatherings were limited to a maximum of 50 people.
- A face covering was required for all individuals in public space.
- International entry, through the Addis Ababa Bole International Airport (ADD) and land border crossings, remained open with reduced capacity.
- Travelers over the age of 10 were required to take a COVID-19 test within 120 hours of their arrival. Then, arrivals were required to complete mandatory self-quarantine for seven days.

Figure 92 Daily new confirmed COVID-19 deaths, 7-day rolling average.

Note: Limited testing and challenges in the attribution of the cause of death mean that the number of confirmed deaths may not be an accurate count of the true number of deaths from COVID-19.

Due to the limited hospital capacity, The Federal Ministry of Health (FMOH) created the patient flow protocol as described in the diagram below (Figure 93).

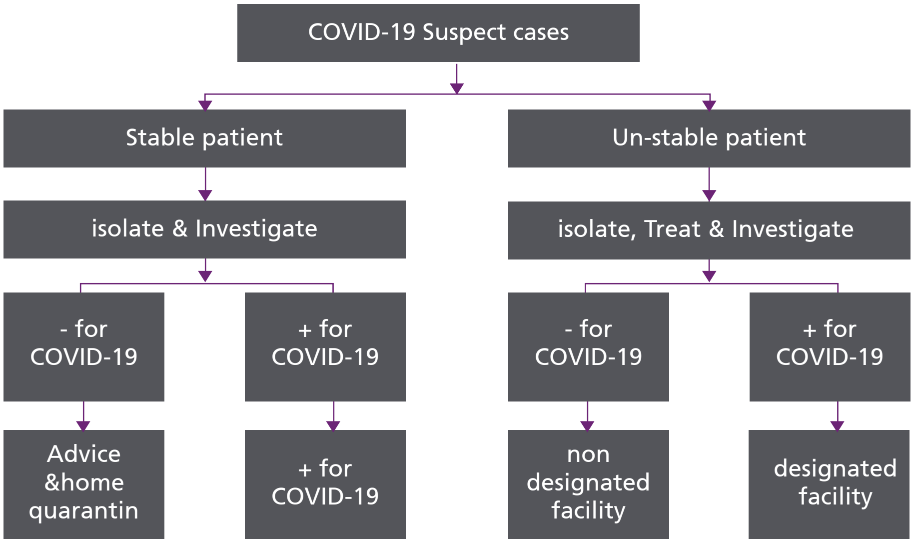
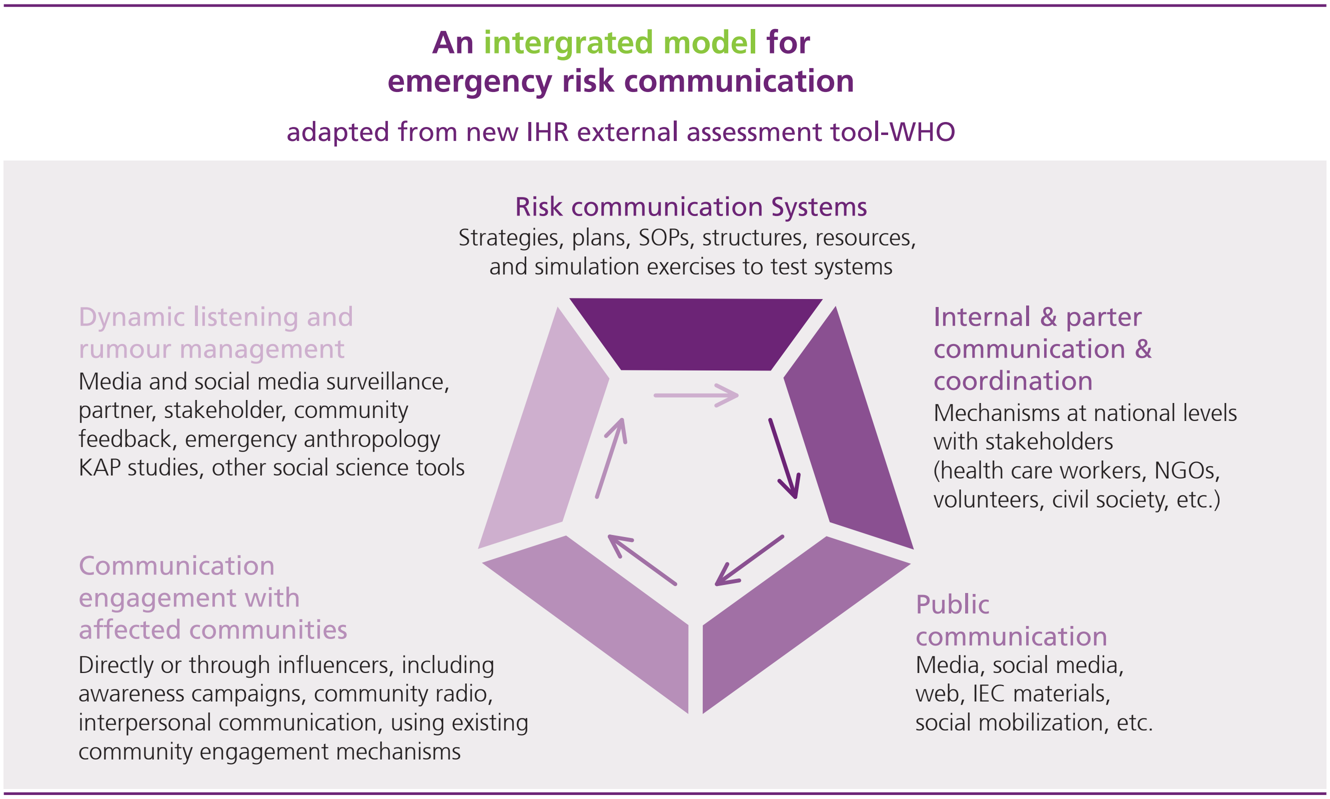


Figure 93 COVID-19 patient flow diagram



An intergrated model for emergency risk communication

adapted from new IHR external assessment tool-WHO

Risk communication Systems
Strategies, plans, SOPs, structures, resources,
and simulation exercises to test systems

Internal & parter communication & coordination
Mechanisms at national levels
with stakeholders
(health care workers, NGOs,
volunteers, civil society, etc.)

Public communication
Media, social media,
web, IEC materials,
social mobilization, etc.

Communication engagement with affected communities
Directly or through influencers, including
awareness campaigns, community radio,
interpersonal communication, using existing
community engagement mechanisms

Dynamic listening and rumour management
Media and social media surveillance,
partner, stakeholder, community
feedback, emergency anthropology
KAP studies, other social science tools

Figure 94 The Risk Communication and Community Engagement (RCCE)

Source: The Federal Ministry of Health (2020)

Table 20 Lockdown (by August 2021)

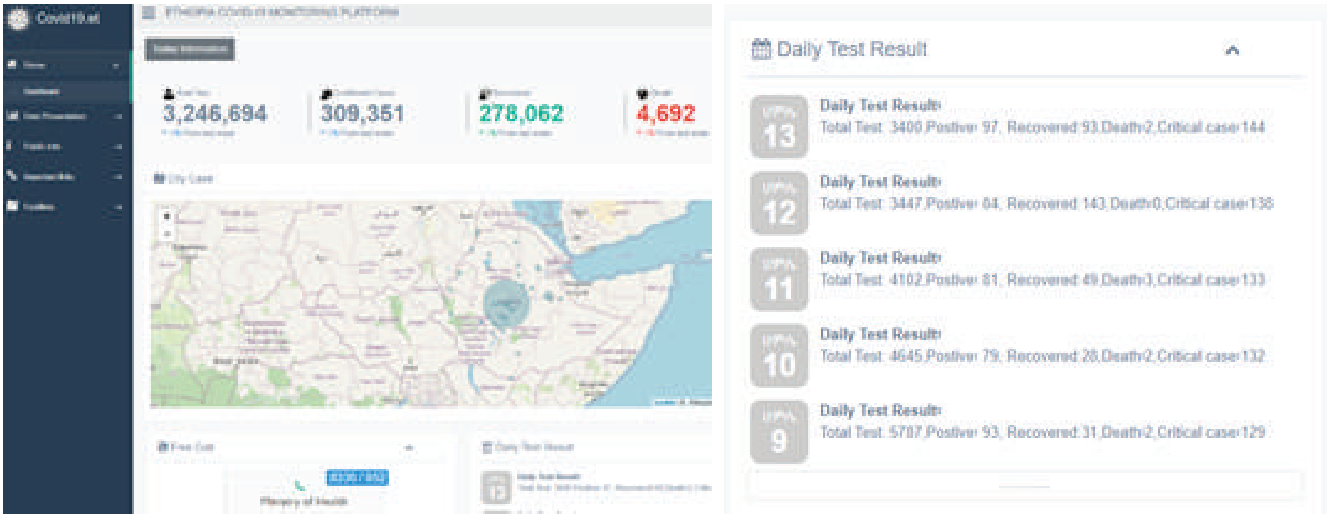
Year	Date (mm/dd)	Measures	Duration
2020	04/08 - 10/26	Recommend not leaving the house	7 months

Table 21 International border control (by August 2021)

Year	Date (mm/dd)	Measures	Duration
2020	01/28 – 03/22	Screen arrivals	2 months
2020	03/23 – 09/10	Ban arrivals from some regions	6 months
2020– 2021	09/11 –	Quarantine arrivals from some or all regions	11 months (ongoing)

6.3 ICT-oriented responses to COVID-19

Ethiopia’s COVID-19 Response website (https://www.covid19.et/covid-19/) provided statistics, interactive maps, social aid programs. Up-to-date COVID-19 information by province was provided through official press releases as well.



Daily Test Result
Total Test: 3400,Positive: 97, Recovered:93,Death:2,Critical case:144

Daily Test Result
Total Test: 3447,Positive: 84, Recovered:143,Death:0,Critical case:138

Daily Test Result
Total Test: 4102,Positive: 81, Recovered:49,Death:3,Critical case:133

Daily Test Result
Total Test: 4645,Positive: 79, Recovered:28,Death:2,Critical case:132

Daily Test Result
Total Test: 5707,Positive: 93, Recovered:31,Death:2,Critical case:129

Figure 95 Ethiopia’s COVID-19 Response website – interactive map, dashboard, and daily test result

6.4 Implications

Addis Ababa has undertaken rapid urbanization. Ethiopia has not established a sound foundation for ICT development yet, but mobile phones have been widely spread, in particular, Addis Ababa. The use of mobile phone applications was limited. Instead, the government website provided updates to the citizens. While the ICT infrastructure is underdeveloped, the high rate of mobile phone ownership demonstrates that big data from mobile phone signals can be employed for contact tracing. This can be employed in Addis Ababa first by virtue of the popularity of mobile phones relative to other regions.

7. Strategies for international collaboration

Inter-city collaborations have attracted attention to tackle increasingly growing global crises. Multiple Korean institutions have been involved with international cooperation. In addition to the Korea International Cooperation Agency (KOICA), a leading Korean Official Development Assistance (ODA) institution, a wide range of public agencies have worked for sharing the know-how of Korean urbanization experiences, often called 'Export of Cities' (Kim et al., 2021). For instance, the Seoul Metropolitan Government (SMG) has the Global Urban Partnership Division, and the Seoul Housing & Community Cooperation (SH) created the Seoul Urban Solutions Agency (SUSA) to share the successful urban policy of the SMA and create new opportunities for private sectors through these public efforts. A national urban development agency, Land & Housing Cooperation (LH), is carrying out overseas urban development projects in which the South Saad Al-Abdullah in Kuwait is a representative example. Besides, the Korea Overseas INfrastructure & Urban Development Corporation (KIND) was established in 2018 by the central government to support overseas investments of Korean companies. The Trade-Investment Promotion Agency (KOTRA) was established in 1962 to facilitate export, but it has also contributed to international collaboration. Those recent efforts have paid attention to ICT-oriented urban management systems. For instance, the SMG carried out a project about a transport card system in Bogota in the period 2011 – 2015. Those experiences have established a sound foundation for inter-city partnerships in developing collective responses against COIVD-19 and possible future disease outbreaks. The outwardly governmental efforts have appeared in the countries that have undertaken economic growth in the late 20th century such as South Korea, China, Japan, and Singapore. Kim et al. (2021) described those governmental efforts as urban development leadership. They illustrated China as money-giving, Singapore as money-making, and Korea as money-leveraging.

As discussed in the case studies, metropolitan areas used to benefit from agglomeration economies, but the health threat from the pandemic also severely appeared in large metropolitan areas. In response to COVID-19, suburban locations have been more favored than high-density inner-city areas (Maalsen et al., 2020). Most countries implemented travel bans causing economic loss, especially in metropolitan areas. Informatization has obviously appeared in the case study areas (Table 22). In particular, metropolitan areas have better-established information infrastructure than regional areas as seen in the number of internet subscribers and mobile phone holders.

Table 22 Informatization of the case study areas

Cities	Informatization
Bogotá	**In Colombia** · 68% of the households had internet access in 2021. · In 2020, internet access increased by 320%. In Bogota, households with internet access were 75.5% in 2018.
Lima	**In Peru** · 33% of the households had a computer, 26% had internet access in 2017. · The mobile phone subscription rate was 66.2% in 2017, but increased to 82.6% in 2019 In Lima, 96.4% of the households owned a mobile phone. In Indonesia, an investment of US$ 2.1 billion was made in ICT development in 2021.
Jakarta	**In Jakarta,** · 85% of households had internet access. · 4G availability increased by 7.7% in the period 2018-2020. · There is an ongoing Jakarta Smart City project.
Kuala Lumpur	**In Malaysia** · Internet subscriptions increased by 1.5 times over the recent decade. ·The internet penetration rate was 87.7% in 2020. · The mobile phone subscription rate was 98.6%.
Accra	**In Ghana** · Internet use was lower than 2% in 2004 but increased to 37.9% in 2019. · Mobile phone subscription increased from 8 per 100 people in 2004 to 134 per 100 people in 2019 (some had more than one mobile phone). In Accra, the mobile phone subscription rate was 97.6%.
Addis Ababa	The mobile phone ownership rate was 92-99% (while in other regions, 59.1%, on average).

Table 23 COVID-19 responses: social distancing measures and ICT-oriented approaches

Cities	Examples of travel restrictions	ICT-oriented approaches
Bogotá	· Nationwide travel ban (March 2020) · Travel bans on people over the age of 70 · Ban on international flights, March-August, 2020	CoronApp was developed to detect patients but did not include the tracking function due to the internet and Bluetooth connection issues. SegCovid19 provided statistics and information. PRASS, a phone-based service, provided support for patients.
Lima	· Travel restrictions by moderate, high, very high, or extreme region. · Curfew and Sunday travel restrictions in selected risky areas.	Te cuido Peru (Peru take care of you) integrated medical information, location information of patients for monitoring. Peru en tus manos (Peru in your hands) was a mobile phone app for self-detection. Only 3% of the citizens downloaded the app.
Jakarta	· Massive social distancing measures (PSBB and PPKM). · Closure of schools and offices. · Restrictions on religious and cultural activities. · Social gathering capped at 5 people. · Limited operation of public transport within 50% capacity	Online consultation services were operated. The websites provided statistics, location information of patients, and government support. The Jakarta Smart City Service assisted booking for vaccination, measuring risks, providing information.
Kuala Lumpur	Strict travel restrictions (March 2020). · Travel bans on inter-regional movements (two weeks) · Restrictions on religious, sports, and cultural activities. · Restrictions on childcare centers and schools. · Border closure and mandatory self-quarantine for 14 days	MySejahtera, a mobile phone app., was developed for tracking and managing patients.
Accra	· Staying at home order · Restrictions on international arrivals · Closure of workplaces	GEPP was developed by KT for disease prevention. The government websites provided statistics and basic information.
Addis Ababa	· Staying at home order · Restrictions on international arrivals · Closure of workplaces	The government websites provided statistics and basic information.

Public policy focused on social distancing measures by limiting physical mobility. Working from home was mandated in many cities and countries if not essential workers. While physical distancing was effective, strict regulations on mobility generated economic and mental crises. There were protests against those restrictions to ensure human liberty. Those who did not have space for working from home were living in small-size housing, preschoolers, and in hospitality were severely affected by the mobility restrictions. Contact tracing was implemented but ICT was not actively employed in the disease management in the six case study areas. Given the high use of mobile phones, telecommunication big data was under-utilized.

South Korea has not yet established integrated governance for inter-city collaboration although multiple institutions have made progress. The establishment of governance for inter-city collaboration would be useful not only for COVID-19 responses but also for global urban challenges such as Sustainable Development Goals (SDGs). Government-to-Government (G2G) arrangements may be able to support leveraging private actors. Global partnerships will require advanced technology that can be provided by private sectors. COVID-19 responses would benchmark the current strategies that are to make use of G2G arrangements to leverage private actions.

While medical approaches are effective, telecommunication big data can enhance the efficiency in managing infectious diseases such as contact tracing and patient management. Korean ICT is anticipated to contribute and lead epidemiological advancements.

Citizen wating in the COVID-19 PCR test clinic in Seoul (c) Hyungwoong Chang, December 2021

Chapter 6. Conclusions and Implications

1. Conclusions and Implications

1. Conclusions and Implications

This research was carried out in response to the COVID-19 outbreak to improve the efficiency of contact tracing by actively employing MBD. The research has developed an epidemiological model in the smart city environment against the global health crisis. The two datasets were established: (1) the route of movements of mobile phone subscribers and (2) the O-D matrix by administrative unit.

Three sets of analysis were developed based on MBD: (1) analysis of the spread of infectious disease, (2) prediction of the infectious disease, and (3) analysis of alert text messages. The first set of analyses can assist to identify people at high risk due to their contact with confirmed case(s), which can contribute to the early detection of new outbreaks before the appearance of symptoms. The second set of analyses confirmed that social distancing measures (such as limiting social gatherings with more than five people) reduced mobility and, therefore, the spread of the virus. The third set of analyses discovered that alert text messages about COVID-19 were effective for up to six hours. In particular, the text messages were useful in warning young people under the age of 30.

From those analyses, inter-city collaborations were explored for smart epidemiological management. G2G arrangements can encourage private sectors and ICT professional firms to collectively contribute to global health crises. Research institutions can also contribute to benefit the public thanks to their emphasis on public interest.

The findings from this research provide policy implications. First, the clusters of the infectious disease

can bring about an exponential increase in new patients. Hence, early actions are extremely important. The MBD approach can reduce the workloads of human epidemiologists and enhance the quality of early detection of the (potential) new cases. Second, the reliability of simulations needs to be improved by combining with micro-level geospatial information. Research & development with MBD should continue as infectious diseases are likely to outbreak again. MBD involves privacy issues. Thus, this research in this report used MBD by 50mx50m grids that do not pinpoint precise locations of individuals being unable to figure out mobile phones in indoor or outdoor locations. Further fine-scope spatial units will be able to improve the quality of contact tracing. Similarly, the O-D matrices were based on the administrative unit (dong), but finer-scale analyses (e.g., at a building scale) will enhance the quality of simulations. Third, cooperation between local and central governments and between public and private sectors will play a significant role in enhancing the implementation of epidemiological policy. Telecommunication companies produce raw data. After de-identification from the IMSI, the dataset can be forwarded to research institutions for analysis. Then, the results of the analysis can be provided to local governments and the KDCA who can further utilize analysis results for epidemiological policy by combining with information about patients and mobile phone holders. Fourth, this research was limited to MBD from SKT or KT only, but the integration with all telecommunication companies will be able to create complete sets of MBD.

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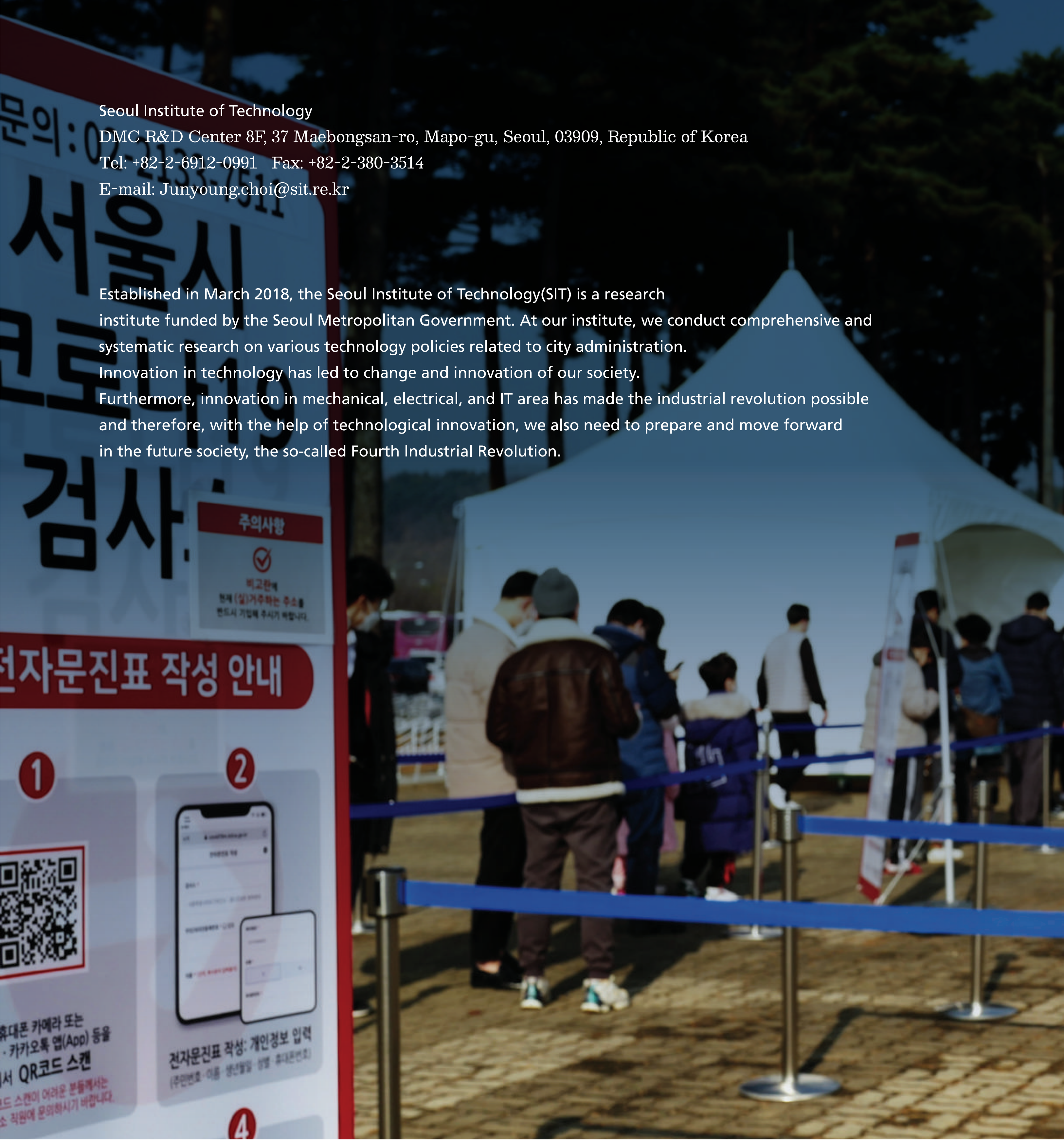

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