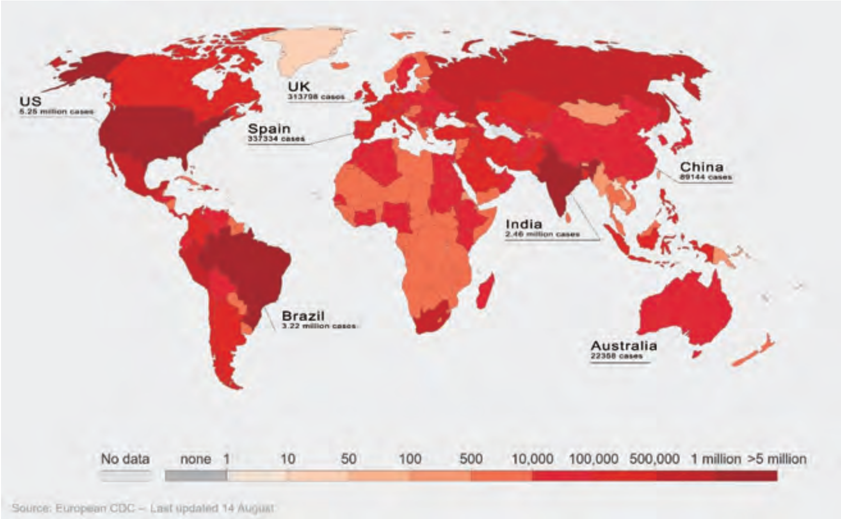

FIGURE 10.1
Global Variation in COVID-19 Cases

response to managing the pandemic. Recent research [8] has mapped a country's response to the pandemic by the timeliness to implement efficacious public health responses. Responses such as, the implementation of physical distancing strategies, remaining at home other than for essential purposes, ongoing enhancements of the health system, extensive travel restrictions, extensive contact-tracing and quarantining of infected individuals and social and economic provisions to assist individuals with the impact of closing-down much of a country's economy in an effort to minimise transmission. As observed in Figure 10.2, two months after the first notification of COVID-19, individual government response to the pending pandemic varied with countries reporting cases of COVID-19 implementing many of the public health responses described above whilst other countries being much slower to respond, presumably associated with no or few cases being reported. Responding quickly to the pandemic, however, did not confer a rapid reduction in infections. As highlighted by the dark brown colour in Figure 10.2, countries such as China, the United States of America (US) and Brazil instituted many public health responses by March 22, 2020 and at the time of writing (August 2020) both the US and Brazil have not suppressed the transmission of COVID-19. It should be noted, however, that implementation of 'stay at home' orders in countries such as the United States were not implemented on a country-wide level, but rather on a state or region-by-region basis that followed the progression of new COVID-19 cases across the country.

Not only is there is considerable variation in COVID-19 cases between countries there is also considerable variation between regions and cities within countries. Figure 10.3 highlights the considerable variation observed in COVID-19 cases within the US and the United Kingdom.

The variation within countries observed in Figures 10.3 is not easily explained as it likely reflects a multitude of factors ranging from governance structures, a poor safety culture within the country, lack of resources (including the ability to institute quarantine measures), inadequate health resources, and poor communication with the public, to name a few [9]. Importantly, the influence of a city's urban design and the variation of such designs between cities in a country may also be an important factor influencing the transmission of COVID-19. Only recently, has the research literature explored a number of these designs with respect to health outcomes (specifically road trauma) [10] and certainly not with respect to COVID-19.

In the remainder of this chapter we describe how city designs can be classified based on land-use characteristics such as road networks, public transit, green space and blue space (e.g., water bodies). Once a classification system is identified for specific city designs, we will assess whether specific city designs are associated with the reported cases of COVID-19.

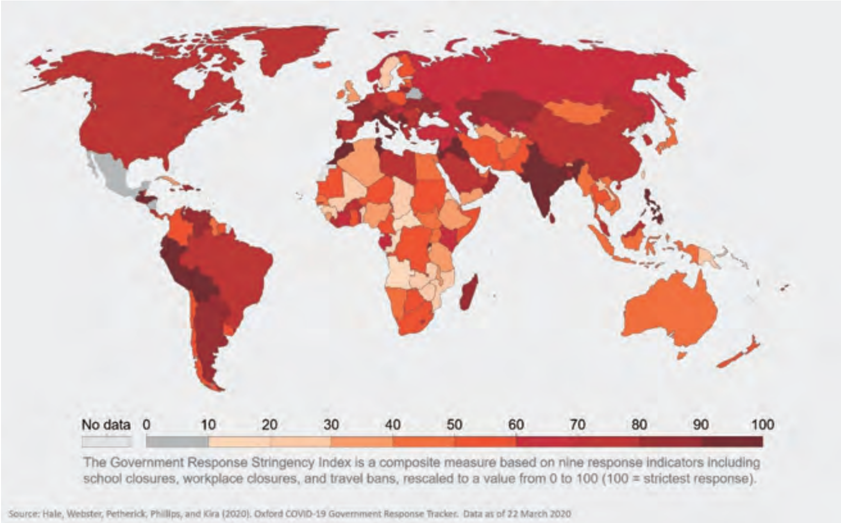

FIGURE 10.2
Country Variation in Government Response to COVID-19 as of March 22, 2020

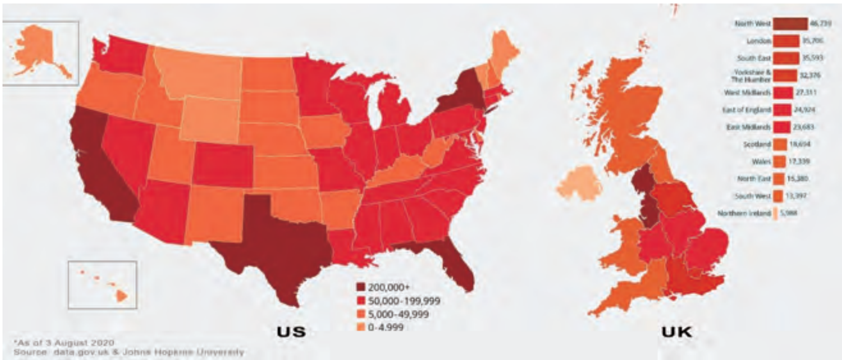

FIGURE 10.3
Variation in COVID-19 Cases in the US and the United Kingdom

10.2 Using Spatial Data to Identify Global City Design

To assess whether specific city design elements could be classified into discrete categories, we used the Google maps API to analyse a set of 1000 stylised maps for every city listed in the 2018 United Nations world population prospect report [11] with a population exceeding 300,000. A total of 1667 cities across the globe were identified. Using a convolutional neural network (CNN) modelling approach based on 'Inception V3' architecture [12], we identified whether cities could be correctly classified as being from their actual (ground truth) location. Each map was of approximately 400m x 400m size and contained representation of road networks, public transport networks, green space (e.g., parks and reserves) and blue space (water bodies). Details of the approach including the calibration of the stages are described in Thompson et al [10].

Once classification of cities to their ground truth location was completed, a graph of the confusion matrix produced by the CNN was created that represented nodes (cities) connected by vertices that represented cities occasionally mistaken for one another in the CNN process. A modularity analysis (similar to a cluster analysis) was then performed on the graph to isolate groups of cities among the 1667 that were regularly misclassified (i.e., confused for one another). This process produced a set of nine major city design types. Table 10.1 describes the nine city designs, a brief description of the design and lists the proportion of cities that fall within the respective city designs. The majority (64%) of low- and middle-income countries and their respective cities, fall within the city design Informal and Irregular; city designs with informal road infrastructure and limited public transit. In contrast, many cities from high income countries were classified under city designs described as either the Motor City and or Intense city design characterised either by high capacity road networks or high-density road networks and high public transit (see Figure 10.4).

Clearly not all cities in a country have the same design. Figure 10.5 illustrates the variation in city design within a country. The proportion of city design types within a country are based on the results of the convolutional neural network analysis. It is evident there is considerable variation in city designs within some countries and absolutely no variation in other countries. For example, there is considerable variation among cities in Vietnam with 4 city designs identified and similarly in China. In contrast, cities within Sweden, Switzerland, Norway, Ireland and Denmark only fall within one city design namely, the High Transit city design, which reflects urban form that is medium density with high capacity formal road networks and high public transport.

The opportunity to classify cities using objective data from standardised maps highlights the utility of spatial data. Such data provides insights on urban form not previously reported. However, the classification of nine city designs is limited to the four land use characteristics that could be systematically attained from the google maps. Nonetheless, these characteristics are important elements particularly in the context of pandemics whereby highly integrated public transit systems can escalate the transmission of infectious diseases.

TABLE 10.1
Types of city design and the proportion of cities classified under each design

Type of City Design	Description	Cities classified in the design (%, N)
Informal	Sparse, low capacity informal road infrastructure, limited rail transport, low formal green space	23% (365 cities)
Irregular	High green space, mixed formal and informal infrastructure, few high capacity road networks, limited mass transit	21% (311 cities)
Large Blocks	Medium density, formal low and high capacity road networks, medium railed transport	9% (146 cities)
Cul-de-sac	Very high density, low capacity mixed formal and informal road networks, low mass transit.	1% (26 cities)
High-Transit	Medium density, high capacity, formal road networks, high public transport	10% (163 cities)
Motor city	Medium to low density, high capacity, grid-based, road networks, medium railed transport	10% (158 cities)
Chequerboard	High density, medium capacity mixed formal and informal road networks, medium public transport	16% (257 cities)
Intense	Very high density, mixed formal high capacity and informal road networks, high public transport	1% (22 cities)
Sparse	Low capacity, low density formal and informal road networks, low public transport	9% (142 cities)

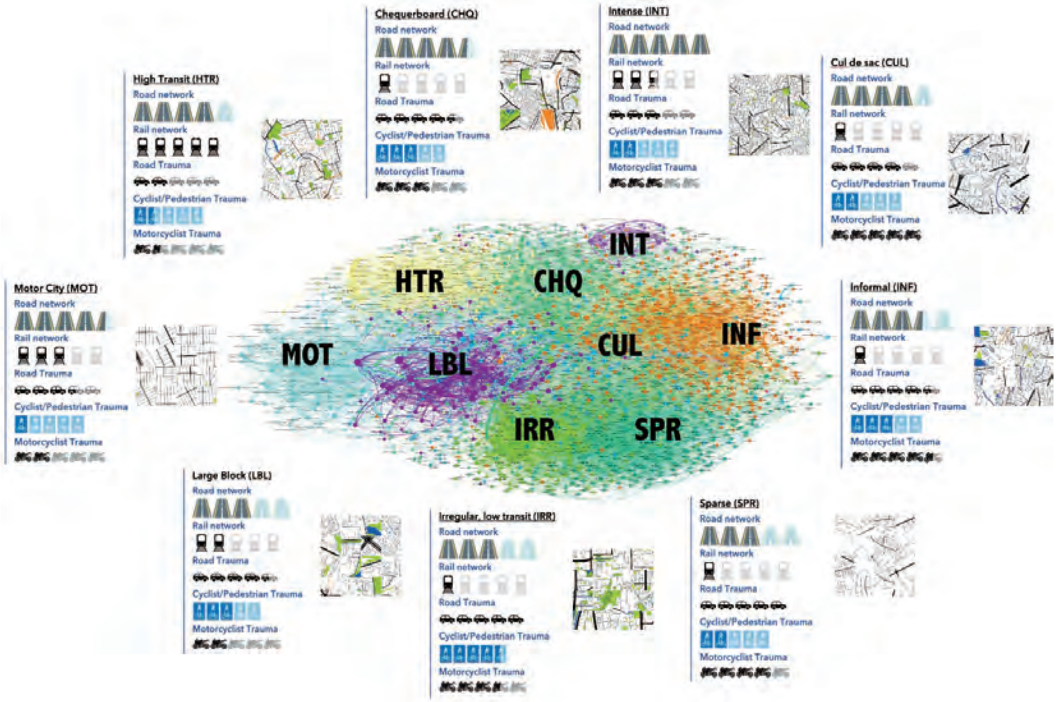

Figure showing each city design's road and public transport characteristics, sample map images and the relationship between each city type and road trauma outcomes.

FIGURE 10.4
Confusion Matrix Produced by the Convolutional Neural Network

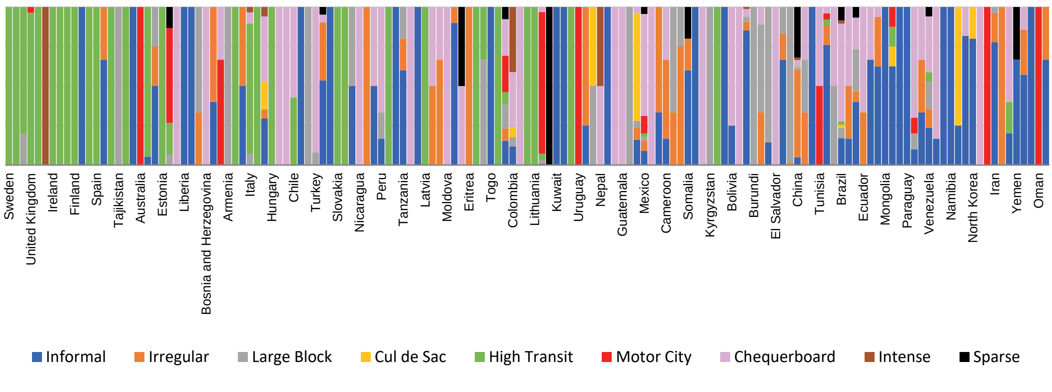

FIGURE 10.5
Proportions of city design types identified in each country

10.3 Relationship Between City Design and COVID-19

As the COVID-19 pandemic enters its 9 month and many countries such as Australia are grappling with a second wave of outbreaks, important public health responses to mitigate the transmission particularly managing public transit and boarder control both between cities and countries are of increasing importance. Understanding which city designs (if any) are likely to increase the propensity to mitigate transmission is of utmost importance. Given the characteristics of the nine city designs, one might expect that cities that are categorised under the following designs as particularly vulnerable for increased transmission especially if the government response is not proactive namely; *Large Block, High Transit, Chequerboard* and *Intense* city designs; these designs have higher population densities along with greater density of road and public transit.

While the relationship of city designs that include reference to road and public transport networks bears a logical relationship to rates of road trauma across countries, the extent to which city design contributes to communicable disease is less certain. It could be hypothesised that a higher proportion of public transit infrastructure and consequent use might lead to greater likelihood of close contact between individuals and person-to-person transmission. Alternatively, the proportion of public transit may be less important than population density in the city, which could determine how close citizens may be forced together on any given day. Finally, it may be these factors are ultimately less important than the timing and intensity of public health and social policies (e.g., stay at home orders) that promote social distancing and limit the potential negative impact of features associated with compact city design – features we have increasingly come to associate with good rather than poor health [13].

To investigate the relationship between city design features and COVID-19, we took an available subset of cities and assessed, up to the time that initial 'stay at home' orders were implemented, an array of factors against the mean growth in COVID-19 cases for each city. We considered the following factors: i) the proportion of each city's land-area dedicated to railed public transit, ii) the proportion of each city's land-area dedicated to road networks, iii) the recorded population density of each city in persons per km^2, iv) the mean block size of each city, v) the regularity of each city's blocks (e.g., how 'square' they are), and vi) the timing of implementation of initial 'stay-at home' orders for each city. This last factor is important to consider alongside the characteristics of city design in order to understand the growth (or decline) in COVID-19 cases under a relatively 'natural' or unmitigated scenario, before the implementation of stringent public health policy measures that might otherwise restrict the free movement and interaction of city residents.

A total of 220 cities from the original list of 1667 were selected. This was the total number of cities for which individual daily cases for COVID-19 data were available at the time of writing. Given the reduced number of cities available for analysis across city designs we restricted our analysis to the measured characteristics of images from within these cities as described above, rather than describing associations with city design types.

Across the selected cities, sixty-three cities were excluded due to missing data across one or more of the factors described above hence, a total of 157 cities were analysed. The findings from the analysis highlighted that a city's design across public transit infrastructure, road infrastructure, block size, and block regularity were not associated with the rates of COVID-19 case growth. Importantly, the findings pointed to a city's population density as significantly associated with case growth albeit, a negative relationship indicating that cities with higher population densities were associated with lower reported case growth from the time the initial case was reported to the first stay-at-home orders. Similarly, days taken between initial case identification and stay-at-home orders were also negatively associated with mean case growth over time.

Focusing on individual cities and regions included in this analysis provides some insight into why both population density and extended delays to the instigation of stay-at-home orders appear negatively associated with the cases of COVID-19. Many cities with high population density are located within countries that also had long delays between identification of their first COVID-19 case and the instigation of stay-at-home orders including those in Japan, Vietnam, Thailand and the city-state of Singapore (see Figure 10.6). This delay does not infer increased transmission as these countries have touted effective control of COVID-19 infections through means other than economic and stay-at-home orders including mass testing, mask-wearing, hygiene promotion, and rapid contact tracing.

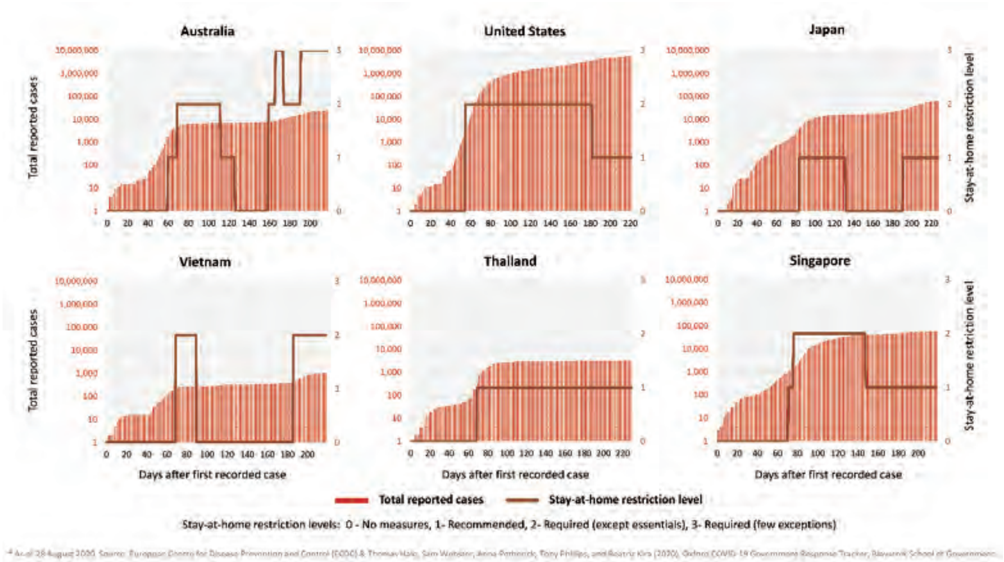

FIGURE 10.6
Total reported cases vs stay-at-home restriction levels, days after first recorded case

As a consequence, our assumption that city designs that reflect extensive road infrastructure, public transit systems and high population densities might exacerbate the transmission of COVID-19, does not hold in its entirety. It appears, that only high population density is associated with COVID-19 cases although it highlights that the densely populated cities have reduced cases of COVID-19. From this cursory analysis, the threat posed by extensive transport systems and highly populated cities is less than first imagined and, is at least not as important factor as the public health orders deployed by city and government institutions to mitigate transmission of COVID-19.

10.4 Conclusion

As highlighted in the chapter, in the early stages of the pandemic, a comprehensive public health response including closing-down the transport systems in response to the rising cases of infection was necessary; this was certainly the situation in China. Similar responses were instituted across the globe albeit at varying time periods. In this chapter we explored, using mapping techniques, the role of city designs in the transmission of COVID-19 with the likelihood of cities with extensive public transit and high densities (described in this chapter as *High Transit* cities) having an increase propensity for transmission.

Despite being able to classify cities into distinct designs based on a combination of spatial characteristics and methods of artificial intelligence, when the city designs were assessed against the number of COVID-19 cases, the design of the city was not associated with the likely number of COVID-19 cases observed but rather high population densities and longer times to initiate stay-at-home orders reduced the COVID-19 cases observed.

What the findings in this chapter points to is that whatever the potential threats posed by cities with high population densities, extensive public transit or smaller block sizes with respect to the transmission of COVID-19, their effects are not dominant over the comprehensive implementation of social or public health interventions. This is not to say that living conditions in individual neighbourhoods, highly utilised public transit networks, or other city features might not provide circumstances for more ready transmission of communicable disease between individuals, but rather, that the evidence is not strong that city design is the primary driver. One alternate explanation to what is observed here is that what we are seeing reflects community resilience. Community resilience is the ability of communities/cities to respond positively to crises such as the pandemic. Countries/cities that responded comprehensively (and not necessarily promptly) to the threat of COVID-19 by instituting appropriate public health responses (as described in this chapter), see rapid declines in the rate of infections. This points to the role that good governance and community resilience can play when faced with emergencies such as a pandemic.

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11

Sensing Community Resilience Using Social Media

Felicia N. Huang, Kelly Lim, Evan Sidhi and Belinda Yuen

This chapter discusses social media use and community resilience development during the COVID-19 pandemic in Singapore. Although around one in four Singapore residents are Twitter users, little is known about their attitudes and sentiments or the roles that social media fulfils in supporting community resilience during a pandemic. The chapter investigates how social media affects citizens' self-resilience capacities during various stages of the COVID-19 pandemic evolution, in particular, in terms of information gathering, information dissemination, information exchange, collaborative problem-solving, coping and promotion of connectedness in order to derive opportunities and challenges for community resilience building. More than a tool for collaborative problem-solving, Twitter is used to coordinate top-down community response and promote connectedness. Geo-tagged data analysis suggests that different regional characteristics do not lead to difference in community resilience efforts across Singapore. Singapore, as a nation, works together as a community in fighting the pandemic.

11.1 Introduction

The COVID-19 pandemic has unleashed unprecedented disruption to economy and society. In its wake, COVID-19 related posts on social media platforms such as Facebook, Twitter, and YouTube have increased. Publicly accessible data posted on social media platforms by users around the world are increasingly used by researchers to quickly identify the main thoughts, attitudes, and feelings surrounding COVID-19 [1]. The scientific community has reported the potential effects of mass isolation on an individual's well-being, and mental health [2, 3]. Yet, there is little or no discussion on the use of social media to sense community resilience during the COVID-19 pandemic.

This study aims to fill this knowledge gap and sense community resilience during the COVID-19 pandemic in Singapore by examining tweets with the *SGUnited* hashtag. This study validates the use of #SGUnited tweets to study how community resilience evolves during the COVID-19 pandemic in Singapore. Additionally, it demonstrates the importance of the Singaporean online community, especially the grassroot communities, to spread community resilience. Results reveal that pandemic increases community resilience, especially in the prelude and the aftermath of a severe lockdown. During a strict lockdown, community resilience is high, but an opposing current of negativities, anxieties, and self-concerns is also high, with potential to undermine group unity if not addressed well. Geographical characteristics of different regions in Singapore are reflected into the content of the tweets. Analysis shows that regional characteristics do not lead to differences in community resilience efforts across Singapore, perhaps because of its small land area (721 sq km) and high population density (7821 persons per sq km).

11.2 Previous Research

11.2.1 Community Resilience During Disasters

Much has been written about the definition of community resilience [4]. Suffice to summarise that community resilience is the ability of a society to cope with and rebound in the face of adverse events or crisis [5, 6]. Understandably, communities with high resilience are usually able to bounce back quickly from adversity and building resilience is often connected with building strong communities [7]. Even though state institutions are important, a community's citizens and public awareness of and responsibility for managing local disaster are critical to sustaining and increasing national resilience in disasters.

In response to the COVID-19 pandemic, the scientific community has increasingly reported on individual well-being, including the potential effects of mass isolation on mental health [2, 3]. Prime, Wade, and Browne [8] discuss the literature on past adversities that have affected populations, such as natural and man-made disasters and recessions, to illustrate numerous aspects in which the well-being of children and families can be at risk during COVID-19.

While resilience exists at the individual and family level, it also occurs at societal level. Vinkers et al. [9] discuss the importance of resilience at both the individual and societal level during the COVID-19 pandemic. Kimhi et al. [10] explore the contribution of community resilience towards decreasing or enhancing anxiety and depression during the pandemic among members of Israel's Jewish and Arab communities.

11.2.2 Community Resilience and Social Media

Social media has become an integral part of many people's everyday lives. It is not surprising that social media is widely used in emergency scenarios. Social networking can influence citizens' self-reliance in the event of a crisis by providing avenues for getting quick and reliable information that reduces uncertainty [11]. Other studies suggest that the public rely on a mix of formal and informal information sources to seek information when using social media during disasters [12, 13]. More specifically, research on the use of Twitter in an emergency context reveals emergency information diffusion of retweets and private messages [14, 15], and information sharing behaviours on Twitter during disasters [16, 17].

Riding on the rapid growth of COVID-19 content on social media, researchers have been using social media to identify the main thoughts, attitudes, and feelings surrounding COVID-19. Li et al. [18] sampled and analysed Weibo posts to explore the impacts of COVID-19 on people's mental health. Su et al. [19] accessed Weibo and Twitter posts to examine and compare the impact of COVID-19 lockdown on individuals' psychological states in China and Italy. Park et al. [20] investigated information transmission networks and news-sharing behaviours regarding COVID-19 on Twitter in Korea. Budhwani and Sun [21] assessed if there was an increase in the prevalence and frequency of the phrases 'Chinese virus' and 'China virus' on Twitter after the 16 March 2020 US presidential reference of this term.

Aside from country-specific studies, others have interrogated worldwide trends. Lwin et al. [22] examined worldwide trends of four emotions—fear, anger, sadness, and joy—and the narratives underlying those emotions during the COVID-19 pandemic. Abd-Alrazaq et al. [1] identified the main topics posted by Twitter users globally during the COVID-19 pandemic, from 2 February to 15 March 2020. They observed the need for proactive social media monitoring to address the spread of fake news and misinformation on social media.

Social media is not just popular among the community. Rufai and Bunce [23] explored the role of Twitter as used by the Group of Seven (G7) world leaders in response to COVID-19. Chen, Lerman, and Ferrara [24] developed a multilingual COVID-19 Twitter dataset that other researchers can use while Mackey et al. [25] detected and characterized user-generated conversations that could be associated with COVID-19-related symptoms. So far, however, no existing study has used social media to explore community resilience during the pandemic. In the pages that follow, we will use Twitter data to sense community resilience in Singapore during the COVID-19 pandemic.

11.2.3 Singapore Community Resilience During COVID-19 Pandemic

Singapore won praise from the World Health Organisation for its early response to dealing with COVID-19 pandemic without the need for enforced lockdowns [26]. Even after the migrant worker dormitory cases emerged and circuit breaker (lockdown) enforced, Singapore's COVID-19 pandemic response has been swift and fatality is generally low [27]. Singapore's success is, however, not unique.

Epidemiologists universally acknowledge that communities in Asia including Hong Kong SAR, South Korea, Taiwan, and Vietnam have been more successful than the United States and most European countries in 'flattening the curve' and limiting the spread of the COVID-19 virus among its populations [28]. Some have attributed this to cultural traits such as the collectivist Confucian mindset internalized among Asian societies that prioritise social unity, group goals and greater good of the community over individual desires [28]. Creating social cohesion is important to community resilience [29].

In February 2020, Singapore has launched SGUnited campaign to encourage the population to work together and overcome the challenges arising from the pandemic. The clarion call is to 'stay safe, stay strong and stay united'. In early February 2020, the prime minister and other members of the government advocated using #SGUnited, that soon gained traction in the social media. The timeline of how the COVID-19 outbreak in Singapore had evolved from 1 January to 30 June 2020 is summarised:

- **Imported Phase** (1 January – 3 February 2020). During the imported phase, imported COVID-19 cases increasingly entered Singapore. The first confirmed case was reported on 23 January, a tourist from Wuhan [30]. The first confirmed case involving a Singaporean was confirmed on 31 January, a Singaporean returning from Wuhan [31].

- **Early Local Cluster Phase** (4 February – 23 March 2020). During this phase, local clusters and transmission developed. The first cluster of local transmission was reported on 4 February at Yong Thai Hang, a shop that mainly served Chinese tourists [32].

- **Stronger Measure Phase** (24 March – 6 April 2020). During this phase, the number of cases began to rise exponentially around the world. Singaporean overseas were encouraged to return [33], causing a spike in imported cases. This spike signalled a new phase in Singapore's fight against COVID-19. Various safe distancing measures and travel restrictions were introduced. Singapore registered 1,000 cases on 1 April [34].

- **Circuit Breaker (Lockdown) Initial Phase** (7 April – 20 April 2020). During this phase, the government of Singapore introduced the Circuit Breaker, an elevated set of safe distancing measure to pre-empt the trend of increasing local transmission of COVID-19 [35]. The exponential increase was caused by infection among migrant workers living in dormitories. The first dormitory cluster was identified on 30 March, with four infections at S11 dormitory [36]. Cases quickly ballooned to 4,427 on 16 April, 60% of which were migrant workers [34].

- **Circuit Breaker Tightened Phase** (21 April – 11 May 2020). The exponential increase in cases did not slow down. On 21 April, the prime minister announced tighter measures to the Circuit Breaker period, to further reduce the transmission of COVID-19. He also announced that the Circuit Breaker period would be extended by another four weeks until 1 June 2020 [37].

- **Circuit Breaker Relaxed Phase** (12 May – 1 June 2020). On 2 May, the Multi-Ministry COVID-19 Taskforce announced that it would ease some of the tighter circuit breaker measures in the coming weeks. Particularly from 12 May, a significant number of retail and businesses were allowed to resume operation [38].

- **Safe Reopening Phase NG Phase** (2 June – 30 June 2020). As the daily number of new community cases had declined significantly and the dormitory situation had stabilized, Singapore exited the Circuit Breaker on 1 June 2020 [39].

11.3 Methods

11.3.1 Data Collection

#SGUnited was used as a proxy for resilience tweets. Tweets with the #SGUnited were collected using the Twitter Standard Search API from the start of the project, in mid-April to 30 June 2020. Twitter users' information were extracted from the tweets collected. Overall, there were 5,784 users. Their tweets since 1 January 2020 were then scraped using the Twitter Timeline API. The Twitter Timeline API was less restrictive than the Twitter Standard Search API. Finally, all the tweets with #SGUnited were filtered. We collected 17,367 tweets from 1 January 2020 to 30 June 2020, of which 1,011 were geolocated tweets.

11.3.2 Data Pre-Processing

Punctuation marks and stop words such as 'an' and 'the' were removed from the tweets. Furthermore, various forms of the same word (e.g. travels, traveling, and travel's) were lemmatized by converting them to the main word (e.g. travel) using the *WordNetLemmatizer* module of the Natural Language Toolkit Python library. Following the terms and conditions, terms of use, and privacy policies of Twitter, all data were anonymized and were not reported verbatim to any third party.

11.3.3 Data Analysis

Five types of analysis were performed on the tweets to understand different aspects of resilience: (a) frequency count and analysis of popular information sources, (b) topic extraction, (c) sentiment analysis, (d) pronoun analysis, and (e) geospatial analysis.

The frequency of #SGUnited tweets and retweets was analysed according to the earlier mentioned COVID-19 evolution timeline. Then, popular users and influencers were extracted from two popularity measures. The first popularity measure was based on the number of tweets a user posted that were retweeted by others. The second popularity measure was based on the number of retweets that a user received for his/her tweets.

Sentiment and pronoun analyses were performed to discover how and when tweets were used to create a venue for collaborative problem solving and promotion of connectedness. Pronouns were calculated by listing them and finding them in the tweets. First person singular pronouns included 'I', 'me', 'my', and 'mine'. First person plural pronouns included 'we', 'us', 'our', 'ours'. Second person pronouns included 'you', 'your', and 'yours'. Third person singular pronouns were 'he', 'him', 'his', 'she', 'her', 'hers', 'it', 'its'. Lastly, third person plural pronouns were 'they', 'them', 'theirs'. Sentiment scores (ascription of positive or negative emotional valence) were given to tweets using *Vader* library in Python.

Topic modelling technique, specifically the *TwitterLDA* [40], was used to extract topics from tweets. Topic distribution in a day would identify popular topics from the tweets. The topics were visualized using R library *LDAViz* [41]. Tableau was used for visualization of other graphs.

There were 1,011 geolocated tweets. Eliminating the ones that were in other countries, and that were too generic (i.e. only mention Singapore), 840 tweets remained for analysis. Of these, 442 tweets had geocoordinate points, whereas the rest only had polygon coordinates that showed in which of the five Singapore regions they belonged to: North, East, West, North East, or Central. Topics of the tweets of each region were extracted to discover the topics discussed at each region.

11.4 Results

The examination of how social media affects citizens' self-resilience capacities during various stages of the COVID-19 pandemic evolution involved three areas: (1) how social media affected self-resilience in terms of information gathering, dissemination, and exchange; (2) how social media affected self-resilience in terms of collaborative problem solving, coping, and promotion of connectedness; and (3) whether social media showed any regional-specific community resilience.

11.4.1 Information Gathering, Dissemination, and Exchange During the COVID-19 Pandemic

According to Bruns and Liang [42], Twitter is particularly suitable for crisis communication. With its flat and flexible communicative structures, any visitor can access public tweets. Such communicative structure facilitates fast, and large-scale collection of information [43]. Particularly during major events, the follower-followee relationships can lead to emergent social properties at a macro-scale, which are driven by a bottom-up self-organization of information [44], thus providing unique access to information deemed important by the community. Additionally, Twitter is a persistent source of data about individual responses to a disaster within a community, establishing Twitter as a valuable tool for measuring disaster resilience across communities [45]. The exploration into how Twitter, as a medium of information gathering, dissemination, and exchange, affects the capacities of community resilience in Singapore during the COVID-19 pandemic involves reviewing the intensity of information gathering and dissemination at various stages of the pandemic, the topic of information exchanged, and popular information sources.

11.4.1.1 Tweets Intensity at Various Stages of the Pandemic

Social media provides clear opportunities for two-way crisis communication between authorities, media and citizens [46]. This two-way communication helps to build community resilience by providing emergency information and facilitating community response and recovery [47]. Intensity of tweets during various stages of pandemic is analysed to discover at which stages are the crisis communication information exchanges among Singaporeans most prevalent.

The number of tweets, and retweets appears to follow closely the COVID-19 phases in Singapore (Table 11.1). Intensity of tweets gained momentum during the implementation of stronger measure when the global and national infected cases increased (Figure 11.1). The intensity reached its peak during the Circuit Breaker tightened measure period following the emergence of dormitory clusters in Singapore that created an upsurge of national infected cases. As the number of cases stabilized, the government relaxed the lockdown measures and the number of tweets also seemed to decline.

TABLE 11.1
The number of tweets and retweets across different phases of COVID-19

Phase	Date	No. of Tweets	No. of Retweets	Sum SG Daily Infected
Imported	1 Jan – 3 Feb	6	0	18
Early local clusters	4 Feb – 12 Mar	563	683	492
Stronger measure	13 Mar – 6 Apr	4,241	1,226	866
Circuit Breaker initial	7 Apr – 20 Apr	2,575	1,069	6,649
Circuit Breaker tightened	21 Apr – 11 May	6,102	3,670	15,808
Circuit Breaker relaxed	12 May – 1 Jun	2,930	1,457	11,505
Safe reopening	2 Jun – 30 Jun	2,516	1,236	8,884

The results follow previous studies of Twitter showing that during natural hazards, there is a gradual increase in tweet intensity with hazard proximity [46]. The suggestion is that Twitter presents a disaster communication platform that provides essential information during crucial times throughout the COVID-19 pandemic in Singapore. But unlike natural disaster, where there is an objective definition of hazard, there is no objective definition of hazard during a pandemic. In our results, hazard is equated with strict lockdown, and the highest number of infected cases. But the current pandemic is protracted with no cure insight yet, the "strict lockdown" definition may not be the same for all countries, and no one can really predict whether the number of infected cases has reached a tipping point. Future studies can investigate whether hazard during a pandemic has a universally accepted objective measure.

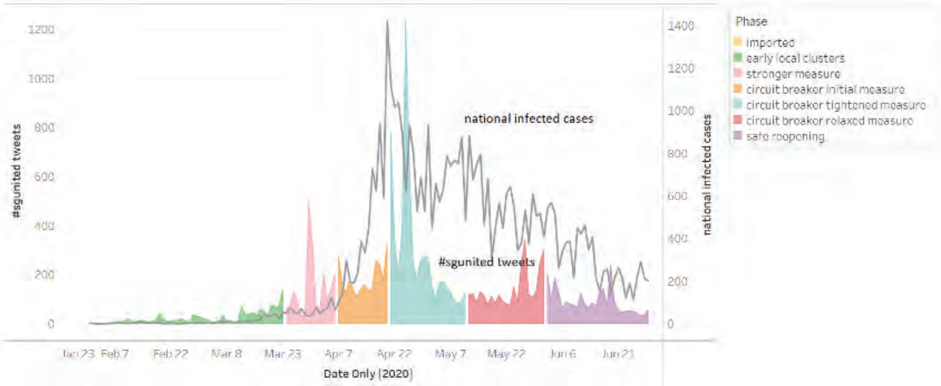

FIGURE 11.1
Community resilience tweets by phase and number of national infected cases, 1 January to 30 June 2020

11.4.1.2 Popular Topics and Tweets

Disasters are inherent with a high degree of uncertainty and the perception of severe threat [48]. The central characteristics, functions, and applications of social media in disaster relate to social convergence to provide support and information sharing to reduce uncertainty [11]. On Twitter, people spread information that they feel or know to be newsworthy through retweeting notwithstanding the possibility of fake news [44].

In Table 11.2, the top two topics in #SGUnited tweets are listed; topic definition can be found on Table 11.3. Here's how the table should be read. For example, during the imported phase, topic 24 (lifestyle and leisure) becomes the most discussed topic for three days, and topic 10 (COVID transmission and test) is the most discussed topic for a day. In total, during the imported phase, there are four days where tweets with #SGUnited are found. During the period, topic 11 (estate economy) is the second most discussed topic for two days, while topic 24 (lifestyle and leisure), and topic 0 (youth, global, and national unity) are the second most discussed topic for a day.

For Singapore, during the COVID-19 pandemic, the community seemed to focus on accessing Twitter to get and exchange information relating to lifestyle and leisure (Table 11.2). For most of the days throughout the six-month period, topic 24 (lifestyle and leisure) was the first or second most discussed topic. Topic 24 communicated information exchange about lifestyle changes that were crucial to curb the pandemic spread, e.g. promotional message of online products that were advertised to help fight viruses, different new safeguarding efforts on travel in public transport, guidelines for the wearing of masks, and introduction to the 'soaper 5'. Singapore introduced the concept of soaper 5 (Wipe Up Wilson, Super Soaper Soffy, Virus Screener Varun, Hands Down Hana, and Mask Up Mei Mei) to help little children build a new lifestyle habit in the midst of the pandemic.

Besides being a tool to promote new lifestyle changes, Twitter was also a popular platform to promote positivity, and connectedness. For example, during the Stronger Measure phase, the ClapforSGUnited event on 30 March 2020 [49] was accompanied with an increase in topic 2 (appreciation for frontliners) and topic 18 (appreciation for healthcare workers) including retweets (Figure 11.2). These topics became the second most discussed topic for a few days during the Stronger Measure phase. Similarly, during the Circuit Breaker tightened phase, SingforSG event saw an increase in topic 0 (youth, national, and global unity), and topic 2 (appreciation for frontliners) discussion on Twitter. SingforSg event was created by MediaCorp (a media and entertainment group), inviting Singaporeans to take part in a nationwide singalong to promote unity during COVID-19. The results highlighted the importance of large-scale fun events at the national level to promote a sense of community unity on Twitter. Not only did these events create an increase in retweets during the event days, but also a few days following the event.

TABLE 11.2
Top two most discussed topics during COVID-19

Phase	Date	Topic	No. of Days the Topic was the 1st/2nd Most Discussed Topic
The first most discussed topic			
Imported	1 Jan – 3 Feb	24, 10	3, 1
Early local clusters	4 Feb – 12 Mar	24, 0, 10, 4, 7, 14, 15, 2, 3, 8, 20, 21	19, 2, 2, 2, 2, 2, 2, 1, 1, 1, 1, 1
Stronger measure	13 Mar – 6 Apr	24, 19, 22, 5, 2, 15, 11, 18, 17	15, 2, 2, 1, 1, 1, 1, 1, 1
Circuit Breaker initial	7 Apr – 20 Apr	24, 9, 8, 19	10, 2, 1, 1
Circuit Breaker tightened	21 Apr – 11 May	24, 5, 21, 0, 7, 10, 15, 4, 2	10, 2, 2, 2, 1, 1, 1, 1, 1
Circuit Breaker relaxed	12 May – 1 Jun	24, 3, 16, 1, 13, 11	13, 3, 2, 1 1, 1
Safe reopening	2 Jun – 30 Jun	24, 1, 5, 10, 13, 0, 6, 17 21, 22	15, 2, 2, 2, 2, 1, 1, 1, 1, 1
The second most discussed topic			
Imported	1 Jan – 3 Feb	11, 24, 0	2, 1, 1
Early local clusters	4 Feb – 12 Mar	24, 21, 7, 5, 10, 2, 0, 15, 3, 8, 11, 1, 18, 19	12, 5, 4, 3, 2, 2, 1, 1, 1, 1, 1, 1, 1, 1
Stronger measure	13 Mar – 6 Apr	24, 18, 5, 7, 2, 17, 19, 11 0, 4	6, 5, 3, 3, 2, 2, 1, 1 1, 1
Circuit Breaker initial	7 Apr – 20 Apr	24, 21, 9, 19, 8, 5, 17, 15	4, 4, 1, 1, 1, 1, 1, 1
Circuit Breaker tightened	21 Apr – 11 May	24, 21, 12, 23, 5, 7, 3, 9	7, 6, 2, 2, 1, 1, 1, 1
Circuit Breaker relaxed	12 May – 1 Jun	21, 19, 24, 14, 16, 1, 5, 15, 4, 22, 17	5, 4, 3, 2, 1, 1, 1, 1, 1, 1, 1
Safe reopening	2 Jun – 30 Jun	24, 6, 22, 5, 21, 17, 19, 7, 10, 14, 12, 20	7, 4, 3, 2, 2, 2, 2, 2, 1, 1, 1, 1

Note: Refer to Table 11.3 for topic definition.

TABLE 11.3
LDA generated topics

Topic 0	youth, national, and global unity	Topic 12	COVID-19 cases
Topic 1	tourism, and daily entertainment	Topic 13	safe reopening
Topic 2	frontliners appreciation for	Topic 14	food delivery and cooking
Topic 3	stay-home stay-home and cooking	Topic 15	webinar, and digital tech
Topic 4	live updates and livestream	Topic 16	religious celebration and Brompton bike
Topic 5	jobs, companies, and industries	Topic 17	dengue, and Malay words
Topic 6	fitness and health	Topic 18	appreciation for healthcare workers
Topic 7	education and job training	Topic 19	video and radio broadcast
Topic 8	domestic life and foreign worker	Topic 20	stay positive
Topic 9	circuit breaker and lockdown	Topic 21	public holiday nature, and relaxing
Topic 10	COVID-19 transmission and test	Topic 22	art, innovation, and nation rebuilding
Topic 11	estate economy	Topic 23	Ramadhan
		Topic 24	lifestyle, and leisure

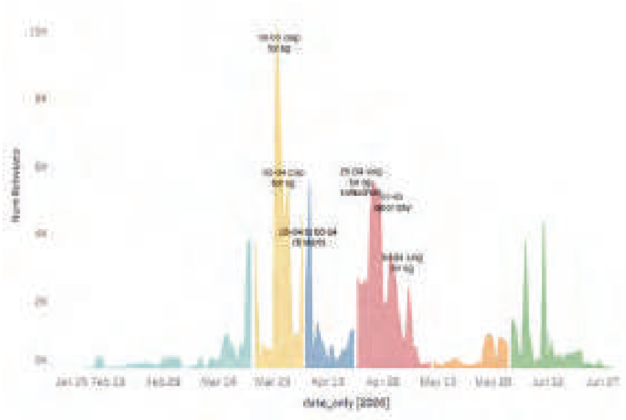

FIGURE 11.2
Number of retweets

Similar to the discovery by Vicari et al. [43] for disaster, our data showed that Twitter was primarily used as a means to disseminate warnings and behaviour guidelines during the pandemic. On Table 11.2, topic 9 (Circuit Breaker) became the most discussed topic on Twitter for a few days during the Circuit Breaker initial phase. This topic contributed to a high number of retweets (See Figure 11.2). Two weeks into the Circuit Breaker, on 21 April, the prime minister announced the extension of the Circuit Breaker. This announcement circulated widely on Twitter (Figure 11.2). The circuit breaker extension caused topic 9 (Circuit Breaker) to appear as the second highest ranked topic for a day during the Circuit Breaker Tightened phase (Table 11.2). During important milestones of the pandemic, Twitter provided an additional channel (besides traditional media like newspaper, radio and television) to announce important measures, specifically the Circuit Breaker.

By posting circuit breaker announcements on Twitter, #SGUnited tweets and retweets offered a glimpse into how social media could provide emergency intelligence through crowdsourcing, and boost the coordination of community response and recovery, lending evidence to how social media could be used to help build community resilience [47].

Festivals and national holidays also contributed to an increase in information dissemination on Twitter, i.e. retweets, during the pandemic. During the Circuit Breaker tightened period, Muslims in Singapore started their month of fasting. The event created an increase in retweets on 25 April (Figure 11.2) and topic 23 (Ramadhan, the fasting month and related activities) also became the second most discussed topic for a few days during the Circuit Breaker tightened period (Table 11.2). On 1 May, tweets about Labour Day (a public holiday) celebration spread widely on Twitter, inducing an increase in retweets (Figure 11.2). In consequence, topic 21 (public holiday, and relaxing activities) became the most discussed topics for a few days during the Circuit Breaker tightened period (Table 11.2). Besides expressing happiness during public holidays, messages during those days were also accompanied with resilience messages, such as encouraging words, a call for fundraising, and volunteerism. Festivals nurture community resilience through the sharing of values, interests, and traditions central to the host community [50]. The finding suggests that national holidays and festivals could be utilized to spread positive messages on social media as community cohesion increases during those days.

Our topic results seemed to be quite different from previous research. Abd-Alrazaq et al. [1] in their study of COVID-19-related tweets between 2 February and 15 March 2020 discovered that the five most discussed topics were deaths, fear, travel bans, economic losses, and panic buying. Generally, these tweets were largely negative. Currently, there was no previous research that specifically addressed the most discussed topics about COVID-19 in Singapore. Our analysis on tweets with #SGUnited revealed that the COVID-19 and related tweets were mostly positive and concentrated on introducing measures and lifestyle changes. This could be due to the content of postings introduced on #SGUnited. For example, during the stronger measure phase of the COVID-19, travel ban and advisory were introduced by the Singapore government but, the tweets with #SGUnited that were most widely disseminated during that phase were not about travel ban, but about encouragement, the Clap for SG activity.

Previous research on the use of Twitter for nurturing community resilience is usually focused on natural disaster. In these studies, Twitter mostly works as an early warning system [11, 43–45]. Requests for help and information on disaster recovery are also posted on Twitter, improving the lines of communication, thus enhancing self-resilience of citizens [11]. The community resilience fingerprints during natural disasters are largely related to ecological and infrastructure categories [45]. But, COVID-19 pandemic appears to have a different pathway from natural disaster.

Unlike natural disaster, the COVID-19 pandemic is protracted. Local communities need to be ready for the next waves, as long as there is no cure yet for the pandemic and the incidence and deaths related to COVID-19 continue to rise within the global community. In Singapore, through #SGUnited, Twitter is being used as an early warning system for the pandemic as well as for introducing and encouraging lifestyle changes in the community, which are important to sustaining the care and safety of the community. In consequence, lifestyle topic takes the majority of conversations on Twitter.

11.4.1.3 Popular Information Sources

Influential actors including heroes, and role models are important stakeholders during a disaster [43]. They can play an active role in nurturing community resilience through social media. Table 11.4 lists the top 20 popular users who were retweeted. They include government representatives, citizens, influencers, and private entities.

The most widely retweeted users appeared to be citizens while other entities (e.g. mainstream journalism) appeared to be the most likely retweeted users (Table 11.4). Postings from government entities are likely to be retweeted, and they are widely retweeted as well. Since citizens are more widely retweeted, the importance of building community resilience at the grassroots level should not be underestimated. That is, bottom-up activism is as equally important as a top-down directive in responding to the pandemic. Additionally, other non-governmental entities, especially online news portals, as the most likely retweeted users offer great options to encourage the implementation of top-down directives as their messages are highly likely to gain traction. In sum, official information dissemination by the government agencies though important, may not be sufficient on its own during a pandemic; the process could be complemented by both citizens and other entities like mainstream journalism to further support information exchange and promote connectedness.

TABLE 11.4
Top 20 popular users by popularity measure and user category

User Category	Popularity Measure Based on how widely they are retweeted	Based on how likely they get retweeted
Government (government departments and individuals like prime minister and ministers)	6	6
Other Entities (e.g. mainstream journalism business and private sector)	5	9
Citizens	8	4
Influencer (e.g. individuals with social media following)	1	1
	20	20

11.4.2 Promotion of Connectedness and Collaborative Problem Solving

Singaporeans generally appeared positive during the pandemic. There were more positive tweets than negative tweets (Figure 11.3). Nevertheless, a handful of negative tweets still existed. Their frequency generally did not fluctuate and remained low, and flat throughout. One exception was seen during the Circuit Breaker tightening phase where there was a surge of negative tweets alongside the positive tweets. Negative tweets could erode the promotion of connectedness during the pandemic. Most of the negative tweets were complaints about government institutes and government-imposed measures. Some of the tweets expressed dissatisfaction with how the government handled the COVID-19 situation. Some of the tweets complained about having to wear mask on the mass rapid transit system. There were also tweets that complained about racism.

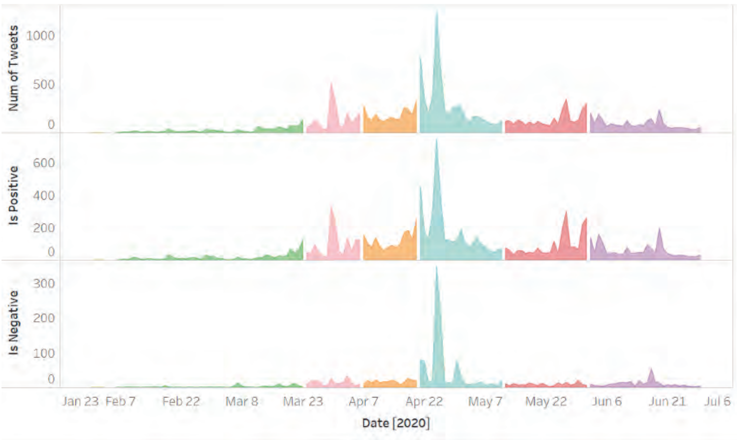

FIGURE 11.3
Positive and negative tweets from 1 January to 30 June 2020

The results of the pronouns analysis agreed with the results of the sentiment analysis. As shown on Table 11.5 and Figure 11.4, during the Circuit Breaker tightened phase, although there was a prevalence of the first-person plural pronoun ('we'), first-person singular pronouns ('I') also increased a lot as compared to other periods. The first-person singular pronoun suggested selfishness and attention to the self [51]. Yet, during the circuit breaker initial phase, and safe reopening phase, the number of first-person plural pronoun ('we') were significantly higher than first-person singular pronoun ('I'). The results seemed to indicate that during the prelude and the aftermath of a hazard (lockdown), community unity was higher than individual concern. However, during the lockdown, community unity was accompanied by negative emotions and individual concerns. The implication is that the city and community need to be very vigilant during the lockdown (a hazard) because individual anger, exasperation, and selfishness could easily build up and spread. Top-down directives and bottom-up activism could be employed to boost positivity, hope, and bonding during such times.

TABLE 11.5
Total number of different pronouns

Pronoun	Total
First Person Singular	3,592
First Person Plural	12,581
Second Person	5,182
Third Person Singular	3,348
Third Person Plural	2,188

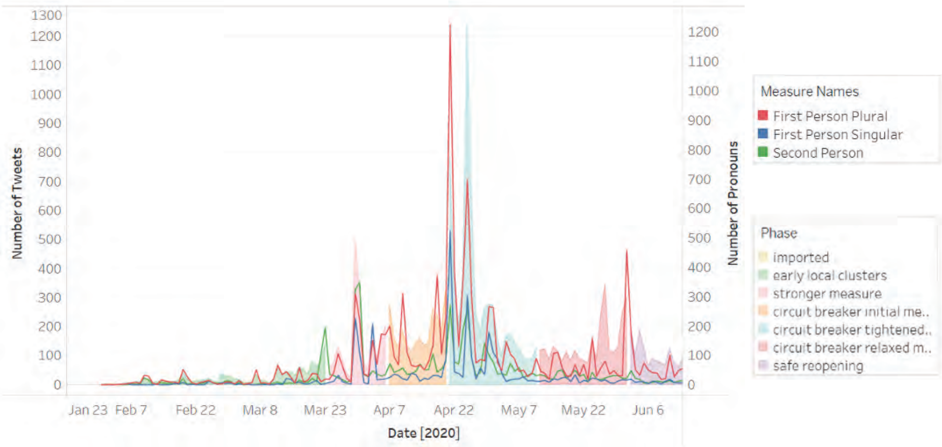

FIGURE 11.4
Number of tweets and different pronouns throughout different phases of the pandemic

As first-person plural pronoun ('we') in a sentence indicates unity [51], 119 tweets with the highest number of first-person plural pronoun ('we') were further analysed to discover the types of collaborative problem solving and promotion of connectedness done through Twitter. The top three messages with the highest community unity markers (the word 'we'), were about the promotion of connectedness (64%), namely, expressing appreciation for healthcare workers, urging fellow citizens to follow COVID-19 preventive measures, and sharing positivity and words of encouragement (Table 11.6). Our results agree with previous research that social media is useful to offer help, ask for help, and aid in recovery services [11]. During the pandemic when job losses, wage cuts and economic contraction are being experienced by many citizens, Twitter users used the platform to request for donation, sharing new job and volunteer opportunities. For example, crowd wisdom provided solutions for unemployed persons and small businesses by posting job opportunities and rallying people to help and support small businesses.

The ability of social media to connect people through time and space enhances collaborative problem-solving and citizens' ability to cope and make sense of the situation, particularly in a highly ambiguous social context [11, 52]. However, collaborative problem-solving occupies less than 50% of the communication on Twitter. Mostly, the bulk of the communication revolves around the promotion of connectedness including spreading positivity and urging fellow citizens to follow rules.

TABLE 11.6
Tweets with high number of first-person plural pronouns

Category	Total	Percentage
Appreciation for frontline, and healthcare workers	32	27%
Urging fellow citizens to strictly follow measures	27	23%
Sharing positivity	17	14%
Sharing information	16	13%
Selling product/service	10	8%
Requesting donation or other support	8	7%
New COVID-related job opportunities	4	3%
Encouraging citizens to support small businesses	3	3%
Volunteer opportunities	1	1%
Complains about government measures	1	1%

11.4.3 Regional-Specific Community Resilience

Community resilience concepts apply best to place-based communities, i.e. a community that is bound together by a place [53]. Singapore, as a nation, has given place-based planning a particular emphasis in the country's long-term development plan with much focus on place identity [54]. Place and urban spatial structure exert a powerful influence on people's everyday activities [55]. This section explores whether regional characteristics lead to regional-specific community resilience. The number of tweets and the top five topics across the five regions of Singapore are tabulated in Table 11.7.

TABLE 11.7
Distribution of topics and tweets across Singapore's five regions

Region	Number of Tweets	Top 3 Topics	Topic[1] %1
Central Region	479 (0.57)	21, 24, 0	42%, 30%, 4%
North Region	74 (0.09)	24, 21, 0	43%, 20%, 4%
North East Region	78 (0.09)	24, 21, 0	32%, 14%, 9%
West Region	166 (0.20)	24, 5, 21	47%, 33%, 4%
East Region	43 (0.05)	21, 24, 0	35%, 26%, 7%
Total	840		

Note: [1] shows percentage of topic in Top 3 Topics in sequence.

The most popular topics for all regions are topic 24 (lifestyle and leisure), topic 21 (public holiday, nature, and relaxing), and topic 0 (youth, national, and global unity). Nevertheless, there is an aberration in the West Region where there is a relatively high number of topic 5 (jobs, companies, and industries). One may quickly conjecture that the West Region, as the industrial region of Singapore, becomes the main source of jobs topic. However, looking deeper into the tweets, all tweets from the West region that talks about topic 5, come only from one user, MukundanAP, a data scientist and motivational speaker who shares business leadership quotes daily.

The analysis seems to suggest that regional differences in Singapore are not big enough to warrant a difference in community resilience across regions during the COVID-19 pandemic. This could be due to the small land size, high population density, compact urban development and coherent policy response in Singapore. Unlike in the United States where people of different states can take different responses to wearing a mask to reduce COVID-19 transmission, the COVID-19 policy responses are implemented uniformly nationwide in Singapore.

Furthermore, people-place relationship in community resilience is often based on the assumption that different communities within geographically defined space have different levels of vulnerability and resilience, the result of different sense of community and ideals as well as attachment to place [56, 57]. In Singapore, where land is small, transportation is convenient, and government directives are strictly imposed, regional difference does not create different vulnerabilities. For example, during the water shortages in 1961 and 1963, regions near the reservoirs do not have advantages because water is rationed evenly across the nation [58]. Ethnic integration policy in Singapore's housing programme that mixes different races in public housing estates where 80% of resident population live, has strengthened social cohesion [59]. As a result, from what is shown by the tweets, different region in Singapore does not show different community resilience effort.

Berkes and Ross [56] identified two different strands of community resilience studies. The first strand treats community resilience as a social-ecological system strongly affected by geographical locations. The second strand treats community resilience as a social entity affected by personal development, social connections, and mental health. Perhaps, for the case of Singapore, the resilience of a community as a social entity is more relevant than the resilience of a community as a geographical unit.

Singapore has two different COVID-19 clusters, that are geographically unseparated, but socially separated, i.e. the dormitory cluster, and the community cluster. A stark difference in the living condition of the two clusters produces different infection rate. Dormitory cluster infection rate has been very high, even when community cluster infection rate remains moderate. The difference in social classes in Singapore has created different vulnerabilities to the pandemic.

11.5 Conclusion

In this study, #SGUnited tweets were analysed to sense community resilience in Singapore during the COVID-19 pandemic. Various analyses were performed on the tweets to understand different aspects of resilience tweets: (a) frequency count, and popular users analysis, (b) topic extraction, (c) sentiment analysis, (d) pronoun analysis, and (e) geospatial analysis. Frequency count shows that resilience tweets follow different phases of government measures in curbing the pandemic. During the time when strict lockdown is imposed, resilience tweets are high, and during relaxed measures, resilience tweets are low. Popular user analysis reveals the importance of citizens in popularizing tweets while topic extraction indicates that although the 'lifestyle and leisure' topic takes the bulk of the conversation on Twitter, it rarely gains traction. Other topics, such as Circuit Breaker, and appreciation for healthcare front-liners, are more likely to get popular during a health pandemic.

Sentiment and pronoun analysis show that #SGUnited tweets are generally positive and contain a lot of first personal plural pronouns ('we'), indicating group unity. Tweets with the highest number of group unit markers ('we'), are mostly about the promotion of connectedness, and community response coordination than about collaborative problem solving. It would appear that Twitter is mostly used in Singapore as a tool to promote connectedness and coordinate top-down government directives during the pandemic. Perhaps because of this effort towards connectedness, the geospatial analysis does not show much regional differences. Instead, the indication is that Singapore works as one community to fight the pandemic even though there might be differences in infection rate among population groups. Overall, our study illustrates the use of social media as a population-level sensor for community resilience during the pandemic; it provides a promising data source for understanding user attitudes, thoughts and feelings towards the unprecedented health epidemic. Central to strengthening community resilience is partnership and a coordinated approach that informs and engages all stakeholders including the people themselves, to mobilise collective efforts and practise social responsibility.

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12

Role of the Professional Body in a Pandemic

Lesley Arnold, Zaffar Sadiq Mohamed-Ghouse and Tony Wheeler

Surveying and spatial sciences professional bodies are highly conscious of the impact that the novel coronavirus COVID-19 is having on Members and sustaining partners. This awareness has seen member services and activities repackaged across the globe accordingly. This chapter gives an Australian perspective of the role of the professional body during the pandemic: from ensuring the continued availability of professional development events, advocating on behalf of Members and industry, and maintaining professional networking opportunities.

12.1 Introduction

The COVID-19 pandemic has created a public health emergency that has had a massive impact on society and economies worldwide. Almost everyone is being impacted in some way by the unprecedented enforced business closures, border lockdowns and social distancing measures enacted to reduce the spread of the virus.

This disruption has, and continues to have, an impact on professional bodies and their members. Members are faced with the fear of unemployment, having to come to grips with home schooling and social isolation, sifting through misinformation to stay on top of evolving pandemic-related policy and regulations, and confronting a new way of life where health concerns and the wellbeing of family are the highest priority.

Understanding how the professional body can provide value during these unprecedented times is not clear cut. Like governments and businesses, the Surveying and Spatial Sciences Institute (SSSI) Australia, is grappling with the question 'What are the impacts and consequences of the COVID-19 pandemic on our members and industry?' – and, as a voice for our members, 'What are some of the services and solutions we can offer Members to boost opportunities for continued learning, networking and career development - in a time when job security, financial markets and economies are so uncertain'?

To answer these questions, SSSI conducted a COVID-19 Member Survey in April 2020 to gauge Member concerns and understand their needs. The responses received were encouraging - SSSI was on the right track, but with scope for improvement in six areas explained in this Chapter, namely:

1. **Advocacy**: Advocate on behalf of the surveying and spatial sciences as an essential service during the pandemic.
2. **CPD**: Continue to provide opportunities for Continuing Professional Development (CDP) but in an online format across all disciplines – surveying, hydrographic, engineering and mine surveying, spatial information and cartography, and remote sensing and photogrammetry.
3. **Member Connect**: Provide opportunities for Members to connect including channels where

they can seek support and advice on professional matters from other Members, while working from home environments.

4. **Job Opportunities**: A National 'Jobs Board' and support for curriculum vitae/resume writing.

5. **Member Services**: Adapt member processes to align with COVID-19 restrictions, such as removing the need for face-to-face communications.

6. **Economic Sensitivity**: Review the cost of services and hardship guidelines to align with economic uncertainties faced by Members.

For many Associations [1], the COVID-19 pandemic has created more work. Keeping members up-to-date with information updates, increased advocacy on behalf of members (including liaison with government, industry and other associations), moving professional development and member meetings online, and increasing webinar and digital content production, has had a substantial impact on workloads. According to the COVID-19 Impact Survey 'Finding Opportunity in Crisis' conducted by the Australian Society of Association Executives (AuSAE), 'through this disruption, associations have been working tirelessly to collect, curate and disseminate information, advocate to government to assist in the formation and impact of policy, and provided support and assistance for the professions and industries they represent'.

This Chapter discusses the role of the Surveying and Spatial Sciences Institute (SSSI), Australia during the COVID-19 pandemic. Results from the COVID-19 Member Survey are discussed, along with how the Institute is responding to Member feedback.

The lessons learned have application to similar industry associations and professional bodies, looking for ways to respond to Member's needs during these extraordinary times, as well as providing pathways for Members to apply their unique surveying and spatial sciences skillsets to help communities better manage infectious disease outbreaks.

12.2 Serving Surveying and Spatial Science Professionals

The Surveying and Spatial Sciences Institute (SSSI) is Australia's peak body representing the interests of surveying and spatial science professionals. SSSI combines the disciplines of land surveying, engineering and mining surveying, cartography, hydrography, remote sensing and spatial information science.

SSSI Members work in diverse roles across various sectors (health, transport, energy, planning, security, resources, education, property, etc.) including academia, government and private businesses throughout Australia and New Zealand, as well as overseas nations.

SSSI gives a voice to Members of the surveying and spatial sciences community, building upon the traditions, values and history of the surveying and spatial sciences profession, as well as fostering and empowering Members to achieve excellence and make positive contributions to the global community through learning programs that showcase innovative technological developments in both the national and international arena. SSSI recognises and showcases the excellence achieved by surveying and spatial sciences practitioners and the significant contributions they make to the wellbeing of communities.

While SSSI conducts ongoing reviews of Members services, the challenges posed to Members and developments in the profession itself have been fast-paced during the pandemic. One of the biggest impacts by far, has been the lockdown restrictions as these have prevented face-to-face meetings, Continuing Professional Development (CPD) events, and networking opportunities. These challenges are not unique to SSSI. The International Federation of Surveyors[1] (FIG) notes

[1] International Federation of Surveyors (FIG) a United Nations and World Bank recognised non-governmental organisation of national member associations, cadastral and mapping agencies and ministries, universities and corporates from over 120 countries

significant developments in surveying professional education due to the COVID-19 restrictions and the need to adapt to online learning and teaching. According to Associate Professor David Mitchell, Chair of FIG Commission 2 FIG, this has presented a range of challenges including which learning management system and video communications platforms to use, how to reach those students without adequate internet connection or with poor ICT quality, and how to teach those tasks that are heavily based around face-to-face contact, such as practical field projects, computer lab sessions and cartographic design projects. The result of these considerations has revealed some valuable lessons for blended learning opportunities [2].

12.3 COVID-19 Member Survey

To better understand how Members are faring during the COVID-19 Pandemic, SSSI issued a survey early April 2020 to Members asking them how SSSI can support their professional needs during this difficult time. There were seven questions. The results are summarised below and addressed in the following sections:

1. **Are you currently concerned about achieving your CPD points to maintain your professional and/or certified status?** (50% No; 38% Yes; and 12% Undecided)
2. **What type of CPD are you most interested in participating in?** Respondents could choose more than one option. (67% Surveying; 47% Geospatial; 28% Data Science; 27% Business Practices; 14% Project Reviews; and 39% Soft Skills)
3. **Are you aware that SSSI offers a program of online live webinars and recorded eCPD events, to assist you to maintain CPD?** (92% answered Yes; and 8% answered No)
4. **Have you participated in a SSSI webinar?** (19% answered No; and 44% answered Yes)
5. **What has prevented you from participating?** (19% said topic was not of interest; 34% said time not convenient; 22% said the cost was too high; 8% were not comfortable with the technology; and 41% said they did not have the time)
6. **How has COVID-19 impacted your work life?** (3% Made redundant; 16% Work hours reduced; 5% partner/spouse made redundant; 48% Working as normal; 42% Working as normal but from home; 13% Juggling work and home schooling; 15% Other – e.g. retired)
7. **Are you interested in participating in online social events with other surveying and spatial professionals, for example afternoon virtual drinks, online quiz nights?** (36% answered Yes; and 66% answered No)

The survey was completed by 362 Members. This low response rate told its own story – that Members were faced with other more pressing issues during the onset of the pandemic.

Nonetheless, the results were revealing and the feedback has helped SSSI respond differently in terms of advocacy, CPD, Member Connect (networking), job prospects, member services, financial sensitivities and volunteer opportunities.

12.3.1 Advocacy

SSSI has been encouraging growth and increasing the level of the understanding of the surveying and spatial profession across allied professions and the wider community over many years. This is typically done through incentives to support education in schools, informative articles, blogs and white papers on topics of critical relevance to the industry, as well as building the relevance of surveying and spatial sciences in government policy and, more recently facilitating online panel discussions.

In recent years, the focus for SSSI has been advocating on Australia's Services Export Plan [3], 2026 Spatial Industry Transformation and Growth Agenda [4], Diversity and Inclusion [5], Asia Pacific Capacity Development [6], Square Kilometre Array [7], mentoring for young professionals [8], geospatial in schools [9], Australia's Decadal Plan for Geography [10], and Australia's Spatial and Space Road Map, and so forth.

With the COVID-19 Pandemic, policy positions are evolving rapidly, and SSSI is now advocating alongside other industry associations – calling on all Australian Governments to ensure that responses to COVID-19 include dedicated strategies and take all necessary measures to protect and support people.

SSSI is also helping our professionals to be heard – advocating for surveying to be classified as an essential service for the community during the pandemic. Hydrographic surveyors are essential to maintaining the safety of our ports, engineering and mine surveyors are crucial to mining operations, and cadastral surveyors are essential to construction projects. All these services have ramped up as the government increases mining and construction to buoy up the economy. GIS professionals have also been busier than usual, particularly in the health sector where the crucial need for mapping services, COVID-19 dashboards and spatial analysis have increased as outbreaks have escalated. And yet, surveying and professionals are struggling to meet higher than usual demands due COVID-19 restrictions, for example:

- Surveyors costs have increased due to survey teams travelling in individual vehicles to worksites to maintain social distancing.
- Intrastate border lockdowns, such as those between regions in Western Australia, have prevented surveyors travelling to worksites, as travel permits only apply to recognised essential services.
- Engineering and Mine Surveyors are struggling to get to mine sites, because of the lack of local flights and restrictions on seating allocations.

While the methods of advocacy remain largely the same (policy statements, newsletters, telephone communications, opinion pieces) during the pandemic, the topics have undergone a considerable change – creating new 'advocacy territory' for SSSI and likeminded organisations. With this new environment, brings the need to engage more often with Members in order to respond on their behalf and in a time-sensitive manner.

12.3.2 Continuing Professional Development

SSSI offers members a Continuing Professional Development (CPD) Program designed to complement the busy professional wishing to undertake activities to further their current skills and experience within the workplace.

Given the cancellation of face-to-face events to comply with social distancing measures, it was surprising that the majority of survey respondents were not concerned about achieving their CPD accreditation for the year. Their optimism was buoyed by the increase in webinars and the ability to participate in monthly CPD meetings online.

As the COVID-19 outbreak unfolded, the ability to respond quickly with online CPD webinars was enabled through the support of Member volunteers, government, private industry and regional associations. SSSI held regular communications with cooperating regional associations – ASEAN Federation of Land Surveying and Geomatics[2] (AFLAG), Pacific Geospatial and Surveying Council[3] (PGSC) and Surveying & Spatial New Zealand[4] (S+SNZ). The outcome of these

[2] ASEAN Federation of Land Surveying and Geomatics (AFLAG), is the professional association duly accredited by the ASEAN Secretariat based in Jakarta, Indonesia representing the Geodetic Engineers, Surveyors and Geomatics practitioners in the region).

[3] Pacific Geospatial and Surveying Council (PGSC) vision is to focus on sustainable development in the Pacific Islands region enabled by world-class geospatial information and surveying services.

[4] Surveying & Spatial New Zealand (S+SNZ) is the professional body representing survey and spatial

discussions was the addition of jointly supported online events to provide mutual CPD opportunities for members of respective organisations.

The SSSI has been proactive in establishing Memorandums of Understandings (MOUs) and reciprocating arrangements with several likeminded professional associations and not for profit organisations including Open Geospatial Consortium[5] (OGC), Urban and Regional Information Systems Association[6] (URISA), FIG and International Society for Photogrammetry and Remote Sensing (ISPRS). These collaborations are proving crucial during the pandemic, particularly as the appetite for learning programs has increased, as they foster shared resourcing opportunities and knowledge-sharing. Collaboration is ongoing, and there has been a high-degree of information sharing through online panel discussions, to explore mutually beneficial opportunities for Members. The SSSI continues to monitor webinar activities globally for relevant content and opportunities for Members, and conversely, is also recording attendance levels to see if webinar fatigue sets in, to see if other opportunities need to be considered.

12.3.3 Member Connect

One of the primary roles of a professional body is enabling networking opportunities for members, locally, nationally and internationally. SSSI supports a network of strategic partners across all levels of government, Not-for-profit (NFP) and the private sector. The aim is to proliferate influence and broaden the support base to increase the reach and benefits for the membership.

Before the pandemic, SSSI provided a dedicated series of network building opportunities. For many Members this network helps to build careers, stay connected with peers, and to share experiences and learn from each other. At the local level, the regional committees customise networking events that have local interest to Members; at a National level, events are coordinated by the National Events Manager, and international events are typically organised through a steering committee, made up of interested parties.

With face-to-face events cancelled, SSSI has had to find creative ways to enable Members to connect. For example, the Locate 20 conference was reinvented as Locate Connect[7] – a virtual series bringing experts together to present on location-based topics and contribute to Q&A panel sessions.

While socialising has been difficult during the pandemic, survey respondents indicated that they were not especially looking for virtual social events from their professional body. People cited being 'time poor' as the main drawback, while others noted they happy to wait for face-to-face socialising to return.

Nonetheless, amidst the COVID-19 pandemic, SSSI went virtual for the annual Oceanic Asia-Pacific Spatial Excellence Awards (APSEA), held 28 May 2020. These awards recognise the achievements of enterprises and individuals in the surveying and spatial sciences industry. While it wasn't the gala dinner evening that Members are accustomed to, it still provided the opportunity to congratulate those that have contributed extensively to the four pillars of the profession – academia, government, research and the private sector. APSEA has been a highlight for 2020 and given the industry an opportunity to celebrate excellence.

The SSSI adopted a ChatApp to enable participants of the Bushfire recovery Map-a-thon[8] to connect. The App was rated a huge success, as it brought people together to share knowledge and ask questions of those who understand surveying and spatial sciences matter. At one point during the map-a-thon, there were over 200 participants logged in to the chat channel. It was an ideal way for the Map-a-thon community to network with each other and not feel isolated when working

professionals who work collaboratively to strengthen and celebrate the knowledge, capability and innovation within this exciting sector for the benefit of society.

[5] Open Geospatial Consortium (OGC) Global Resource for Information and Standards.

[6] Urban and Regional Information Systems Association (URISA) a non-profit association that provides education and training, a vibrant and connected community, advocacy for geospatial challenges and issues, and essential resources for GIS professionals throughout their careers.

[7] Locate Connect is a program of Locate Conferences Australia which SSSI is 50% shareholder and contributor https://www.locateconference.com/2021/locate-connect-program/

[8] OpenStreetMap is a collaborative project to create a free editable map of the world, accessible at https://wiki.openstreetmap.org/wiki/Mapathon

from home locations. In addition, organisers could make announcements to assist mappers, and supporters, such as Nearmap and OpenStreetMap (OSM), were able to participate and solve any technical issues immediately. Even after the map-a-thon, participants were still engaging on the chat channel, and it was exciting to see our international participants log-in during the day to get feedback before they started mapping.

SSSI is currently testing the method to enable professionals to keep in-touch during pandemic. The Chat channel includes conversations to share information on (1) spatial technologies being used to Tackle COVID-19; (2) privacy and sensitivity issues around data usage, particularly for contact tracing Apps; (3) impacts to business resulting from lockdowns and social distancing requirements; and (4) general announcements about events and Webinars.

12.3.4 Job Prospects

A common thread among survey respondents was the future of the profession, job prospects, and support for job seekers. Currently, SSSIs provides services that enable Members to maintain professional industry standards. This is achieved through certification programs that are relevant to current and emerging industry requirements. The certification essentially recognises that a person has demonstrated that he or she has the necessary knowledge and experience to competently work in their area of expertise.

Government organisations are increasingly adding certification as a criterion for businesses responding to tenders. This is because certification affords insurance of currency and knowledge. Since the COVID-19 outbreak there has been increased interest from regional associations to leverage these internationally accredited certification processes locally to increase job prospects for their Members. SSSI is also the authorised assessing authority for surveying and spatial sciences professionals emigrating to Australia. This experience of Migration Skills Assessment could be utilised by other countries to setup a similar process in their region and train assessors.

As a consequence of the pandemic, Members are now faced with work redundancies and the need to upskill to find new opportunities. The pandemic has highlighted that SSSI has a broader role in assisting Members to be ‘Job Ready’. In addition, to CPD and certification to enhance career progression, survey respondents are keen to have support for professional curriculum vitae/resume writing, and notifications of job openings and scholarship opportunities in the surveying and spatial sciences field. Job application writing, interview training, presentation skills and a ’jobs board’ are new areas for the SSSI to focus on.

12.3.5 Member Services

Magazines, journals and bulletins provide the most effective method for keeping Members up-to-date. The majority of these communiques are now online. However, for SSSI, some processes were still tied to the postal service and that created some concern due to delayed services, brought about by the increase postal traffic during the pandemic as people moved to online shopping delivery. For this reason, newsletters and renewal notifications were moved to online/email-only transactions. Members have been quick to approve the change – noting a reduced environmental footprint.

COVID-19 has resulted in several process improvements. To become a Member, applicants were required to meet a Justice of the Peace in person to have original academic records certified. Due to social distancing requirements, this requirement has been removed and the process to become a Member is now far more streamlined.

Cash payments for renewals are also no longer acceptable to Members during the pandemic. As a result, SSSI had to fast-track more flexible payment options for events, professional certification, membership renewals and re-joining fees – with BPay, PayPal and credit card options now available to Members in addition to the existing cheque and Electronic Funds Transfer (EFT).

SSSI regional committees also had to rethink how they engaged with Members and provided services. The SSSI Board, regional committees, and other interest groups moved to online platforms to continue their important work and socialise.

The pandemic has also fast-tracked the need to consider other process improvements, such as speaking with businesses and surveyors' boards to better understand the pain points for Members and employers alike. According to [11], now is the time to reimagine business models, confront challenges and position for future opportunities; this includes recovering revenue, rebuilding operations, rethinking the organisation and accelerating the adoption of digital solutions.

12.3.6 Economic Sensitivity

Both associations and Members are facing economic setbacks during the pandemic, and this is posing a conundrum. The cancellation of conferences and face-to-face events has removed an income stream for Professional bodies, and this revenue is required to keep Member fees down. Yet, increasing Member fees is not a palatable option. Members are also facing hardship due to reduced household incomes resulting from redundancies. This poses a dilemma for the professional body faced with having to spend additional resources (without receiving additional revenue) to be able to provide new services.

Professional bodies survive by being able to achieve sustainable 'economies of scale'. As the number of Members increase, services become more cost effective, for example the unit cost of printing a publication is reduced as the number of copies increases. This means that retaining Members and increasing Member numbers has a direct effect on the number and quality services offered, and the price-point for Members.

Interestingly, the AuSEA noted that 'Through this crisis Associations have reported increased member engagement and in some cases growth in membership as they became a trusted source of truth for their members and communities' [1].

However, the question remains, 'what can the Professional Body do to address the current economic sensitives brought on by the pandemic'?

SSSI Members are our most important asset, and providing 'value for money' to Members has never been more crucial than during the pandemic. The new financial year provided the opportunity to consider new member services, renewal options and renewal incentives.

SSSI introduced the **MemberOne Program**, essentially an incentive scheme for existing members to introduce new members to SSSI. The more members referred, the greater discount the Member receives to their SSSI membership fee – a substantial saving during these uncertain times. The program outline is as follows:

- Introduce one new person that becomes a financial member during 20/21FY and receive 20% discount off your membership fee in 21/22FY.
- Introduce two new people that become financial members during 20/21FY and receive 25% discount off your membership fee in 21/22FY.
- Introduce three new people that become financial members during 20/21FY and receive 30% discount off your membership fee in 21/22FY.

In addition, SSSI has introduced monthly payment options to assist those facing hardship. Members can choose to pay monthly instead of paying an annual upfront fee. Also, SSSI has reviewed the Membership Policy to ensure the guidelines for hardship applications are applicable to pandemic situations and are simplified so as not to exacerbate the circumstances generating the hardship. While it is not possible to list all the possible circumstances, the 'Hardship Application' exempts annual subscriptions for:

- extended illness that results in a member being on extended sick leave from their work place; and
- a period of extended unemployment.

From 1 July 2020, SSSI made all webinars free to Members. This action was in response to Members' survey feedback. SSSI Webinars offer value for money when considered part of Membership fees. In addition, when SSSI does return to face to face events, that aim is to ensure that event pricing is reflective of a significant financial advantage to SSSI members over non-members. This will be important, as the financial impacts of the pandemic are expected to last for some time to come.

12.4 Moving Back to Normality

There is a general perception that there is no returning to normal after COVID-19, but professional bodies do need a pathway forward. The world is likely to recover at differing speeds, and the speed will vary depending on the type of industry.

Professional bodies require a strategic decision-making framework that is a staged approach to assessing needs and priorities – one that looks beyond the current disruptions to reposition Member services to suit a post-pandemic society. This is the next big challenge for the professional body.

The pandemic affords the opportunity to step back and reposition Member services so that when life starts to get back to normal, whatever this may look like, there are new initiatives, hopes and opportunities for Members to look forward to.

12.5 Conclusion

During a pandemic, the professional body has an important role to play in supporting its Members and the profession it represents. This paper has presented a case study of the challenges faced by the Surveying and Spatial Science Institute (SSSI) Australia, and its Members. Through the COVID-19 Membership Survey, SSSI has been progressively responding to Members suggestions and concerns in the areas of advocacy, CPD, Member connect, Job Prospects, Member services, economic sensitivity, and opportunities for volunteering.

The next big challenge for the professional body is to look beyond the COVID-19 disruptions, and reposition Member services to suit a post-pandemic society. This will require a strategic and staged approach to implementation, and consideration of the lessons learned during the pandemic. In summary, the major lessons learned have been to:

- Vastly increase the amount of content that Members can access online, including an ambitious plan for online CPD and learning, that has since been well publicised, recognised and respected. The current climate has provided an opportunity for some Members to upskill, progress qualifications and learn new skills such as programming and latest software developments. For those Members that are 'time poor' content is available and can be downloaded after the live events.

- Establishing strong networks with other likeminded associations and organisations. The opportunity to think globally and act locally, by leveraging national and international exclusive partner agreements, has enabled SSSI to provide members with the best possible content for them to improve and grow their knowledge and competitive edge.

- Adopt a mindset of 'process improvement'. During the COVID-19 pandemic, SSSI took the opportunity to streamline processes across the business, particularly around membership applications, renewals and flexible payment options, as well as removing the need for face-to-face communications – no longer appropriate during the pandemic.

- Enhance Certification Programs. SSSI, through its Engineering Mine Surveying Commission volunteers, has enhanced the Engineering and Mine Surveying Certification process – providing Members with an additional incentive to learn, and have that learning recognised.

- Maximise value for Members by opening up communication channels in times of crisis. The SSSI connected with Members via the COVD-19 Member Survey. The feedback has enabled SSSI to makes decisions that create value for money for members including free Webinars and opportunities to enhance job prospects; as well as consider the financial constraints on Members and their families during this difficult time.

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13

OpenStreetMap Data Use Cases During the Early Months of the COVID-19 Pandemic

Peter Mooney, A. Yair Grinberger, Marco Minghini, Serena Coetzee, Levente Juhasz and Godwin Yeboah

Created by volunteers since 2004, OpenStreetMap (OSM) is a global geographic database available under an open access license and currently used by a multitude of actors worldwide. This chapter describes the role played by OSM during the early months (from January to July 2020) of the ongoing COVID-19 pandemic, which - in contrast to past disasters and epidemics - is a global event impacting both developed and developing countries. A large number of COVID-19-related OSM use cases were collected and grouped into a number of research frameworks which are analyzed separately: dashboards and services simply using OSM as a basemap, applications using raw OSM data, initiatives to collect new OSM data, imports of authoritative data into OSM, and traditional academic research on OSM in the COVID-19 response. The wealth of examples provided in the chapter, including an analysis of OSM tile usage in two countries (Italy and China) deeply affected in the earliest months of 2020, prove that OSM has been and still is heavily used to address the COVID-19 crisis, although with types and mechanisms that are often different depending on the affected area or country and the related communities.

13.1 Introduction

The OpenStreetMap (OSM) project was started in University College London in 2004 and has subsequently grown to be arguably the largest and most popular Volunteered Geographic Information (VGI) and open geographic data project in the world today [1]. The data within the OSM database is completely open and is available under an Open Database License (ODbL). The contributors of geographic data to OSM are predominantly citizens not specifically connected to the professional production or management of geographic data. However, in recent years, governments and commercial companies have become involved in the contribution of data to OSM and the editing and maintenance of the existing data. Mooney and Minghini [2] provide an extensive description of the users and uses of OSM data. Many people who encounter OSM mistakenly consider the online maps and associated digital cartographic products from OSM as the entire OSM project. This is incorrect. OSM is primarily a very large spatial database of geographic data. Online maps and other services such as routing or information services are derived products and could not exist without the underlying OSM database. The data model used within the OSM database is simple to understand but is powerful enough to prove capable of expressing the complex geographical relationships and topologies encountered in real world environments such as road networks, commercial and industrial settings, landuse features such as lakes and rivers, and residential buildings.

The data model expresses three object types: nodes (or points), polygons and polylines (collectively called ways). Relations are a logical object expressing a collection of these objects to represent complex compound geographic features such as railway stations, airports, transport routes, etc. Every object (except those nodes making up ways) must have at least one descriptive attribute associated with it. These attributes are called tags and are stored as key-value pairs. Very detailed guidance on the available tags, acceptable values for specific keys, and usage examples are provided on the Map Features page in the OSM Wiki [3] and often within software. However, the application and use of tags on objects in OSM is not strictly enforced and follows a folksonomy approach allowing contributors to choose tags as they see appropriate. This approach has led to many criticisms of the quality of OSM data over the years [4]. One unique aspect of the OSM database is the ability for anyone to access the entire contribution and editing history of the data within the database. This allows researchers to study the evolution of the OSM data in specific areas, study contribution patterns over time, analyse how the OSM database grows with influence from external events such as natural or humanitarian disasters.

There are a number of methods which support contribution or insertion of geographic data into the OSM database. These methods are supplemented by a myriad of software tools and services available with the entire OSM ecosystem. Field survey, implying a physical knowledge of the area under survey, using GPS tools, cameras and other software is supported widely. Social events called "mapping parties" often involve people meeting up at group events to undertake field mapping of a specific area ([5, 6]). However, the most commonly used approach is remote mapping using web-based interfaces such as the popular iD editor allowing contributors to remotely map an area by digitizing data on top of satellite imagery. Contributors using this approach are urged to have some knowledge of the area being mapped and at minimum consult the extensive documentation and guidance on the OSM wiki on how to map properly. "Mapathons" are popular events where people, even located in different parts of the world, meet virtually and do remote mapping on the same area. Finally, the software-automated import of existing geographic datasets and databases is also possible and has been used widely in OSM to import datasets such as road networks and buildings. Automated imports are complex database operations and those undertaking such imports are strongly encouraged to seek the approval of the local OSM community in the geographic area of the import before proceeding. Imports should also be clearly documented in the OSM wiki.

Previous to the COVID-19 pandemic OSM had been used in many humanitarian and environmental disaster situations where access to up-to-date and accurate geographic data was immediately required and remote mapping and field mapping exercises could quickly generate geographic data for an area if none existed. This chapter will analyse and understand how OSM has been used during the early months of the COVID-19 pandemic. By early months we are referring to the period between January 2020 and July 2020. In January 2020 the World Health Organization (WHO) announced the COVID-19 epidemic, a public health emergency of international concern. The coronavirus disease 2019 (COVID-19) has subsequently become a global pandemic and has imposed unprecedented change all over the world in how we interact as humans, in our working practices, and how medical professionals carry out their work. Most countries in the world have experienced many COVID-19 related deaths and high rates of COVID-19 spread amongst their populations. This chapter will be a strong and defined contribution to the knowledge on how VGI initiatives such as OSM respond and are used or accessed during a global crisis such as the COVID-19 pandemic. The novel aspect of this work is that this critical assessment is being delivered during this unfolding and unprecedented event rather than from an a posteriori position. Furthermore, we believe that this work will produce knowledge about humanitarian mapping in a context never studied before - a global event with significant impacts in developed regions.

The remainder of the chapter is organized as follows. In Section 13.2 we provide a discussion of background and related work. Section 13.3 provides an overview of the methodology and research employed in this work. In Section 13.4 we discuss the use of OSM data in the COVID-19 response, while section 13.5 discusses the collection of new OSM data for COVID-19 responses. Section 13.6 briefly discusses current academic research with OSM during the COVID-19 response. In section 13.7 we make some conclusions and outline some future work.

13.2 Background and Related Work

The potential of OSM for supporting humanitarian efforts during crisis situations was noticed as early as 2010 after a magnitude 7.0 earthquake struck Haiti. Volunteers across the world supported humanitarian efforts through mapping activities across multiple platforms, including OSM contributors who produced much data using available aerial imagery within only a few weeks [7]. These efforts have led to the formation of the Humanitarian OpenStreetMap Team (HOT), an international charitable organization which organizes and oversees open mapping in humanitarian contexts [8]. Since then, HOT was involved in initiating and coordinating mapping efforts in multiple cases, including following the 2013 Yolanda Typhoon in the Philippines [9] and the 2015 Nepal Earthquake [10]. The open source Tasking Manager (TM) software [11], developed by HOT and aimed at coordinated collaborative mapping, was also re-used by several communities worldwide, such as the Italian one to coordinate mapping after the 2016 earthquake [12]. Today, digital humanitarianism in OSM goes beyond disaster response with the organization of activities that aim at supporting vulnerable communities to increase their resilience [13–15]. Furthermore, the richness of OSM data facilitates further applications, frequently including the development of third party tools that utilize OSM data for creating additional data or carrying geographic analyses. For example, efforts after the 2010 Haitian earthquake also included the application of an Emergency Route Service relying on up-to-date OSM data [16]; OSM data was also used as a baseline for the Flooded Streets tool used to produce a crowdsourced map of flooded streets in Chennai, India during a 2015 flooding event [17].

One issue that is also being considered within this context is the management of health crises and the possible contributions of OSM to managing health crises and monitoring epidemics. Mooney et al. [18], when discussing the role of VGI in pervasive health applications, identify OSM as a potential "virtual audit instrument" describing local environments. Accordingly, much effort is being put into collecting information required for monitoring health-related outcomes, e.g. mapping settlements and buildings to assist malaria prevention in Kenya and Mozambique [19], health facilities[20], and other critical infrastructure [21], while other works strive to utilize existing data to mitigate health effects and assess accessibility to medical facilities [22–25]. The response to the 2014-2016 Ebola outbreak in West Africa, which turned from a local response to an extended international effort [26] presents a relevant and unique example. During the breakout, HOT volunteers mapped large portions of the infected regions, providing support for on-the-ground teams of the Médecins Sans Frontières and facilitating the production of epidemiological maps [27, 28]. Additionally, an OSM-based navigation service (OSM Automated Navigation Directions - OsmAnd) was used to support data collection activities by locals [29]. The studies surveyed above present crisis relief and disaster response as a multi-dimensional framework. The support of relief efforts may begin with providing reliable basemaps but extends even beyond the production of the information that these maps require into the development of new products and services, based on OSM data, for the benefit of responders and the general population.

In the following sections we use this to survey and analyse the different dimensions through which the OSM community has responded to the COVID-19 crisis. Bearing in mind the cross-boundary effects of the pandemic, we also consider the formation of inter-regional collaborations, as in the case of the Ebola outbreak discussed above.

13.3 Methodology and Research Approach

To survey and analyse the different dimensions through which the OSM community has responded to the COVID-19 crisis we considered the following *OSM Response Frameworks* (our terminology) as follows:

- **OSM usage as a cartographic basemap in COVID-19 related applications** which can indicate the project's maturity and ability to compete as an alternative to commercial and authoritative mapping service providers;

- **COVID-19 related applications or services using OSM data** (such as points of interest, road networks, building data such as hospitals or medical facilities);

- **Initiatives or applications aimed at the collection of new OSM data** immediately relevant to the COVID-19 pandemic response or management;

- **COVID-19 influenced imports of authoritative geospatial data into OSM** where there are gaps in the OSM database for a particular country or region; and,

- **Academic research about the role of OSM in the COVID-19 response**.

The proposed methodology for understanding the role played in each of the OSM Response Frameworks is comprised of a number of research tasks which are summarised as follows:

- traditional literature review focused on standard academic sources, web searches of social media, and research of available gray literature such as multimedia, reports, presentations and mailing lists;

- analysis of OSM map tile access and usage on a global scale, including comparison with the pre-COVID-19 situation to find out whether the pandemic has generated more OSM tile access and usage than pre-COVID-19 situation.

While most readers will be familiar with traditional literature reviews, the tiled web map system requires some explanation. The tiled web map system divides the earth into a set of regular tiles corresponding to different zoom levels. Web-based maps usually display geographic information by loading map image tiles (or lately, vector tiles) corresponding to a geographic area and stitching them together to a visually seamless map experience. A description of tiled web maps is found in Juhasz and Hochmair [30]. OSM tiles can be displayed on any map free of charge if adhering to the tile usage policy [31]. We extracted OSM tile usage statistics from Planet OSM [32] for affected areas in Italy (Lombardy) and China (Wuhan) along with control areas within the same country (Sicily and Beijing, respectively) to reveal whether COVID-19 increases tile usage. Our detailed methodology and technical details can be found in Figure 13.1. We choose zoom level 13, in which details correspond to the regional level with one tile covering 23.9 km^2 (Figure 13.1) and compare usage between pre-COVID-19 (January 1 - 21) and affected times (February 5 - 25 in China and March 11 - 31 in Italy).

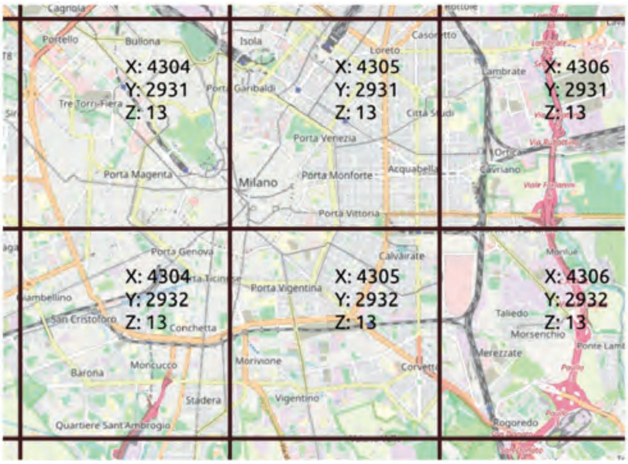

FIGURE 13.1
Illustration of web map tiles in zoom level 13 in the area of Milan, Italy.

13.4 Use of OSM Data for COVID-19

We searched for websites offering web maps and geospatial services related to the COVID-19 pandemic. The bulleted list below (at the end of this Section 13.4) presents a typology of the websites with references to prominent examples. We identified two major types of websites - visualizations of COVID-19 data and geospatial services. The most prominent example of data visualizations are dashboards which simply overlay OSM data with other types of data, i.e. OSM was used as a basemap only (see some examples in Figure 13.2 and Figure 13.3). Online dashboards are typically driven by open data on the pandemic released by governments and/or other organizations (e.g. the popular dataset from the Center for Systems Science and Engineering at Johns Hopkins University [33]) and communicate numbers and statistics, usually updated on a regular basis, through tables, graphs and thematic maps. These dashboards serve to inform experts, decision makers and the general public. Many of the dashboards designed by national governments, research organizations and volunteers use OSM as the basemap. A subtype within this group of websites are websites presenting dynamic visualizations of the spread of the virus. It seems that most of the dashboards featuring OSM basemaps are also realized with open source mapping software and designed by volunteers, and research or not-for-profit organizations and businesses. Dashboards produced by governments (which show the same COVID-19 data) seemed instead to rely more heavily on proprietary technology and basemaps.

The geospatial services group includes three subtypes. The first provides more types of geospatial information, extending beyond contagion patterns. The information content in these websites is very diverse, ranging from general information on issues such as resilience and support measures for enterprises to practical information, e.g. locations for testing for COVID-19 and on the availability of masks in pharmacies. The second subtype extends this approach (and hence there is some overlap between the two subtypes), allowing users to contribute data themselves, i.e. become "produsers" [34]. Notice that these are platform-specific data (e.g. where masks are 3-d printed) and not data that are fed back into OSM. The third subtype facilitates more complex spatial queries, e.g. by comparing users' location history to assess their exposure to COVID-19 or when identifying areas allowed for travel in the vicinity of users' homes. Swedish TV [35] stands out among these by utilizing the isochrones functionality of OpenRouteService [36] (see Figure 13.4, thus extending beyond the "OSM as basemap" type of data usage. This is related to the unique restrictions imposed in Sweden which were defined by driving time instead of Euclidean distance, hence requiring more complex spatial querying capabilities.

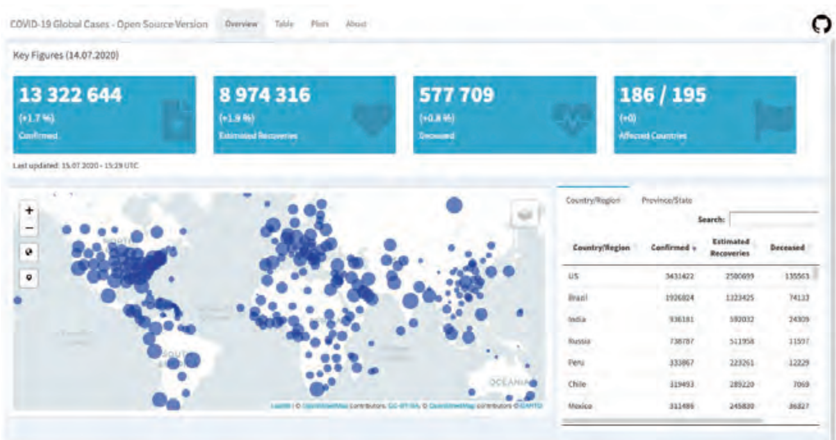

FIGURE 13.2
A dashboard focused on global COVID-19 cases. Source: [37].

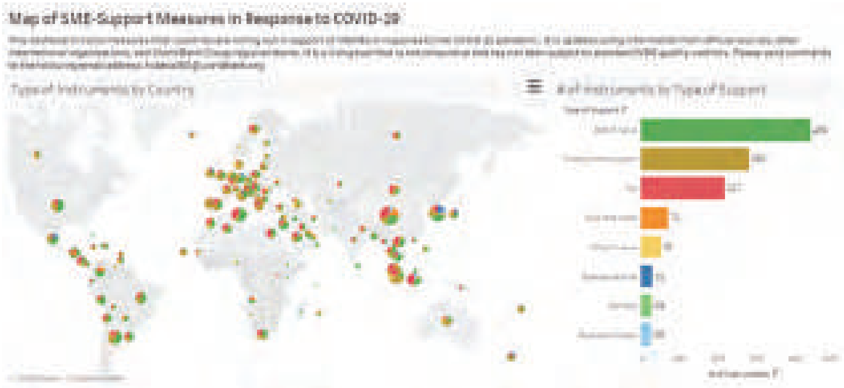

FIGURE 13.3
World Bank map showing the measures of each country to support small and medium-sized enterprises (SMEs) in response to COVID-19. Source: [38].

Typology of websites and services using OSM data, with examples

- **Website type: COVID-19 data visualizations**
  - ***Dashboards:***
    Examples: Global [33, 37, 39–41]; continental/regional [42]; national/local [40, 43–48];
  - ***Dynamic visualizations:***
    Examples: the spread of virus infections over time [49]; the phylogeny of SARS-CoV-2 viruses from the ongoing novel coronavirus COVID-19 [50].
- **Website type: COVID-19 related geospatial services**
  - ***Geospatial information services:***
    Examples: measures supporting small to medium-sized enterprises [38]; social media posts [51]; change in mobility patterns [52]; 3-d printing of masks for medical staff [53]; locations of clinical trials [54]; locations of food resources [55]; resilience measures for businesses [56] and population [57]; locations for testing for COVID-19 [58]; stocks of masks in pharmacies [59]; queuing time in border crossings [60]; change in air quality during lockdowns [61]; state of public transport [62];
  - ***Services facilitating (non-OSM) data contribution:***
    Examples: 3-d printing of masks for medical staff [53]; initiating joint delivery of goods [63]; queuing times in supermarkets [64];
  - ***Services performing geospatial queries:***
    Examples: assessment of exposure to COVID-19 using location history [65–67]; identification of areas allowed for travel from a location, given travel restrictions [35, 68].

The dashboards and web maps above make use of a wide range of different OSM basemaps. Many of these are provided by commercial mapping companies such as CARTO [69] and Mapbox [70]. Other websites and services, especially community-developed projects without financial means to afford using commercial providers, rely on the freely available tiles provided by OSM. To assess whether OSM tiles were used in connection with COVID-19 response, we compared tile usage statistics between two greatly affected regions (Lombardy in Italy and Wuhan in China) with their relatively unaffected counterparts within the same countries (Sicily and Beijing). The left panel of Figure 13.5. a-b plots the number of times tiles were loaded for study sites between January 1 and June 30, 2020. The baseline for the comparison was set to a 3-week-long period between January 1 and January 21 (purple, shaded vertical area), which were compared to 3-week-long affected periods (orange, shaded vertical area, February 5 - 25 in China and March 11 - 31 in Italy). Control and

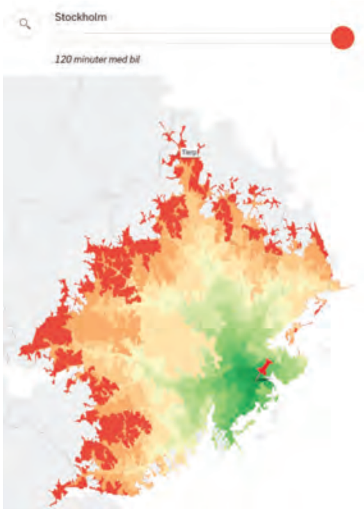

FIGURE 13.4
Swedish Television's interface using OSM road network data and the isochrones function of OpenRouteService for computing areas within 2 hours driving distance from a location in Sweden (example shows the isochrones from Stockholm's center). Source: [35].

affected periods start with a Wednesday and end with a Tuesday 3 weeks later to eliminate the daily temporal trend that is visible in the left side of Figure 13.5. We assume that the seasonal trend is constant across affected areas and their unaffected counterparts within the same country, therefore seasonal patterns were left untreated. Plots in the right panel of Figure 13.5 show the difference between normalized tile usage patterns for a region. A value of 1 means that tiles were only loaded during the period affected with COVID-19, and -1 means the opposite. The red horizontal shows that equal numbers of tiles were loaded during the control and affected periods on a given day. The normalized difference is higher in Lombardy and in Wuhan than in Sicily and Beijing respectively, which suggests that areas greatly affected by COVID-19 were viewed more frequently than would be expected under normal conditions as seen in the tile logs. Two paired t-tests were conducted, which confirmed that the increased attention affected areas were experiencing was statistically significant, $t(20) = 5.00$, $p < 0.001$ for Italy and $t(20) = 8.63$, $p < 0.001$ for China.

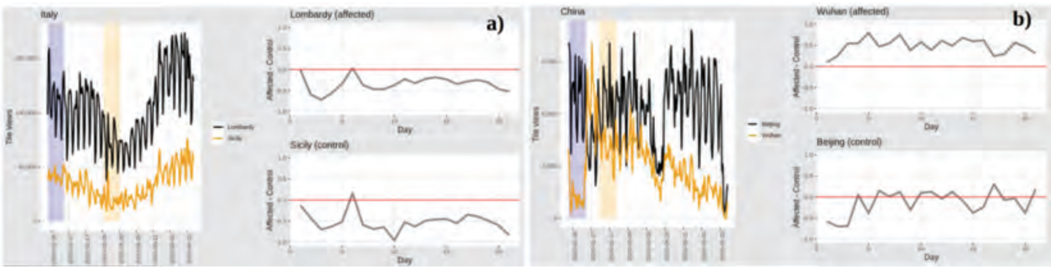

FIGURE 13.5
Tile usage statistics for selected areas in Italy (a) and China (b). The left side of figures shows the number of times tiles were loaded. Purple vertical area is the control period where orange vertical area shows a 3-week-period affected by COVID-19. The right side of sub-plots show the difference of normalized tile usage patterns for an area.

13.5 Collection of OSM Data for COVID-19

The ongoing COVID-19 pandemic has also seen an unprecedented amount and type of activities to collect new OSM data. Not surprisingly, May 2020 has set the all-time records for the numbers of daily OSM contributors (7,209), newly registered OSM users (6,259) and newly registered users who contributed data (1,019) - all of them on May 14 [71]. This section summarizes the main nature of such activities and provides, whenever possible, details on the reasons for collecting OSM data and/or the communities or organizations which actually requested those data. However, a key strength of any VGI project is the chance that data can be used by anyone, at any time, and for purposes that might be different and even unknown to the users who originally collected those data [72]. Proliferation of Artificial Intelligence (AI), which has reached a massive uptake during the COVID-19 crisis [73], does nothing but reinforce this statement. OSM data collection to address the COVID-19 pandemic has happened in all the ways described in Section 13.1. Remote mapping is by far the method by which most data was contributed and it is not surprising that such efforts were led by HOT. At the time of writing (mid-July 2020), the HOT TM lists 183 projects targeted at COVID-19 emergencies worldwide with aims for the collection of baseline OSM data such as buildings, road networks, land use areas and placenames [74]. These projects mainly address regions in African and South American countries where baseline maps are still not available, with Peru being the most popular one with a total of 84 projects. The OSM contribution records mentioned above were directly attributed to increased activity in HOT's projects in Peru, Botswana and Central African Republic, with a mapping peak in the Cusco region in Peru [71]. A recent tweet from HOT [75] reported about more than 10,000 volunteers who have mapped over 1.7 million buildings and over 41,000 km of roads in COVID-19 projects so far. The organizations requesting the activation of these HOT projects, which will use the collected OSM data afterwards, are national or regional governments, health authorities, humanitarian organizations and NGOs. As usual, also during COVID-19 times mapathons (mostly virtual, given the mobility restrictions) have been extensively organized by several organizations worldwide to perform coordinated remote mapping in specific areas, with HOT itself providing tips and suggestions on how to map COVID-specific OSM objects [76].

In addition to the HOT TM, another tool that has been widely used during the COVID-19 crisis is `healthsites.io` [77], which aims to build an open geospatial dataset of every health care facility in the world, allowing to map e.g. hospitals (`amenity=hospital`), pharmacies (`amenity=pharmacy`) and doctors (`amenity=doctors`) and to add tags to the already available ones. This type of mapping clearly requires a personal knowledge of the health facilities to add and therefore it is not a task for remote users like those involved in HOT projects. Similarly in the MapRoulette application for fixing OSM data bugs [78], projects were created for improving health-related OSM data, e.g. by adding information about the number of beds in hospitals. Other different types of OSM mapping activities require field surveys to record the locations of specific objects. As an example, in Cape Town (South Africa) communal pit latrines pose a COVID-19 transmission risk, similar to other places frequented by many people, such as public transport, shopping centres or communal water taps. In the Cape Town area (Dunoon), the Western Cape Government used OSM to map at least 900 communal toilets in informal areas, and these were included in their risk analysis and risk management approach [79–81].

The ways to contribute OSM data during the COVID-19 pandemic have been very different in other countries where the baseline cartography was already available and the focus was placed on adding detailed COVID-19 information. For example, the popular application *Ca reste ouvert* [83], created by the OSM French community and then extended to other countries (including Italy, Germany, Austria and Switzerland), offers a thematic visualization of commercial activities based on whether they are open during the COVID-19 crisis; information on the COVID-19 specific opening hours, takeaway and delivery service are also shown and can be added/edited by users. This explains how dynamically the OSM communities reacted to the emergency by creating new OSM tags such as `opening_hours:covid19=*`, `takeaway:covid19=*`, `delivery:covid19=*`. Given that such information was either not available elsewhere or made available only in a very fragmented way (e.g. lists of activities that were open or offered takeaway/delivery services were published as plain

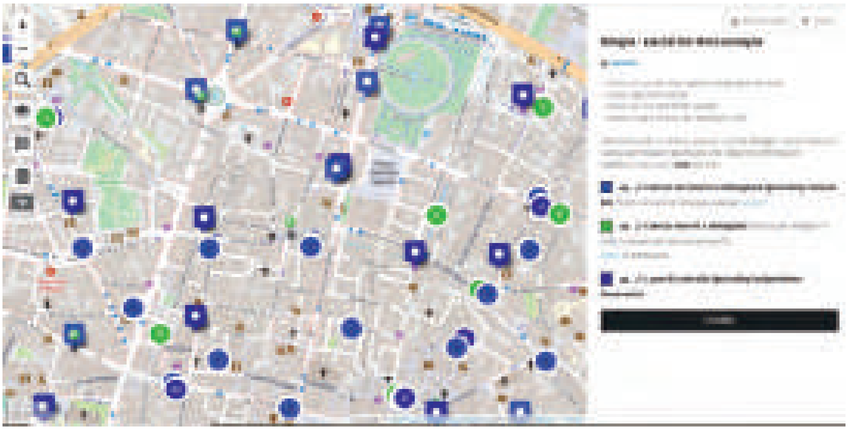

FIGURE 13.6
uMap project to facilitate the OSM import of commercial activities offering delivery service in the Municipality of Bologna, Italy. The colors of the OSM markers distinguish the activities already imported from those still to be imported. Source: [82].

text on websites of local governments or newspapers), OSM has acted as the only platform to store and offer such data in a structured way. As an exception to the general situation described above, some Italian municipalities provided the datasets of commercial activities offering delivery services on their open data portals under OSM-compatible licenses to allow their import. An example is a dataset from the Municipality of Bologna[84], that was imported in OSM by the Italian community through a documented procedure [85] based on a collaborative uMap project [82] (see Figure 13.6).

Another key dataset in Italy that was made available for integration in OSM was the dataset of all Italian pharmacies provided by the Italian Ministry of Health. In this case, given that most pharmacies were already available in OSM, the work performed by the community was not a bulk import but a manual integration of the missing information. Finally, given the high use of OSM data in Italy from emergency agencies such as Red Cross, Civil Protection and fire fighters, the Italian community also decided to focus the mapping efforts during COVID-19 times on substantial imports that were prepared or started in the past but not yet completed, e.g. the one for all addresses in the Municipality of Milan [86].

13.6 Academic Research with OSM During the COVID-19 Response

Although the literature covering COVID-19 is fast changing, there is evidence that OSM is a valuable resource for the scientific community. Published research in the early months of the pandemic mainly appeared in medical and health related outlets, however, at the time of writing, there are several examples of utilizing OSM data and related infrastructures spanning across different scientific disciplines. French-Pardo et al. [87] reviewed 63 articles on the spatial dimensions of COVID-19 and found that most national and regional web viewers use the ArcGIS Online platform [88], however, they also noted that some works utilized OSM because it was free. Some studies used a passive approach and utilized OSM data only for display, such as showing aggregate survey results based on neighborhoods extracted from OSM in Israel [89], or displaying detected hotspots on an OSM basemap [90]. Another study went beyond the basic use of OSM data and extracted social concentration places (e.g. ATMs, bus stops) from OSM to predict mortality trends as part of the first comprehensive study of COVID-19 in Iran [91]. Qazi et al. [92] compiled more than 524 million COVID-19 tweets and used OSM's Nominatim service to geocode and reverse geocode toponyms found in tweets [92]. This highlights that the ecosystem built around OSM data provides researchers with free to use tools for a number of use cases. Apart from these few examples, a quick literature search on Google Scholar for "OpenStreetMap" and "Covid-19" keywords yields several early stage research hosted on arxiv, medrxiv, ResearchGate and other preprint publishing services.

If one had to share data representing the home locations of COVID-19 infected people, their location privacy would be infringed. Geographic masks make it possible to share data in a representative way, without risking the individual's location privacy. Swanlund et al. [93] propose a new method for masking locations of individuals. Instead of displacing locations randomly to other houses (which is done in traditional methods), they move them along a street in the OSM road network. One of the advantages of this method is that OSM data is readily available. For other methods address data and/or population data are required, both of which are more difficult to get hold of.

13.7 Conclusions and Future Work

OSM is mostly used as a basemap, whether for dashboards or for other services. This is not unique to OSM, as there are many dashboards and services using Google Maps and the like. The only cases we have found (so far) that actually used OSM data was when the restrictions called for complex spatial queries that could be completed by OSM-based tools. Yet, this is still not something that is inherently unique to OSM and could be developed also with other frameworks. Given the unique nature of OSM we had expected a more widespread utilisation in the situation of a global pandemic. However, OSM usage is still impressively high and global. Humanitarian efforts in OSM are well suited for disasters and hazards, but not to rolling events like epidemics. While OSM has a very flexible data model and many easy-to-use data contribution methods there is a tendency to map permanent entities (at least for the short term) while much of the mapping during COVID-19 is all about temporary response (e.g. stocks of masks, exposure, supermarket queuing, changes in opening times). There is probably a need to produce a practice of COVID-19 tagging in OSM which requires discussion and coordination in order to make tagging practices fit for pandemic response purposes. Given the global nature of the pandemic, such non-trivial efforts should in principle involve all OSM communities worldwide and would benefit from the coordination of the OpenStreetMap Foundation, which supports the OSM project but does not take decisions about tags [94]. However, the establishment of global COVID-19 tagging practices appears to be hard, not only because of the traditional differences in OSM tagging practices across the world [95], but also due to the legal and ethical aspects that COVID-19 information might bring, at least in some countries or areas of the world.

OSM provides citizens and agencies an easy way to contribute or help in a pandemic response as opposed to not being able to contribute to authoritative datasets. Even if OSM data does not exist before the event it can be created almost in real-time by citizens locally or around the world. The data is accurate and high quality. The increased tile usage in badly affected COVID-19 areas also suggests that there is a need for freely accessible map services. OSM has been utilised in a wide variety of ways during the early phase of the pandemic. However, because OSM is truly open data we may never know of all the uses of OSM data during this period and estimation of usage could be difficult.

There are a number of very interesting questions for future work. Further investigation is required to understand if, and why, governments predominantly used proprietary tools and basemaps during the COVID-19 pandemic whilst research institutions, universities, community organisations used OSM. Analysis of the OSM contribution history will help to understand COVID-19 related OSM data contributions and/or data contributions during the pandemic. This could provide insights into possible correlations between the volume/activity/nature of contributions and the spread/evolution of the pandemic in a given country. The contribution of new data in OSM to address pandemics such as COVID-19 followed different contribution patterns than those observed before and these will offer fruitful grounds for future research work [96]. In Mooney and Juhász [97] the authors comment that many web-based maps produced during the early stages of the COVID-19 pandemic appear different or even contradictory. Urgent attention is required in order to consider how to deliver this information effectively within the constraints of the web-based map. Finally, it would be very interesting to consider a deeper exploration of the causes for differences between OSM communities during the pandemic given that COVID-19 has affected both developed and developing regions in the world.

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14

Utilization of Geospatial Network Analysis Technique for Optimal Route Planning During COVID-19 Pandemic

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The local government bodies (LGBs) in India have taken several steps to reduce the spread of the virus. Disinfection of common public spaces such as roads and streets are one such step adopted by municipal council of Basmat city after lock down from March 2020. Basmat city is a 'B' class municipal council with 80,000 population located in Hingoli district of Maharashtra, India. The spraying of Sodium Hypochlorite (NaClO) solution on roads and government establishments with the help of firefighting services is a novel as well as cost effective responsive measure as per guidelines of the central government of India. This chapter aims to analyze the efficiency of disinfection with the help of Network Analysis tools in Arc GIS. Various components such as shortest route analysis for refilling the tanks and analysis of various impedance factors such as time-cost analysis and route tracking form an integral part of the study. In addition to this, the availability of stock and consumption pattern of disinfectant are also analyzed. This research focuses on the attributes of distance traversed, cost of fuel and labor and time taken for sanitization vehicles at service stops. The results are evident that with the use of geospatial technology, all the attributes have reduced values as compared to the previous situation.

14.1 Introduction

Since the outbreak of the novel coronavirus in 2019, a substantial amount of research has been carried out to address the inter-relationship between technological advancements and the pandemic. The research particularly deals with the spatial aspect of the COVID-19 outbreak and analyzing the use of Geographical Information Systems (GIS) as a tool for providing effective measures in containment of the outbreak. Geographic tracking of spatial features enables us to keep a record of the entities and GIS offers multiple tools for spatial accounting. Recent advancements in Geographic Information Systems, has provided with improved decision making about a location. Spatial analytics and location intelligence are the key aspects which make GIS beneficial for improved geographic recording of assets. GIS enables for effective communication in the form of visualizations and maps by better understanding of geographical attributes.

The multidisciplinary nature of GIS technology means that the diffusion, appropriation and use of GIS technologies are distributed in a variety of subject domains and its application in day to day problems of human beings [1]. GIS applications has covered a varied range of sectors including health geography, cultural and anthropological geography, transportation, and land dynamics.

Many researches have studied the spatial aspect of diseases in purview of its nature and behavior with respect to a geographical area. The most famous paradigm of early medical geography was Dr. John Snow, considered to be the father of modern epidemiology, who demonstrated the water-borne origin of cholera by plotting cholera-related deaths in London during the most severe 1854 epidemic on maps [2]. Disease maps have been used since historic times and with GIS it is now possible to keep a track of diseases in a digital format.

Considering the wide range of analysis tools offered by GIS, the spatial aspect of COVID-19 can be analyzed comprehensively with them. Recent technical features of GIS such as location intelligence and live tracking have made it possible for COVID-19 to be potentially mapped and understand the spread of the outbreak. Features such as temporal analysis have aided in understanding the timely spread of the disease. This research particularly focuses on the utilization of network analysis feature of Arc GIS in decision making for the Municipal authorities. The network analysis toolset has been linked with the spraying of disinfectants in municipal areas. To contain the spread of the outbreak, disinfecting public places such as public buildings, major and minor roadways with Sodium Hypochlorite (NaClO) solution is undertaken by the municipal authorities of multiple Indian cities. As per the Central Government of India, spraying of disinfectants has been mandated in Indian cities to avoid the virus from sustaining at public places.

Spraying of disinfectants over large urban areas involve attributes such as cost and time on account of Government officials. This makes it important to utilize modern technologies that can aid the decision-making abilities of the officials. The purpose of this research is to utilize the potential of geospatial technology in order to aid the Municipal authority officials of Basmat City to reduce the cost and time required to spray the disinfectant using the Vehicle Routing Problem (VRP) for devising the optimal paths for fire-fighting vehicles.

14.2 Literature Review

In this section, the literature reviewed in accordance with the network analysis tools in GIS is presented. Utilization of GIS for effective healthcare planning is presented in many studies across the world. A study by [3] presents the use of network analysis in developing a GIS based emergency response system for Delhi, India. The study focuses on integrating real time traffic data with the existing transportation network. Optimal route planning was used to analyze the best route for reaching the emergency site by avoiding congested routes. Network analysis attributes such as shortest path analysis, Origin destination survey and proximity analysis were deployed for building the emergency response system. In another study by [4] the practicality of the shortest path analysis tool in GIS is improved. The Dijkstra's Algorithm which is the principle that works at the backend of the shortest path analysis is optimized by changing the starting node with the search process. This enables to maintain the nodes using a stack structure to avoid revisiting the nodes. In this case, the real time traffic information is not considered.

Another relevant study carried out for Ghana region by [5] is also based on emergency response service by the firefighting services. This service was developed for the Ghana National Fire Services (GNFS) in the metropolis of Kumasi where the GNFS can take better decisions. The optimal route planning in case of a fire incident in the metropolis was devised by considering model attributes such as slope of the roads, travel distance and time and the delays in travel time. Optimal route planning for determining effective evacuation methods in San Diego is performed by [6]. In this study, GIS network analysis is used for public issuing of evacuation orders in case of emergency situations by using 2007 Wildfire datasets. An Origin-Destination (OD) ranking model was deployed to determine evacuation routes between affected areas and nearest shelters. Multiple road features and land-based attributes were considered while building the OD model.

Advancement in the geospatial technologies have upgraded the GIS tools and services. GIS packages are now being introduced in the market with better spatial analysis capabilities. Services and complex businesses involving fieet of vehicles with multiple orders, stops, restrictions, using roadside utilities need a solution to avoid scaled cost in the process of transportation. These issues are now the things of the past since the introduction of network analyst toolset in the ArcGIS platform. Vehicle Routing Problem (VRP) is one such tool in the package, which can find the best route for a single vehicle to visit many stops (for delivering order or for servicing at the stop). The primary goal of these kinds of analysis is to reduce the transportation time and reduce the overall operating cost. VRP can used to solve much complex problems, involving multiple vehicles with multiple capacities and matching vehicles capacity with order quantities, multiple vehicles with special tools and matching their service capabilities, giving breaks to drivers, pairing multiple orders so the same route delivers them.

14.3 Methodology and Materials

The following section presents the detailed methodology that was followed to conduct this research. The methodology fiowchart depicts the steps that are performed using Arc GIS 10.2 software. The data preparation includes digitizing road vector layer using Open Street Map (OSM) and satellite imagery from Google Earth. The administrative boundary of ward map has been obtained from the municipal council of Basmat city. The major public government buildings and landmarks have been located from ground verification and satellite imagery. Following this, the georeferencing process of municipal boundary map has been performed, and the geodatabase has been created.

After the data preparation, the network layers have been created. The network layers include the service stops of spraying the disinfectant. The attributes such as road name, design speed of the road, road type, length of the road and time taken for the fire-fighting vehicle to traverse the road have all been updated in the network layers. Further, the network topology and network dataset have been created. Finally, the vehicle routing problem for the firefighting services to spray the disinfectant has been solved.

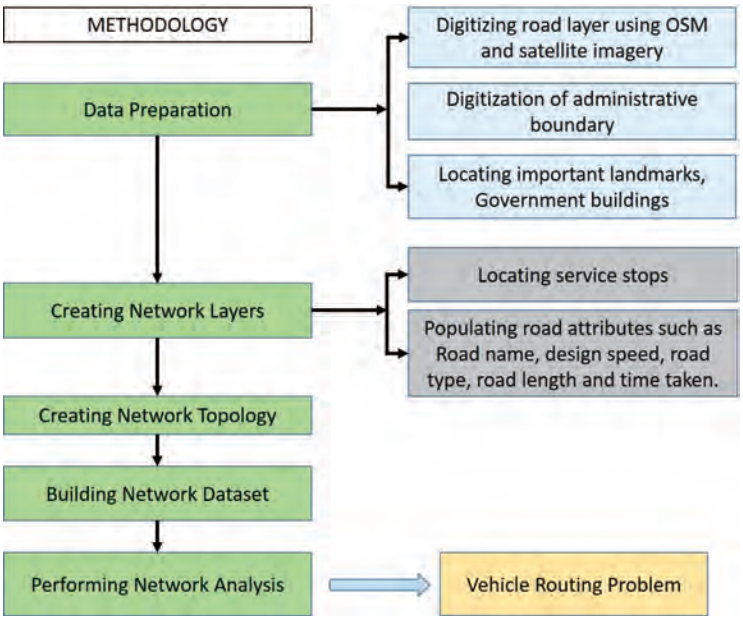


FIGURE 14.1
Methodological Framework of Study

14.3.1 Data Preparation

The data preparation includes downloading the OSM network data and satellite imagery of Basmat city, preparing the network layout, and linking the attribute data. The study area is the Basmat city located in Hingoli district of the state of Maharashtra. This city is a ‘B’ class municipal council.

The study area is extended from 19° 33’ 02” N to 77° 15’ 89” E. The Basmat city area is of 12.06 sq.km with 14 ward divisions. The base map and road network data of Basmat city was downloaded from Open street map. OSM has been accessed through Arc GIS online web mapping service. The road network data has an attribute named Road name for names of the roads that have been matched with Google earth imagery. The Design speed attribute includes design speed of the roads which were assigned by taking IRC 86 – 1983 as reference. The Road type attribute consists of classification of the roads according to the hierarchy which includes Arterial Roads, Sub-Arterial Roads, Collector and Local roads. The Road length attribute includes length of the roads that are calculated using calculate geometry tool.

14.3.2 The Network Dataset

The next step is preparing the network dataset to carry out network analysis for fire-fighting vehicles. The topology tool is deployed to remove unnecessary pseudo nodes and dangles in the network that occur during the digitization process. The road network is integrated using the Integrate tool in Data Management and other layers such as road and stops are included in the feature dataset. Further, the road name and landmarks are assigned for directional fiow of vehicles.

14.3.3 Building the VRP Route

After building the network dataset, the Vehicle routing problem layer is created and all the VRP layers are activated from the toolbar. The stops which are assigned for spraying of NaClO solution are imported for a shift of the day. The service time which is the spraying time for the fire-fighting vehicle is assigned to the stops. The spraying time data is provided by the Basmat Municipal Council. The filling stations which are the depots are the locations where the Sodium Hypochlorite (NaClO) solution is filled in the tanks of fire-fighting vehicles. After this the routes through which the fire-fighting vehicles traverse are assigned to the route layer. The initial stop of filling station and terminating stop of filling station are assigned. The Start time of the vehicle is taken as 7 a.m. and end time is taken as 8 a.m.

14.4 Results and Discussion

This study presented the analysis of Vehicle Routing problem of fire fighting vehicles that are used for sanitisation to spray Sodium Hypochlorite solution. With the surge of Covid-19 cases, the sanitisation process of public buildings and was taken up by the Basmat Municipal Council. Municipality assigned this task to the sanitation department, which must be carried out in a stipulated time. Major landmarks, government buildings, major religious places, markets, colonies with symptomatic patients were identified for disinfection. Fire-fighting vehicles were assigned for transportation of sanitation workers to the service locations where disinfection was supposed to be carried out. From the ground-based questionnaire survey conducted on 28, 29 and 30 March 2020 and the recorded odometer readings, the time taken by the fire-fighting vehicles was higher as the routes taken to reach the sanitisation destinations were random. This incurred higher time and cost for the government officials being spent on the sanitisation process. The government officials expected a sound way for reducing the cost and time. To address this issue, study tried to address this issue using geospatial technology to analyse whether the cost and time spent on sanitisation process can be reduced. For the same, this study applied the Vehicle Routing Problem to the fire-fighting sanitisation vehicles. For this the optimal route analysis was carried out for all the routes. The optimal route analysis generates the most optimal route between two locations.

With the network analysis extension in Arc GIS, it becomes very easy to set the network parameters for optimal route analysis such as the travel time that is the impedance factor, the start time of the travel and restrictions such as road directions whether unidirectional or bidirectional. The starting point and terminating point of travel is the Sodium Hypochlorite (NaClO) filling station.

The route for sanitization is developed such that all the locations where the service is to be provided (service locations) are visited once during the total travel. From the table 1 given below, comparison between the previous route and the optimal route is analysed based on pre-determined attributes. The three major routes are divided over the period of three days from 28th March to 30th March.

The VRP for the three major routes is given i n the following maps for the three consecutive days (Figure 14.2) respectively. The odometer reading, time taken for travel by the fire-fighting vehicle, the fuel cost spent by the government officials and the labor cost are compared for the previous route taken and the optimal route taken later. It can be inferred from the readings that all the factors considered perform better in case of optimal routes. Time taken for the fire fighting vehicles, fuel cost and labor cost are all comparatively lesser in case of optimal routes when compared with the routes originally followed. The comparison is also presented in graphical format.

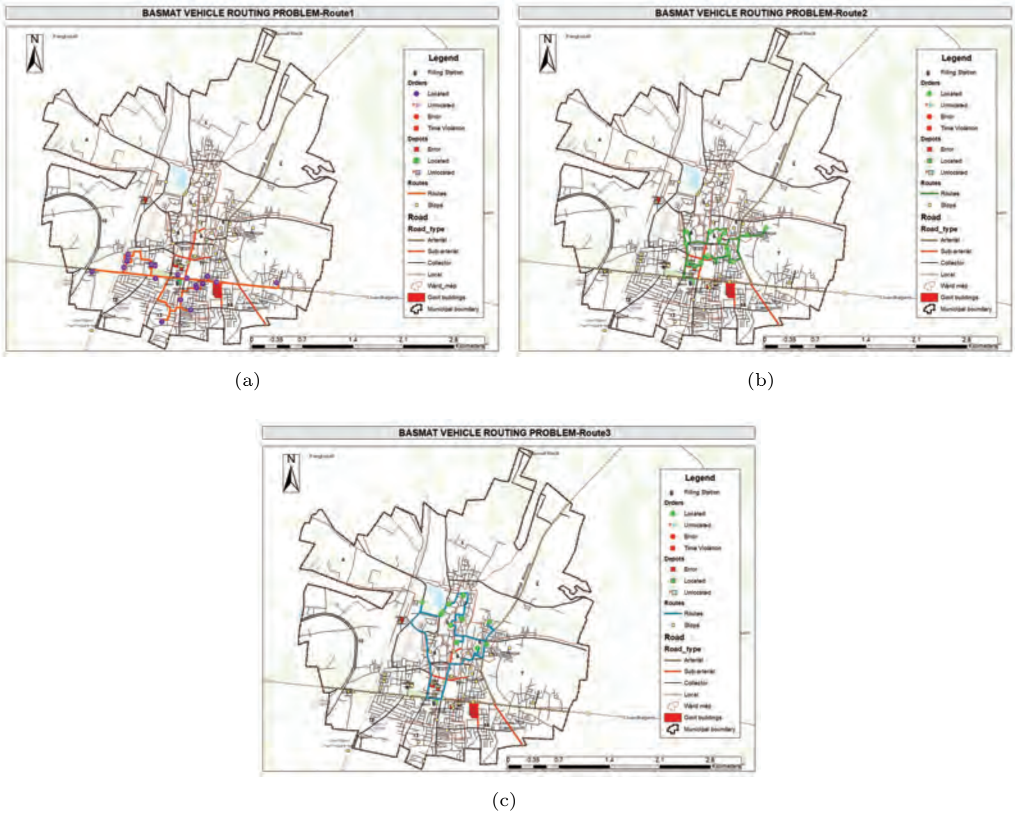
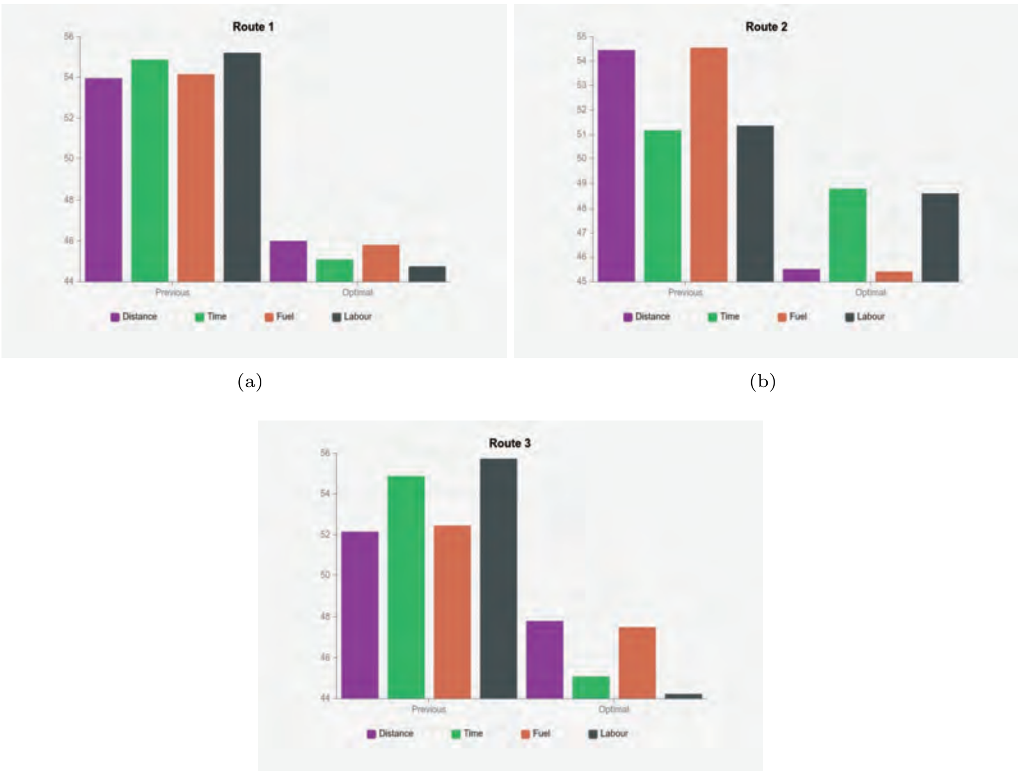


FIGURE 14.2
Basmat Vehicle Routing Problem: a) Route 1; b) Route 2; c) Route 3

TABLE 14.1
Comparative Analysis of Attributes between Previous and Optimal Route

Shift	Previous Route	Optimal Route
Route-1	Odometer reading: 11000 m	Analyzed distance: 9377.8m
	Time Taken: 12 hours	Time Taken: 9 hours 52 min
	Fuel cost: Rs.389	Fuel cost: Rs.329
	Labor cost= Rs.1320	Labor cost= Rs.1070
Route-2	Odometer reading: 6250 (approx.)	Analyzed distance: 5224m
	Time Taken: 8hrs. (approx.)	Time Taken: 7hrs. 38 min
	Fuel cost: Rs.221	Fuel cost: Rs.184
	Labor cost= Rs.840	Labor cost= Rs. 795
Route-3	Odometer reading: 7500 (approx.)	Analyzed distance: 6874 m
	Time Taken: 7hrs. 30 min (approx.)	Time Taken: 6 hrs. 10 min
	Fuel cost: Rs.265	Fuel cost: Rs.240
	Labor cost= Rs.780	Labor cost= Rs. 619



(a) (b)

(c)

FIGURE 14.3
Comparative Analysis between attributes of: a) Route 1 in percentage; b) Route 2 in percentage; c) Route 3 in percentage

14.5 Conclusion

In this research, an augmented approach of Arc GIS based network analysis using Vehicle Routing problem is applied to the Basmat city area. With the outbreak of Covid-19, sanitisation of public spaces has been made mandatory and this involves spending of huge monetary cost and time on account of government authorities. The Djikstra optimal routing algorithm in Arc GIS offers best results for network analysis. The vehicle routing problem applied in this research to find the optimal route which saves time and cost. The VRP for route 1 has reduced the travel distance and fuel cost by 8% and the travel time taken by 12%. The labor cost is reduced by 10%. Similarly, for route 2, the travel distance is reduced by 8% and the travel time by 4%. The labor cost is reduced by 2% and the fuel cost by 10%. For VRP route 3, the travel distance is reduced by 4% and travel time by 8%. The labor cost is reduced by 4% and fuel cost by 12%. After obtaining positive results with the use of network analysis, in future research this study propose to utilize geospatial technology for analyzing the attributes of cost, time and quantity of disinfectant spraying for building level data by incorporating building level information data such as height of building, size and total fioor area , material, building use etc. to predict the attributes for sanitisation automatically. Result out of such studies will help in better emergency preparedness and quick response of Urban Local Bodies (ULB's) as like Basmat.

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15

Formalizing Informal Settlements to Empower Residents Against COVID-19 and Other Disasters

Chryssy Potsiou

With the COVID-19 it became obvious that the significant social and economic benefits of the urbanization and globalization era may be accompanied by a globalized threat and risk. This deadly virus struck fast and hard and with little warning and all countries, even the most developed, have proved to be unprepared. Governments have urgently explored short- and long-term actions on how to sustain a resilient economic and social activity while keeping their people safe, but also on defining policies that would help them to deal with the post-COVID-19 challenges. In this respect, the 2019 UNECE publication on Guidelines for Formalization of Informal Constructions may be useful to facilitate a global planning process to support a large number of states that face the challenge of construction informality in developing fit-for-purpose policies while preparing for a post-COVID era. According to UNECE, benefits from formalizing informal constructions could contribute to economic recovery by integration into land markets with clear ownership titles and registration. Security of tenure and rights to ownership of land and property provide access to credit; environmental planning, construction, and utility-provision improvements can be initiated to a standard by which people can live in adequate and healthy homes to the benefit of all. This chapter provides an insight of the above issues and draws the attention to the benefits of a clear and inclusive strategy and of a fit-for-purpose formalization framework.

15.1 Introduction

The COVID-19 pandemic is threatening cities and settlements all over the world, endangering not only public health but also the economy and the structure of society, forcing us apart as we try to slow the spread of the virus. However, we - as individuals - are still finding ways to help each other, inspiring and showing appreciation for those helping our communities, keeping in touch with family members wherever they may be, and most importantly, helping the poorest and most vulnerable, those least able to respond.

But how can we, as experts, do more? How can we support governments to do the same at a larger scale successfully? More specifically, how can surveyors, as geospatial and land professionals, provide appropriate tools that will support governments in their efforts to be more efficient in empowering those most vulnerable, increasing recognition of disease and pandemics? “Who” and more importantly “where” are the most vulnerable, those exposed most to the pandemic?

This discussion will address the following questions:

1. how can geospatial experts and land surveyors provide the technically driven policy tools to

support governments to identify and empower those most vulnerable and those exposed most to the pandemic?

2. why the measures taken by governments to empower people against the pandemic are also related to the good management of land and therefore need to be more "localized", evidence-based, and fit-for-purpose? and

3. how governments may develop "fit-for-purpose" formalization projects to empower residents in informal settlements for the benefit of all?

15.2 The Need for Geospatial Data and Tools to Improve Decision-making

It is said that flooding and other natural disasters are more or less "localized" and authorities, with the support of geospatial experts, know that they may turn "there" to help, while the current COVID-19 disaster is or may exist "everywhere", which complicates recovery actions, and that affects everyone with a priority for the elderly, those with chronic health problems, and those who have difficulty protecting themselves.

As with any natural disaster, the way countries and communities prepare for a damaging event makes the difference for a successful, long-term resilience and recovery. Decision-making for such preparation must be evidence-based; therefore, availability of reliable and affordable geospatial data in a timely manner is crucial. This is at the center of surveyors' professional skills, interests and activities. There are already several modern, low-cost but still reliable tools and methods that may be used for acquiring the needed geo-referenced information including information derived from social media and crowdsourcing [1] and several applications for contact tracing, that may help in providing sound decision-making for applying more "localized" rather than "general" measures, and for providing humanitarian support when dealing with such disasters [2].

Unfortunately, this virus struck fast and hard and without warning and all countries, even the most developed, were unprepared. It has been a common and long-established public confidence that medicine has improved significantly and that humanity has managed to overcome problems caused by pandemics that once killed large numbers of people, and which have thus influenced the history and the future of many cities [3]. Since that development in the history of medicine, and for several years since, research in infectious diseases has lost its institutional urgency.

As a result, rapid and dense urbanization became more and more a global trend for several decades and has been considered as the tool to deal with poverty which would lead us to economic growth for all. A globalized economy has developed and the world has been on a constant move to urbanization. Surveyors have always been in the front line aiming to provide the most appropriate policies, methods and tools to provide the required geo-referenced data to support the management of the emerging mega cities [4]. A global action plan on how to deal with deadly pandemics is still missing; there is a significant lack of awareness among populations and unfortunately a dangerous lack of coordination among governments in terms of disaster-response measures. The result is a dangerous confusion. Coronavirus was a test, and the world's supposedly most advanced nations have all too visibly failed [5].

Governments are now urgently exploring short- and long-term actions on how to sustain a resilient economic and social activity while keeping their people safe, but also on how to deal with post-COVID-19 challenges; it is anticipated that the pandemic will have a continuing multidimensional impact. Such actions and policies should be based on reliable geospatial data.

The situation becomes worse in unplanned and/or dense informal settlements and slums that often exist on the outskirts of many large urban areas, but which also provide unskilled service support to the nearby urban economies. Residents in informal settlements usually are not registered, they may even lack citizenship, identity cards and addresses but also health care, basic services like clean water and sewage disposal, etc. It has become obvious that unfortunately COVID-19 has a higher, "localized" concentration among informal settlement residents where people are not prepared, basic infrastructures are poor, and where there is a significant lack of reliable geo-referenced data. (A strategy for containment of the virus is "contact tracing" in which an attempt is made to track the progress of the disease from population center to population center, requiring an efficient geo-referenced measuring and monitoring system.)

The World Bank reports that the COVID-19 pandemic has plunged the global economy into its deepest recession since World War II. It estimates that this particular disaster will create the worst economic contraction in decades, with numerous job losses and the creation of 60-100 million of "new poor", mainly those self-employed, many informally, which will soon join those most vulnerable - those poor living in the informal settlements; and foresees that the COVID-19 pandemic is a once-in-a-century crisis that presents extraordinary challenges to policymakers around the world [6].

According to the IMF the economic impact of this crisis will be like no other; GDP is expected to fall by some 6-7% this year in the advanced economies, and it will not return to its pre-virus peak until at least 2022. Given the uncertainty around how long the pandemic will last, it may be far worse. Entire sectors of the economy are at risk. Millions of people have already lost their source of income. The International Labor Organization (ILO), at its press release of 29 April 2020, estimated that 1.6 billion workers in the formal or informal economy, amounting to nearly half the global workforce, are at risk of losing their livelihoods. This is due to the lockdown measures and/or because these people are occupied in the hardest-hit sectors, such as wholesale and retail, manufacturing, accommodation and food services, or the real estate sector [7]. What is even worse is the fact that usually these people have no access to credit.

It is "there", at such settlements, that governments should turn their attention to help and provide the means for improvements and resilience.

These people are least able to protect themselves. "*As the pandemic and the jobs crisis evolve, the need to protect the most vulnerable becomes even more urgent*" said ILO Director-General Guy Ryder. "*For millions of workers, no income means no food, no security and no future. Millions of businesses around the world are barely breathing. They have no savings or access to credit. These are the real faces of the world of work. If we don't help them now, these enterprises will simply perish*" [8].

The informal economy includes informal construction - self-made, usually substandard, houses - along with the informal labor force and illegal businesses. Informally, self-made cities/settlements in general [9], with informal, unregistered property rights, lacking property titles and/or planning, construction and operational permits, have no access to credit. Informal rights and informal construction constitute a wide-spread challenge threatening sustainability and although "… *access to basic services, ownership and control over land and other forms of property, inheritance, natural resources,…*" is included at SDG1 (target 1.4) of the UN Sustainable development Agenda 2030 [10], so far few countries have reported on real progress in this field in the five years of implementation period, as emphasized at the recent webinar "Five years into the SDGs - Are we on track to deliver the land targets?" [11], with the World Bank predicting that "*the global community's significant progress on poverty reduction in recent decades will likely be partly reversed and that it will also be more difficult to achieve broader development goals by the end of this decade*" [6].

UNECE and FIG have long worked in this field and land surveyors have built experience in developing fit-for-purpose technical, administrative, legal and policy tools both for the registration of informal tenure rights as well as for the formalization of informal constructions. There is an urgent need that governments will now integrate such tools to improve the preparedness measures for the pandemic.

15.3 Measures Taken by Governments to Manage the Pandemic

A common, immediate response of many governments during the disease outbreak was to request their citizens to "stay at home", "work from home", "keep social distance", "follow basic hygienic measures" and "wash hands with soap and clean water frequently".

These measures have been successfully adopted by many citizens, but unfortunately they seem unrealistic for some people as well as for most residents of informal settlements; residents of informal settlements simply cannot cope with such requirements. A number of issues need to be taken into consideration:

1. Housing conditions in informal settlements are usually substandard, lacking access to basic hygienic services such as drinking water and/or sanitation, waste collection and access to basic health care, while density in such areas does not allow residents to maintain the necessary social distancing.

2. These people cannot earn their daily income while social distancing; they can rarely work from home. Occupants of such informal constructions are usually unregistered workers, or are occupied on a temporary basis, in a myriad of businesses, small or medium enterprises, usually informal; these people, every morning, afternoon or night must leave their homes to go out, to ensure that they will bring back enough food for family members while keeping the economy running for the rest of the urban citizenry, experiencing emotional, physical and mental stress every day.

3. A large percentage of such informal labor force is occupied in transportation, construction, and agriculture/food production, supplying farmers and handling food from "farm to fork;" in many cases this is crucial for maintaining sustainability in the supply chain.

4. A significant number of residents of informal settlements, either rural or urban, are women who are harshly impacted by land tenure insecurity due to discriminatory laws and a lingering social bias. The COVID-19 virus threatens to exacerbate a situation of social gender inequality.

As COVID-19 continues to spread through society common measures are not being adopted by all governments and it becomes clear that strict measures that radically change everyday activities cannot easily be enforced and cannot easily control the disease. While restoring global health remains the uppermost priority, as mentioned above, it is apparent that the strict measures required have caused massive economic and social shock. The prolongation of a lockdown, physical distancing and other isolation measures used to eliminate transmission of the virus will lead the global economy into a recession. Unemployment, loss of income and the risk of more homelessness are the result.

Many countries are using additional "social safety net programs" to respond and protect families from the impact of economic shock. They provide, among other devices, loans with low interest, cash, in-kind transfers, social pensions, public works, and school feeding programs targeted to poor and vulnerable households. Some have enacted measures to secure housing tenure for tenants and occupants of camps and informal settlements in response to this crisis. Among those jurisdictions who have put in such measures, many have moved to enact moratoriums on evictions and utilities shut-offs, and some have put in measures to reduce rents or offer moratoriums to non-performing housing loans and foreclosures, or rental subsidies to the most vulnerable households.

However, the cost of such measures is significantly preventing their broad application. Most frequently beneficiaries of such measures are those registered, meaning those working and living in the formal sector; residents in informal settlements are once again likely to be left behind. But, we should acknowledge that allowing substandard conditions in some areas is not only a threat to those residents, but to the general population as well. Infected residents through their activity very soon will transfer the virus to the people they have job contacts within the city or other regions.

Moreover, the COVID-19 crisis is also anticipated to accelerate a disruption in the housing sector that started well before this crisis. The construction and real estate sector is an industry that tends to be vulnerable to economic cycles. External market factors, combined with fragmented and complex industry dynamics and an overall aversion to risk, already had made the provision of formal affordable housing adequate for all, a problematic process. This is expected to worsen due to the virus thus anticipating larger numbers of people seeking an alternative and affordable but informal housing solution.

Governments need to seriously consider new fit-for-purpose ways and tools to manage and administer land [12] as well as to formalize existing informal constructions in order to enable access to credit for those residents, to improve their living conditions and to enhance the needed hygienic and safety improvements in such constructions. It is more important than ever for all actors to see what the "next normal" will look like and make the bold, strategic decisions to create a better future for all by solving the persistent shortage of formal housing.

15.4 How to Formalize Informal Construction in Order to Empower Residents against COVID-19

Informal development is a social phenomenon in which people settle on land that may be owned by others or by the state, where they build dwellings usually sub-standard and temporary in nature. These settlements may have limited or no infrastructure. Informal development may even appear on legally owned land while its illegality is related to zoning, planning, or building regulations. An illegal building is one built without a construction permit, or in violation of a legally issued permit or against the verified basic legal land plan. In many cases illegal construction in the European transition countries is of a good, permanent type, and can be characterized as self-made "affordable housing" rather than as "slums", although they may not meet all construction stability, safety and environmental standards. Illegal buildings are usually out of the economic circle, not registered, not taxed and unable to be transferred or mortgaged. These constructions represent "dead capital" of a country's economy; the problem is well known in the UNECE region. Unregistered, informal constructions cannot be used as collateral to provide access to vital credit for their occupants (and do not appear on the public record for land taxation purposes). A great support that governments may provide to residents in informal settlements may be to enable formalization of informal constructions, where possible, thereby integrating them into the land administration systems and into property markets. As a result access to credit will be enabled and people may use this funding to improve their living situations with improved protection against the disease. But which is the most appropriate method of formalization?

The UNECE and the Working Party on Land Administration (WPLA) initiated joint research together with the International Federation of Surveyors (FIG) in 2007 on the topic of informal development in the region. The main objective of this research was to identify the size of the problem in the UNECE region, the causes, the types of informal constructions and to assess the formalization methods used by governments in eight countries [13–20], and to identify good practices.

The research identified that more than 50 million people in 15 member States of the United Nation Economic Commission for Europe (UNECE) live in informal settlements. The causes of current informal settlements include major political changes in law and regulation coupled with rapid urbanization, and often uncontrolled, massive internal migration. Conflict, marginalization, cumbersome authorization processes for home improvements and modernization, and corruption resulted. But the list of causes is more complex, including the absence of policies by the states and their failure to adopt pro-growth planning as well as affordable housing policies; weaknesses of the private sector; the lack of knowledge and political will to develop land policies to facilitate recognition of existing tenure and private property rights to aid the transition from centrally planned to market economies; and the failure or reluctance of state agencies to implement measures to support economic reforms to facilitate the digital economy and the UN Sustainable Development Agenda 2030.

The types of informal constructions in the region include a large range of buildings from small single family houses to multi-story apartment buildings, shops, hotels and public buildings. They may lack ownership titles and/or building and planning permits, or they may have been built in excess of legally issued permits. Formalization policies adopted from the various governments to address the problem often lack a clear fit-for-purpose strategy and in many countries formalization is a long bureaucratic and expensive procedure; or may start with the best of intentions but become bogged down due to administrative bottlenecks or change of government. Governments often understand the problem but do not fully recognize the extent of its impacts. Therefore, it was necessary to develop guidelines which would explain why a country would choose to go beyond the established scientific/engineering/planning practice in order to successfully deal with property market challenges, funding challenges, structural stability challenges, environmental challenges and difficult ethical challenges as well as the many hostile reactions to a formalization project by otherwise law-abiding citizens [21].

This long research resulted in the compilation of guidelines for a fit-for-purpose formalization framework in support of those countries seeking a quick and sustainable formalization solution in an affordable, reliable, inclusive and timely manner to improve residents' health, living and working conditions and to meet the SDGs by 2030. The guidelines focus mainly on providing instructions on how to organize the formalization project, but it also provides information about the necessary preparatory work (e.g., how to identify the problem's magnitude and how to develop a strategy to achieve a general political acceptance), as well as information about important post-formalization factors.

It is important that the formalization process, as well as its strategy, will clarify and quantify the anticipated economic, environmental and social benefits and ensure that everyone, not just the residents of informal settlements, sees benefits from formalization. The process should be based on three main pillars: (a) to facilitate increased tenure security, (b) to recognize the right to adequate housing for all, and (c) to provide access to credit for the residents in informal settlements. Guidelines are aligned with the UN SDGs, especially SDG 1, target 1.4, SDG 11, SDG 5, the FAO Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests (VGGT) and the New Urban Agenda.

These guidelines, published in 2019 by the United Nations, are written mainly for countries within the UNECE region where informal constructions are of fairly good quality (not slums) and therefore could be considered as a commodity, which may provide access to credit and funds to be used by the residents either for construction improvements or for other general improvements of the neighborhoods e.g., to enable disaster recovery, education and health services, or to develop businesses. The guidelines are meant to be used by all sectors and stakeholders involved, such as politicians, government members, state agencies, all involved professionals, as well as academics, NGOs and banks.

It is anticipated that the guidelines will be applicable in other regions, too. In the "new normal" era titling provision and registration should be quick and of low cost and should be independent from other types of informalities (lack of planning and/or construction permits). Post-formalization or parallel planning, environmental considerations, construction improvements as well as service-provision should be enabled not only for social and environmental reasons, but also to make these properties more economically viable and attractive in order to become part of the broader legal real estate market and to enable access to credit. Otherwise, it is hard to realize equity in a house that cannot be sold or is without interest in the real estate market.

However, there is no "one size fits all" general rule for improvement provision; such improvements can be initiated and funded by the residents in partnership with national and local authorities, as well as the private sector. Tools to be used for urban regeneration may include consolidation of parcels and land readjustment. Such land reforms require a broad public awareness and acceptance, as well as trust and willingness of residents to participate voluntarily to secure ownership rights to their homes. In general, the success of such a project is based on the voluntary participation of residents. Eliminating the informality phenomenon in future requires, apart from title provision and property registration, comprehensive land policies and reforms that may include pro-growth planning, flexible permitting/inspection processes for development, property valuation, policies for creating job opportunities, fair taxation and affordability. Other issues relevant to the establishment of real estate markets should be also addressed, which include the existence of funding mechanisms, professional education, professional ethics and an effective role for the private sector [22].

When dealing with formalization one should remember that demand in real estate markets is defined not only by consumer need, but also by consumer desire and when neither the state nor the private sector provide, legally, the supply of appropriate real estate types and quantities to satisfy the current demand, people may build informally with a result that is inherently risky.

Also, one should remember that security of tenure is a social issue and a human right; security of ownership rights and of titles may also be a social issue as it is fundamental to the well-being of residents. But security of tenure alone cannot facilitate access to credit, while security of ownership rights may. A country without an inclusive formal system for registering property rights limits its own economic development and prevents its citizens from realizing their full potential.

The formalization of informal constructions, among several other improvements, will enable:

1. reduction of evictions by the establishment of updated cadastral systems and increased security of rights;

2. risk reduction thus enabling occupants' access to credit at affordable interest rates, as well as a significant tool for funding their housing and resistance to any natural and/or manmade disasters;

3. occupants to improve their housing and business conditions; improvement of planning of neighborhoods and construction stability; improvement to family health issues; children's education; security;

4. authorities to use this updated spatial data infrastructure for evidence-based decision-making for a series of issues, e.g., to enable digital transformation of society; to build reliable basic registers; to add other necessary information or improve various statistical records; to apply good and fair land and property policies; to monitor and improve important health and other SDG indicators, such as for environmental issues; to support agriculture and food production, education and employment, gender equality and transportation and to provide humanitarian support;

5. the transformation of dead capital locked up in informal constructions to become productive capital thus increasing a nation's GDP with faster economic recovery and poverty alleviation. Such assets as formalized constructions may provide collateral and increased revenue from land taxation to improve basic infrastructure and provide electricity and digital access to all people, which is basic for a restart of national economies especially in the poorest countries.

The UNECE Guidelines for formalization of informal constructions may be of particular interest to governments preparing for the post-COVID era. Benefits from a fit-for-purpose formalization of informal settlements could contribute to economic recovery by providing property titles, registering them in the cadastral systems and integrating them into the local economies.

Experts involved in the compilation of these Guidelines are currently working under the guidance of UNECE for identifying ways to monitor the implementation of the Guidelines in the region. More specifically, a follow up project is carried on with a purpose to review how well countries that face the challenge of informal development have progressed with their formalization projects and if there is a need for some revision of the process, what is actually the impact of Covid-19 in these regions, and what are the actions taken by governments during the Covid-19 period. Some seminars and lectures will be organized soon aiming to raise awareness about the importance of the Guidelines and their fast and inclusive implementation. It is highly recommended though that the experience gained from UNECE region will be shared in other regions, too, that are facing similar challenges.

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16

Spatially Enabled COVID-19: A Review of Applications and Systems

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The ongoing COVID-19 pandemic has profoundly reshaped the world and impacted the lives of billions globally across many facets, including health, economy, culture, education, environment and politics. Since declared as a public health emergency of international concern (PHEIC) in January 2020, the outbreak has attracted significant research attention globally. Governments, industries and academics altogether are investigating various means for monitoring the spread of the virus, assessing the impacts, and planning strategies and policies for reopening. Many tools and applications have been developed to support government and emergency agencies for critical decision-making and situation monitoring at various stage of the outbreak. This paper reviews existing COVID-19 emergency management tools and applications currently being adopted by different countries and jurisdictions, and identifies and compares their key capabilities and functionalities.

16.1 Introduction

The outbreak of the COVID-19 virus has fundamentally changed the way our world operates. The impact of this virus has been felt in almost every country around the globe, disrupting and putting extreme pressure on various industry sectors – such as building and construction, retail, transport, hospitality, education, financial services, agriculture, aviation and tourism, and healthcare. In response to the pandemic, the governments of many countries have adopted strategies to minimise the spread and impact of the virus, which involves quarantining communities through lockdown mandates which have had enormous economic and social impacts. As the spread of infectious disease is inherently a spatial process, the geospatial industry which specialises in geospatial data, technologies, and analytical methods play a critical role in understanding and responding to the coronavirus disease 2019 (COVID-19) pandemic [1]. To contribute and assist with the escalating problem, the geospatial industry, like many other industries, have focused their attention to this global challenge and have founded solutions and developed tools which aid and assist officials in their role of managing this unprecedented event.

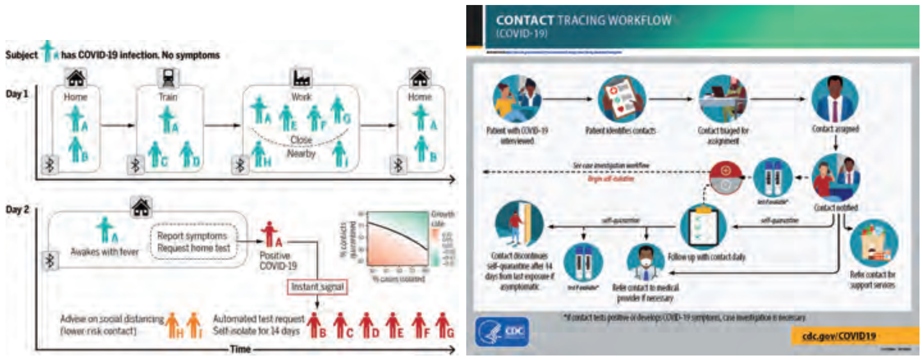
Areas of focus which fit within the scope of the geospatial industry's expertise include: developing spatial data infrastructures (SDI) for surveillance and data sharing; incorporating mobility data into infectious disease forecasting; using geospatial technologies for digital contact tracing; integrating geographic data in COVID-19 modelling; investigating social vulnerabilities and health disparities; communicating the status of the disease or status of facilities for return-to-normal operations; and tracking, monitoring and optimisation of the location of necessary health and safety resources such as personal protective equipment (PPE), ventilators, and available hospital beds [1].

One early contribution from the geospatial industry has been the development of smartphone apps to assist contact tracing. Contact tracing involves identifying persons who may have come into contact with an infected person, and the management these people who have been exposed to COVID-19 to prevent onward transmission [2]. It is an essential activity conducted by public health organisations for controlling the virus. Through tracing of the contacts of infected individuals, testing them for infections, and then isolating the infected, public health aims to reduce the infections in the population. In order to effectively perform contact tracing, specific location and time details are required. To assist with this task, the geospatial industry has responded with a range of applications which can facilitate the tracing, some assisting from the public health side, and others from the citizen side. The apps take advantage of the inbuilt location and timestamp records of smart phones, GPS data from cars, credit card transactions, travel histories and CCTV footage to determine where and at what time a person has been in a specific location, and through analysis can use this information to determine intersections of individuals to determine who has been potentially exposed. Identifying the exact location of sick people, tracing their movements, and isolating them minimises the need to impose mobility restrictions or business closures [3].

Another application which has seen geospatial technology play a critical role has been in the identification and proximities of individuals to essential services. The geospatial industry has developed smartphone applications for use by citizens and also complex platforms to perform detailed analysis for government health departments. Government, industry and academia have put significant efforts and resources to build these applications, which fall into two categories of tracing apps and map-enabled dashboards. These applications are all built upon the same COVID-19 test data, and utilise various technologies and aggregate additional data sources to serve their purposes.

16.2 Tracing Apps

Tracing apps are critical means for the pandemic control, particularly when widely deployed, as they help to detect and notify people who contact with a carrier and can also monitor who breach the isolation rules. In March 2020, Ferretti et al. [4] suggested using digital contact tracing to quantify the virus transmission and proposed a schematic of a tracing app (Figure 16.1 (a)). Contacts of carrier A are traced by the app, and when carrier A is confirmed by a positive test result, the app triggers an instant notification to all the contacts with risk-stratified quarantine (i.e., close contacts B, C, D, E, F, G and low-risk contacts H, I) and physical distancing advice. CDC also released a COVID-19 contact tracing workflow (Figure 16.1 (b)) which can help scientists follow the chain of infection to understand how the virus transmits among crowd [5].



(a) (b)

FIGURE 16.1
a) A schematic of a tracing app, b) COVID-19 contact tracing workflow

Most of the apps adopt Bluetooth technology to detect the proximity to other mobile devices. Unlike GPS or Wi-Fi data, the Bluetooth technology only tracks which device has been near one another, rather than reporting users' actual locations. They are usually classified as "Decentralised Contact Tracing" and considered to be better privacy-preserving and less intrusive, comparing with "Centralised Contact Tracing" methods which utilise cellular network and GPS to determine the location of users. In March 2020, in collaboration with CoEPi [6], Covid Watch [7] was the first team in the world to develop an open-source, anonymous, decentralised Bluetooth digital contact tracing protocol, the CEN (Contact Event Numbers) Protocol. It now has been renamed as TCN (Temporary Contact Numbers) Protocol[8]. In April 2020, similar decentralised protocols like DP-3T (Decentralized Privacy-Preserving Proximity Tracing) [8], PACT(Private Automated Contact Tracing) [9] and Google/Apple Exposure Notification framework [10] were also prevailing. By adopting such a decentralised protocol, contact tracing apps will create and broadcast short-lived pseudorandom values over Bluetooth. These values are recorded by nearby devices and reveal no information about users' identity or location history as they are pseudorandom. When a user is developing symptoms or tested positive, the app will send a report to any potential contacts by uploading a packet of data to a server. Other users can monitor data published by the server to learn whether they have received any reports [11, 12].

Several issues impact the effectiveness of tracking apps in the real world. First, inferring physical distance based these technologies can be unreliable. The range (3-10 m) of Bluetooth-enabled device varies dramatically due to the environment or the way the device is held [13, 14]. GPS-based proximity detection can also be unreliable, smartphones are typically accurate to within a 4.9-meter radius in open space, with accuracy decreasing further in the presence of signal blockage [15, 16]. The cellular network-based proximity reasoning also depends on the density of antenna towers (base stations) and the precision of positioning can achieve down to 50 meters in urban areas [17]. While, in most countries, the social distancing guidelines recommend 1.5 to 2 meters, which could not be reliably and accurately detected by any of these means. False positives might lead to unnecessary self-quarantine and could cause the public to ignore warnings when they find these warnings are untrustworthy. Another problem is the update ratio of tracing apps. The effectiveness of a tracing app depends on how many people use it regularly. If only a small proportion of people participate in, the app is worthless and could be harmful as its indications will be highly inaccurate and could even instill a false sense of security [18]. In Singapore, by the end of September 2020, 2.4 million people (41% population) downloaded the TraceTogether App. The uptake was lower than the optimal number of users required for the contact tracing system to work well, which was 75% of the population [19].

Australia launched its contact tracking app CovidSafe in April, which is completely voluntary. By the end of September, it has accumulated over 7 million downloads (28% population), while how and whether the app is being used has yet been revealed [20, 21]. In the UK, the second version of the NHS Covid-19 app has over 10 million downloads (around 15% population) since it launched in September 2020 [13, 22–24]. As the tracing apps are characterised by strong network effect [18], its efficacy is the square of the proportion of the population using the app, multiplied by the probability of the app detecting infectious contacts, multiplied by the fractional reduction in infectiousness resulting from being notified as a contact [4]. Simulation model shows that approximately 60% of the whole population are required to use the app and adhere to the app's recommendations to stop virus contagion [25].

16.3 Map-Based Dashboard

The history of using maps to understand the spread of disease can go back to 1850's when Dr. John Snow connected location and illness to trace the source of a cholera outbreak in London, as shown in Figure 16.2 (a) [26]. From disease atlases in early 20th century to more recent web mapping of Ebola (Figure 16.2 (b) [27]) and Zika, maps have been considered as a critical tool in coping with contagious viruses [28]. The reason behind is that global mobility is faster and easier than ever before, and a carrier can become a super spreader, infecting a large number of people across a large geographic area [28].

(a) (b)

FIGURE 16.2
a) Cluster map of cholera cases in London, 1854, b) Web mapping of Ebola virus in Africa, 2014

The most famous COVID-19 dashboard (see Figure 16.3) has been created and maintained by Johns Hopkins University since late January 2020. It is a map-based web application, aggregating real-time information about the pandemic at the global level (190 countries and regions included), and has been cited as official COVID-19 data and statistics by many media channels. The dashboard sources and aggregates data globally and reports cases at the province level in China; at the city level in the USA, Australia, and Canada; and at the country level otherwise [29, 30]. The interactive maps of the dashboard include accumulated cases, active cases, incidence rate, case-fatality rate and testing rate. Besides, it also offers critical trends analysis and interactive visualisation, which help user unfold details about the outbreak spread patterns at various geographical levels [31–33].

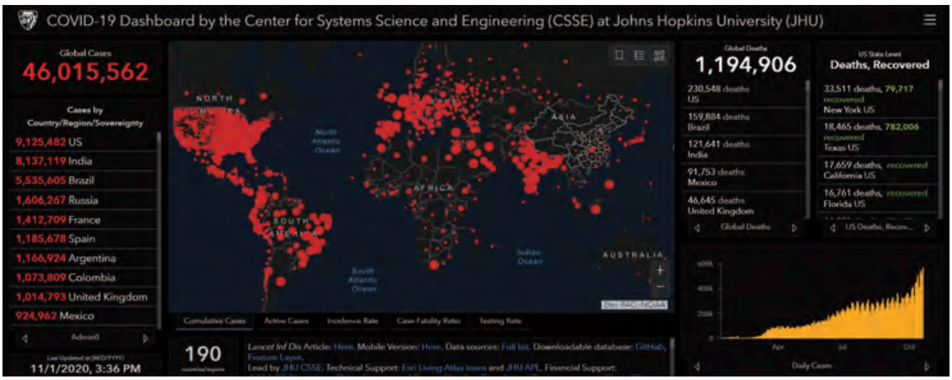


FIGURE 16.3
COVID-19 Dashboard developed by Johns Hopkins University

The Johns Hopkins COVID-19 dashboard has a significant impact on the coming COVID-19 dashboard design and functionalities. Within a short period, many countries and organisations have adopted similar web mapping technology (mostly powered by ESRI Live Atlas) to build their dashboard and customise with additional information [28]. Figure 16.4 shows four dashboards for Italy (top-left), China (top-right), Japan (bottom-left) and Germany (bottom-right) respectively [34–37]. They are all built upon ESRI ArcGIS online map applications and share the same style with

Johns Hopkins University's COVID-19 dashboard. Figure 16.5 illustrates the COVID-19 dashboards created by India (top-left), Brazil (top-right), Australia (bottom-left) and WHO (bottom-right) using different web tools. Though the appearances are different from each other, the maps and statistics charts all remain as the key components [38–41].

FIGURE 16.4
A series of similar COVID-19 dashboards created with ESRI ArcGIS Online

FIGURE 16.5
COVID-19 Dashboards created using different web tools

Besides diseases statistics, dispersion maps and propagation animations, there is another category of dashboards particularly focus on the pandemic impact analyses including mobility, health, economy and society. For example, the COVID-19 Impact Analysis Platform [42, 43] developed by the University of Maryland placed emphases on the mobility and social impact of the virus by incorporating over 30 variables, including social distancing index (top-left), percentage of hospital bed utilisation (top-right), unemployment rate (bottom-left) and COVID death rate (bottom-right), as shown in Figure 16.6.

FIGURE 16.6
COVID-19 Impact Analysis Platform developed by University of Maryland

The Australia COVID-19 Location Tracker developed by the Centre for Disaster Management and Public Safety (CDMPS) jointly with the Centre for SDIs and Land Administration (CSDILA), both at the University of Melbourne also comes with a set of ready-for-use analytics tools by utilising live data through multiple sources for Australia.

The system can perform capacity and service area (e.g., 3, 5, 10 km) analysis for COVID-19 related hospitals and clinics and provide insights medical resource supply chain management at various scenarios. It plots the distribution of the vulnerable population (e.g., 65+ years old) at a fine geospatial unit level based on the latest Census data and identifies regions required particular attention by cross-referencing health condition datasets. The system compiles and visualises the number of closed non-essential businesses during various stage of lockdown, and estimates the impacts on the local economy such as unemployment rate and scale of subsidies etc.

FIGURE 16.7
Australia COVID-19 Location Tracker developed by the University of Melbourne

In general, the map-based dashboards prevail in the COVID-19 pandemic and have been adopted worldwide at various administrative scales. By aggregating, analysing and conveying data in a timely manner, it serves as a critical and effective tool for government and public to communicate and understand the spread of disease and hence helps to increase the pandemic situational awareness and preparedness.

16.4 Conclusion

The geospatial community has a fundamental and critical role to play in supporting government management of COVID-19 through contact tracing and map development applications. In this paper tracing apps that have been developed have been presented and discussed revealing their strengths and weaknesses as well as challenges faced when trying to successfully implement these apps at a large scale to produce valuable data for management of the virus. Successful map dashboards that are serving both government and the community were also presented and discussed. Consensus on these applications are that map dashboards have been the most useful and more widely accepted and adopted, proving an effective tool for presenting and relaying information for government and public understanding and situational awareness on COVID-19.

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17

COVID-19 Spatiotemporal Hotspots and Prediction Based on Wavelet and Neural Network

Neda Kaffash Charandabi and Amir Gholami

In this chapter, a global model of the COVID-19 is proposed to determine the important periods of each country, prediction of confirmed cases, and discover spatiotemporal hot/cold spots. The importance of the COVID-19 periods is assessed for each country and the most important periods are selected as time series prediction delays and temporal neighborhood steps of spatiotemporal analysis. The COVID-19 cases are predicted based on wavelet and neural network with an average RMSEIQR of 0.974 for all countries. Finally, the hot/cold spot maps are prepared by the specified temporal neighborhood steps and the patterns are identified. More than 61% of the earth's surface is surrounded by COVID-19 hot spots.

17.1 Introduction

The novel Coronavirus Disease 2019 (COVID-19) has spread all over the world since it first appeared in Wuhan, the capital city of Hubei province, on 31 December 2019. The number of cases is well above 35 million and the number of deaths is more than 1 million till 5 October 2020, according to the World Health Organization (WHO) situation reports [1]. The WHO announced COVID-19 as the sixth the world's public health concern on January 30, 2020. It is transmitted via human-to-human droplets or direct contact, and the mean incubation period for infection has been estimated to be 6.4 days [2]. However, there is little information about this new virus, researchers in different fields are working towards discovering an appropriate solution to this global issue [2]. One of the new approaches to better management of epidemics is the use of spatiotemporal analyses. These analyses are important tools for preventing and reducing the spread of disease, with the potential to detect trends and critical points of the disease outbreaks.

The Geographic Information System (GIS) is an analytical tool for collecting, editing, managing, and processing of spatial data. GIS is also used as a platform for spatiotemporal analyses by integrating temporal data with location and attribute data. Conventional GIS analyses are very useful in the identification of spatiotemporal patterns and clusters. However, it needs to be combined with robust algorithms to predict time series. Neural network algorithms are among the most common families of non-parametric methods that can be used for predicting epidemic peaks. But they alone are not enough to predict variable, nonlinear, and uncertain issues. Wavelet is used as one of the most powerful methods in signal processing and time series analysis. It is possible to predict complex time series with high accuracy by combining the wavelet with neural networks [3].

In recent years, more researchers have concentrated on predicting epidemic outbreaks. Al-Ahmadi et al. investigated MERS-COV data in Saudi Arabia from 2012 to 2019. The disease was analyzed by extracting spatial, temporal, seasonal, and spatial-temporal clusters [4]. Mongkolsawat and Kamchai identified the critical areas of Avian influenza in Thailand. This study highlighted the use of GIS to investigate the prevalence and identification of critical areas in different epidemics [5]. Li et al. described the spatial and temporal characteristics of human H7N9 virus infections in China using data from 2013 to 2017 and ArcMap^{TM}10.2 along with SaTScan [6]. Zhu et al. used the multi-channel Long Short-Term Memory (LSTM) to predict influenza in China. The neural network training process was performed with number of legal influenza cases and outbreaks, affected cases with different ages, Chinese patent cold medicines, other cold medicines, temperature, rainfall, air pressure, and relative humidity for nine years in nine regions of China [7]. Venna et al. applied data-driven machine learning to predict flu based on environmental factors. Meteorological, proximity, and influenza data from 1997 to 2016 were analyzed using the LSTM deep learning model [8]. Spataru utilized the ArcMap^{TM}10.2 "space-time pattern mining" tool to analyze polio disease. He had extracted space-time clusters and critical locations of the disease based on Mann-Kendall and Getis-Ord Gi* statistic [9]. According to the previous studies, the use of spatiotemporal analysis has been very useful in studying epidemics. However, spatiotemporal clustering and time series analysis had been carried out separately in previous researches.

Numerous studies have started in the field of treatment and management of the COVID-19. Guan et al. studied data from 1099 patients of 552 hospitals in 30 different provinces. Based on their findings over the first 2 months, the COVID-19 has spread around the world with different conditions and symptoms [10]. Lai et al. studied COVID-19 patient data in countries around the world until February 11 and used graphs and maps to examine their patient numbers and specific symptoms [2]. Kuniya predicted the epidemic peak of Coronavirus using the SEIR model in Japan. In his study, early middle summer was known as the peak of the COVID-19 in Japan, so forecasting for all countries based on suitable methods seems to be necessary [11]. Al-qaness et al. proposed a method for forecasting confirmed cases of the COVID-19 in China based on an Adaptive Neuro-Fuzzy Inference System (ANFIS) using an enhanced Flower Pollination Algorithm (FPA) along with the Salp Swarm Algorithm (SSA) [12]. Chakraborty and Ghosh forecasted Coronavirus cases base on wavelet and AutoRegressive Integrated Moving Average model (ARIMA) for Canada, France, India, South Korea, and the UK [13]. Tamang et al. predicted Covid-19 cases based on an Artificial Neural Network (ANN) curve fitting technique [14]. These predictions have been made in line with the current trend of rising cases in different countries and the patterns of change in China and South Korea for one week. The reviewed articles provided an example of researches in the field of space and statistics. In these studies, less attentions have been paid to both the SpatioTemporal Hot/Cold Spot Analysis (STHCSA) and the Coronavirus pandemic time series prediction. Previous research has only been performed in one or some countries and has not been a global model. Periods are not predicted for each country, and the accuracy of the training data is assessed, while the accuracy of the test and train data indicates the actual accuracy of the prediction.

17.2 Materials and Methods

In this chapter, a combined model of wavelet and neural network was used to predict COVID-19 cases based on data reported by WHO, due to its ability to complex time series prediction [3]. Also, its hot/cold spots were identified by specified important periods and features. The theoretical foundations of the methods used in this research were described in this section.

17.2.1 Wavelet transforms

Wavelet transform is a mathematical approach to the decomposition of data into a variety of frequency components. It can extract special patterns hidden in a huge amount of data. The wavelet transform can be used to analyze non-stationary time series data at several different frequencies. Wavelet transforms are generally divided into the Continuous Wavelet Transformation (CWT) and Discrete Wavelets Transformation (DWT) [15]. The DWT and CWT are the wavelet transform implementation using discrete and arbitrary sets of the wavelet scales, respectively. They can be used to decompose wavelets, process signals, extract features, and denoise noisy signals. There are many types of mother wavelets that can be used for wavelet transforms. The different mother wavelets that are used to examine the same signal will yield varying results. Therefore, different mother wavelet types of CWT and DWT were examined to select best of them for capturing the multiscale features of signals [16, 17].

17.2.1.1 CWT

The CWT is an important method for assessing non-stationary signals and providing a number of signal information, such as time, frequency, scale, and local signal correlation. The CWT is used to decompose a signal into small wavelets that are highly localized in time [18]. It generally used short-time Fourier transform for decomposes a signal into unlimited length sines and cosines, basically eliminating all time-localization information and replacing it with time-frequency signal representation that provides very strong time and frequency localization. The wavelet function is defined as Eq. (17.1) The basic functions of the CWT are scaled and shifted versions of a function called the time-localized mother wavelet $\Psi(t)$. Eq. (17.2) express wavelet transform that is the convolution of time series data and wavelets [18, 19].

$$\int_{-\infty}^{\infty} \Psi(t)\mathrm{dt} = 0. \tag{17.1}$$

$$F(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} f(t)\Psi\big(\frac{t-b}{a}\big)\mathrm{dt}. \tag{17.2}$$

Where a and b are the scale and shift parameters, t is the time, $f(t)$ is the data, $\Psi(t)$ is the mother wavelet, and $F(a,b)$ is the time-scale representation of the signal. Several mother wavelets are available for the CWT, including Mexican hat wavelet, analytic Morlet wavelet, generalized Morse wavelet, Bump wavelet, and so on. The Morlet is a wavelet composed mainly of an exponential function multiplied by a Gaussian window. This wavelet is closely related to human perception and demonstrates good performance in analyzing the periodicity of local signals. Generalized Morse wavelets are a family of analytical wavelets with two parameters, symmetry and time-bandwidth of the product. Bump wavelet has a larger variance in time and smaller variance in frequency. Each of these wavelets has different parameters for studying different behaviors and properties [18, 20].

17.2.1.2 DWT

The DWT is a powerful time series analysis tool used to break down the original time series into different components, each of which can produce meaningful information from the original data. The DWT can be decomposed the signal into low and high frequencies. The low and high frequencies are also called as approximation and detail coefficients. Commonly the approximation is decomposed to a higher level after the first level. The DWT is used to reduce time series data in order to save storage space while losing a small amount of detailed information. The last coefficient of approximation and a few of the high-level detail coefficients are typically chosen for preservation that are the only coefficients needed for perfect reconstruction. Hence, The DWT is known as a lossless transformation, whereby transformed domain data can collectively rebuild the original data [16, 21].

The DWT has several mother wavelet families, such as Daubechies, Coiflets, Symlets, Fejér-Korovkin, discrete Meyer, Biorthogonal, and reverse Biorthogonal, which each of them has different orders. The Daubechies family is an orthonormal wavelet, which makes the analysis of wavelets possible in discrete time. The first order Daubechies (db1) wavelet resembles a simple step function and the higher-order Daubechies functions (db2, db3, db4, etc.) are not easy to define with an analytical expression. The order of this function shows the number of vanishing moments or the number of zero wavelet moments. The Coiflet (coif) wavelet family is more symmetrical and has more vanishing moments than the Daubechies wavelets. Symlets' (sym) properties are similar to Daubechies, that are near-symmetric and have the least asymmetry. Fejér-Korovkin (fk) wavelet family minimizes the gap between the ideal since lowpass filter and the valid scaling filter. The discrete Meyer (dmey) wavelet family is defined in the frequency domain. The Biorthogonal (bio) and reverse Biorthogonal (rbio) families use separate wavelet and scaling functions for the analysis, synthesis, and vice versa [22].

17.2.2 Neural networks

ANNs are human brain-inspired methods that consist of a large number of simple and highly interconnected computing elements and use them as a huge data processing system. ANN-based methods are very useful for prediction problems. Three main parts of the ANN are the input, hidden, and output layers [23]. Different models of the ANNs were introduced to solve specific problems. In this research Multi Layer Perceptron (MLP) was used as a class of feedforward neural networks which is an efficient and popular algorithm. The MLP is a type of supervised learning algorithms that uses backpropagation to train. The MLP contains a number of layers, neurons, weights, and transfer functions. Transfer functions are used to aggregate the input neurons with different weights to the output where the neuron is a link between the layers. First, the input neurons are multiplied by their respective weights, then the output neuron is summed up and determined via the transfer function. Tansig is one of the widely used transfer functions that has been selected for this research. This function makes MLP networks so powerful, because of the ability to represent nonlinear functions [23, 24].

Finally, normalized Root Means Square Error by the Inter-Quartile Ranges (RMSEIQR) was used to evaluate the accuracy of the prediction results of the proposed model because it is suitable for comparing the different values obtained for various countries with a different population and confirmed cases. The RMSEIQR is an interquartile range of the RMSE that normalizes values and is less sensitive to extreme values (outliers) than the RMSE. The RMSEIQR is defined as Eq. (17.3) where $\hat{y}_t$ and y_t are predicted and observed values over T time and IQR is the difference of quartile functions. In other words, the RMSEIQR calculates by dividing the RMSE into the IQR [25].

$$RMSEIQR = \frac{\sqrt{\sum_{t=1}^{T}(\hat{y}_t - y_t)^2}}{IQR\sqrt{T}}. \tag{17.3}$$

17.2.3 Hot/Cold spot analysis

Spatiotemporal analysis was used to identified hot/cold spots by specified important periods and features in previous steps. STHCSA is an important component of spatiotemporal analysis since location and time are two critical aspects of important events such as the Coronavirus epidemic. The outputs of such analyses can provide useful information to guide the activities aimed at preventing, detecting, and responding to pandemic problems [26]. There are various methods for spatiotemporal analysis. In this study, Mann-Kendall test was used to detect trends of data and Getis-Ord Gi* statistic was used to identify hot/cold spots.

Network Common Data Form (NetCDF) is a file format to store multi-dimensional scientific data such as temperature, humidity, disease, and crime. The NetCDF cube is generated using the COVID-19 x, y, and time data as x, y, and z axes. It summarizes a collection of points into a NetCDF by aggregating them into space-time bins. The Mann-Kendall p-values and z-scores show the statistical significance of the trend in a hot spot (spatial clusters of high values) or cold spot (spatial clusters of low values) at a location. A positive or negative z-score indicates an upward or downward trend respectively [9, 27]. Then, the pattern in the spatiotemporal data was identified with Getis-Ord Gi* statistic based on neighborhood distance and neighborhood time step. The Getis-Ord Gi* statistic is calculated for each bin as follows [28, 29]:

$$\bar{x} = \frac{\sum_{j=1}^{n} x_j}{n}. \tag{17.4}$$

$$s = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - \bar{x}^2}. \tag{17.5}$$

$$G_i^* = \frac{\sum_{j=1}^{n} w_{ij} x_j - \bar{x} \sum_{j=1}^{n} w_{ij}}{s\sqrt{\frac{n\sum_{j=1}^{n} w_{ij}^2 - (\sum_{j=1}^{n} w_{ij})^2}{n-1}}}. \tag{17.6}$$

Where x_j is the value of feature x at location j, n is the number of data and w_{ij} is the element of the weight matrix. The G_i^* is recorded as a z-score for each variable in the dataset. The more intense the clustering of high values or hot spots are, the larger positive z-scores become and the more intense the clustering of low values or cold spots are, the smaller negative z-scores get. Based on p-values and z-scores of this statistic, 17 pattern types include: no pattern detected, new hot spot, consecutive hot spot, intensifying hot spot, persistent hot spot, diminishing hot spot, sporadic hot spot, oscillating hot spot, historical hot spot, new cold spot, consecutive cold spot, intensifying cold spot, persistent cold spot, diminishing Cold Spot, sporadic cold spot, oscillating cold spot and historical cold spot are extracted [9].

17.3 Results of Proposed Model

In this chapter, the confirmed cases of the COVID-19 in all countries around the world based on WHO reports until June 24 were used as input signals. The proposed model of this research was implemented in four steps: 1) identification of significant periods using CWT, 2) extraction of effective features using DWT, 3) prediction of cases with neural network based on the outputs of steps 1 and 2, and 4) extraction of hot/cold spot patterns. The procedure and the results of each step are discussed below.

17.3.1 Identification of significant periods using CWT

The COVID-19 epidemic is a highly contagious disease and may have a long incubation period, which means that patients understand it late and therefore quickly infects others without regarding social distance. Therefore, many people get the disease in a short period of time, and after an incubation period, the number of patients suddenly increases significantly. This trend is easily understood from the COVID-19 confirmed cases data and important periods can be deduced from them.

The confirmed cases of the COVID-19 were divided into train and test data as input signals. The data for the last 7 days (17 to June 24, 2020) of each country was selected as the test data. Due to the high outbreak of COVID-19 and its long and short incubation periods, signal behavior can be analyzed, its relative and absolute maxima can be identified, and significant periods can be recognized for each country. The CWT was used to extract significant periods and these periods were used as delays in the prediction step. The significant frequency (reverse of the period), the date of its occurrence, and the magnitude were calculated for each country and shown on 3D plot (Figure 17.1). Based on the 3D surfaces, relative or local maxima were identified to determine the peak of important periods. For each country, periods, magnitudes, and dates of its occurrence have been identified by the CWT. The aim of this chapter is to investigate the longer and shorter serial intervals of COVID-19 that are associated with the incubation periods. The period of incubation for COVID-19 is the time between virus exposure and the onset of symptoms, which can be contagious to some people during this period. Understanding the incubation period enables health authorities to establish more effective quarantine systems for people suspected of carrying the virus as a means of monitoring and preventing the spread of the virus [1].Based on WHO reports, the incubation period for seasonal influenza, SARS, and MERS was typically around 2-14 days. Various studies have been conducted to determine the period of COVID-19. Qun Li et al. has found the incubation period to be 5.2 days on average [30] but in another research these periods were between 3 and 7 days, up to 14 days [31]. In addition, other cases with 19 and 27 incubation periods were reported by Hubei province. These periods were between 2-14 and 2-10 days based on the United States' CDC and WHO reports, respectively [1].

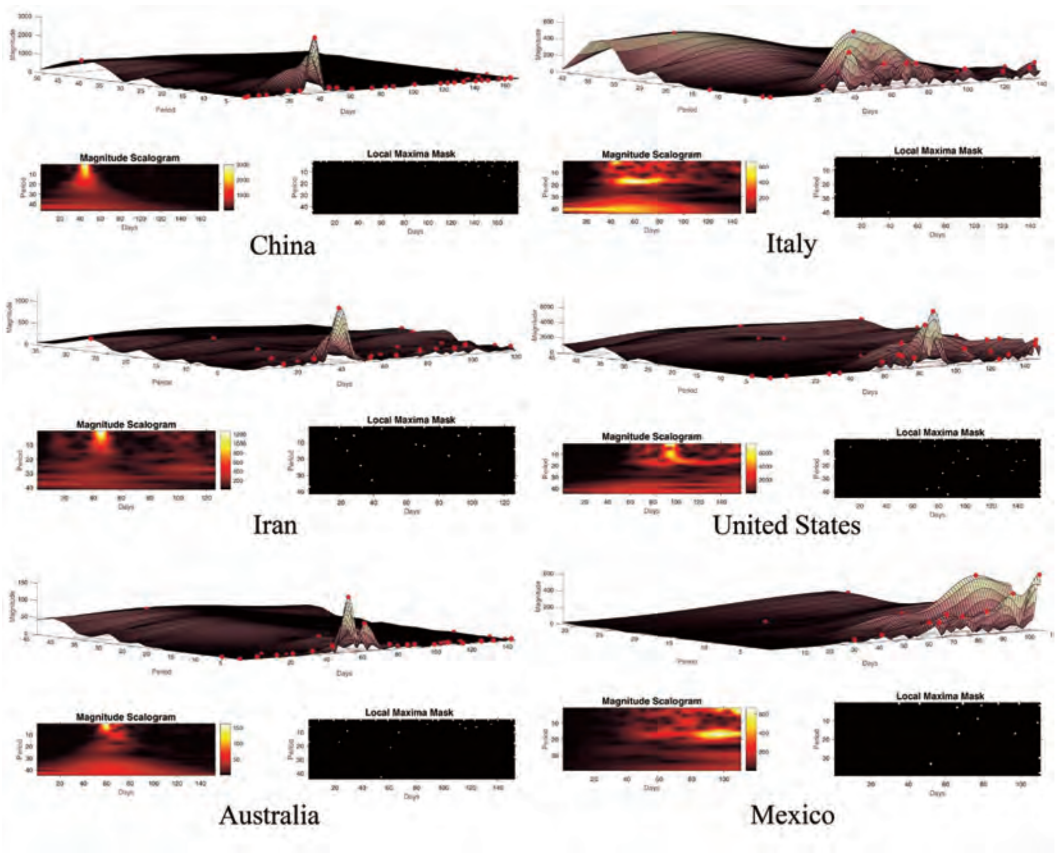

FIGURE 17.1
The CWT results for COVID-19 confirmed cases of six countries.

Previous research, based on clinical trials, identified incubation periods for some countries using restricted cases. While in this chapter, significant periods (the longer and shorter serial intervals of COVID-19) for all countries have been identified based on CWT and the input signal that their accuracy depends on the accuracy of WHO reports. They can considerably represent incubation periods. For example, according to the results of this research, significant periods for China were 2.72, 4.41, 5.43, 16.46, 17.64, 40.53, and 65.85 days which 2.71 and 40.53 days were more important than others. Also, COVID-19 important periods for Italy were about 3, 4, 7, 9, 38, 47, and 53 days while these periods for Iran were about 3, 4, 6, 12, 14, 22, and 47 days. It was done for each country and the important periods of each country were identified. For example, periods in China, Italy, Iran, the United States, Australia, and Mexico are shown in Figure 17.1. The results indicate that the three days period was important in most countries. Periods of 2-14 days and periods greater than 25, 40, and 65 days were also very notable. In particular, the (2-7)-day period was very important as one of the results of this research that was emphasized in previous clinical studies. The range and frequency of important periods that were extracted for all countries are shown in Figure 17.2. Comparison of CWT results and clinical studies reveals that the research outcome is highly accurate, which can be easily derived from the reported COVID-19 cases for all countries.

Also, due to the different results of the use of different mother wavelet functions, each CWT function was examined for each country and the function that had better RMSE was selected for each country. For instance, the best CWT function for the United States, China, Italy, Australia, and Mexico was bump and morlet (amor) for Iran.

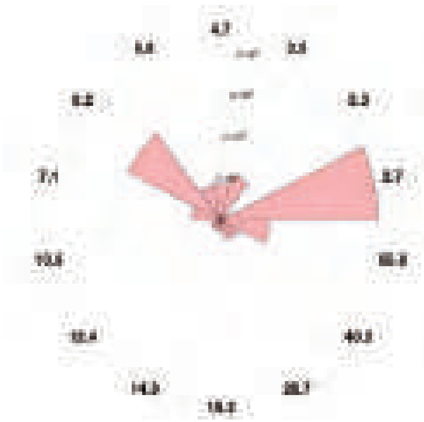

FIGURE 17.2
The range and frequency of important periods of all countries around the world based on CWT results.

17.3.2 Extraction of effective features using DWT

After identifying the significant periods of each country in the previous step, they can be used as a time series prediction delay. In other words, previous days which had an impact on the number of cases each day were determined by these periods for the neural network. The input signal (or the probability density function of patients) alone is not sufficient to predict accurately and it is better to extract the features from the original signal. Because the confirmed number of patients with COVID-19 is affected by many different factors that are not easily identifiable. For example, cultural factors in the timely referral of patients, a number of tests in each country, the integrity of governments in reporting cases, and so on, have a direct impact on the number of reported cases, although they are almost impossible to characterize due to lack of data. Therefore, it is better to extract the features of the daily COVID-19 reports from the input data signals. Artificial intelligence can consider features without identifying the name and type of features.

The DWT is one of the most popular tools for feature extraction. In this study, the five signal levels for each country were calculated by DWT. In the first step, the DWT was applied to the input signal and the approximation and detail were extracted. In the next step, this transformation was applied to the approximation extracted from the previous level. This process continued for five levels and finally, five approximations and details were obtained. All details of the levels and the approximation of the last level were used as ANN features. For example, the result of applying DWT to Iran confirmed cases is shown in Figure 17.3 with D1, D2, D3, D4, D5, and A5. The DWT has been done for all countries, and the features of each country have been identified for entry into the ANN.

Also in DWT, different mother wavelet functions with different orders were evaluated and the function that led to the lowest RMSE for each country was selected. For example, the best DWT functions for the United States, China, Italy, Iran, Australia, and Mexico were fk22, coif1, d6, sym9, db1, and coif5, respectively. Figure 17.4 shows the results of CWT and DWT implementation of different mother wavelet functions for each country. For 213 countries and territories around the world, 3 mother wavelet families of CWT and 6 mother wavelet families with 40 types of DWT functions were implemented. For example, in the 152nd country, Russia, bump and rbio were chosen as the appropriate mother wavelet functions. The numerical proportions of the use of CWT and DWT mother wavelet functions are also shown in the left and right pie charts of Figure 17.4. The results show that morse and bior1.1 were the most desirable functions among the CWT and DWT functions which were used 41.95% and 16.0976%, respectively.

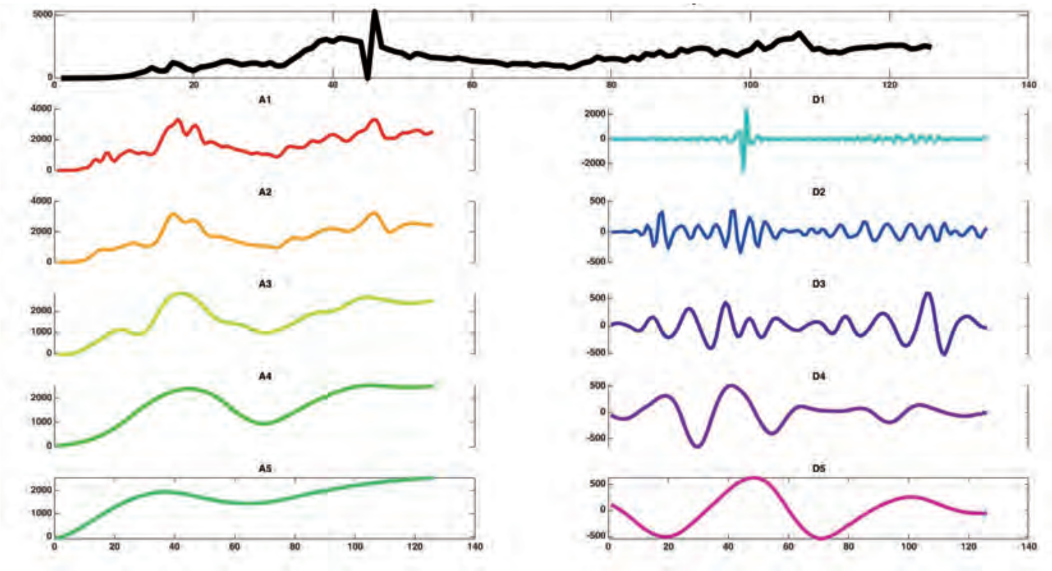

FIGURE 17.3
The DWT results for COVID-19 confirmed cases of Iran.

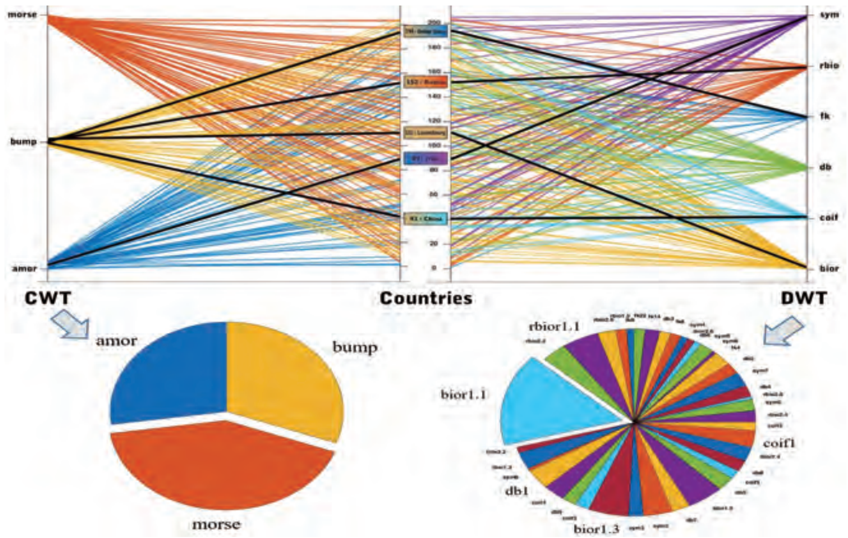

FIGURE 17.4
Comparison of CWT and DWT mother wavelet functions.

17.3.3 Prediction model based on a neural network

The extracted features must be delayed according to the detected periods before entering the ANN. Thus, the number of input features was $(ns + k)^{*}np$, where k is the number of input signals (k=1), ns is the number of sub-series, and np is the number of important periods for each country. In this study, ns was six because there were five levels of detail (D1, D2, D3, D4, and D5) and one level of approximation (A5). For example, the most important periods for Australia were about 3, 4, 9, and 41 days. They applied to the main signal and all subseries (k, D1, D2, D3, D4, D5, and A1) and

4*(6+1) features (28 features) were prepared as the network inputs. A single-layer perceptron neural network with a sigmoid transfer function has been implemented for each country. The advantages of the MLP network and the reason for choosing the sigmoid function were described in the materials and methods section. As a generalization error is so important in predicting time series, an attempt has been made to select a network size as small as possible to prevent overfitting.

After selecting the features and creating an optimal network, based on the confirmed cases of the COVID-19 up to June 17, the networks were trained and, for the last seven days, the forecast was carried out as test data. The prediction models have been developed for all countries and the results for the six countries: the United States, China, Italy, Iran, Australia, and Mexico are presented in Figure 17.5. In these plots, the horizontal axis is the number of the days, the vertical axis is the number of patients, the red dashed line is the observed cases, the continuous blue line is the predicted cases, and the white and gray parts are the train and test sections of data, respectively. These plots show the spread of the disease, its peaks, sudden increases, and the results of predictions in each country. The RMSE of train and test data has been calculated to evaluate the results of the prediction. The best and worst RMSE of predictions among these six countries were for Australia and the United States with 4.23 and 2264.92 for test data as well as 61.6852 and 3631.14 for train data. For a more detailed review, the test and train RMSE values, CWT and DWT mother wavelet functions, and the significant periods in 14 countries that are more affected by the COVID-19 are shown in Table 17.1.

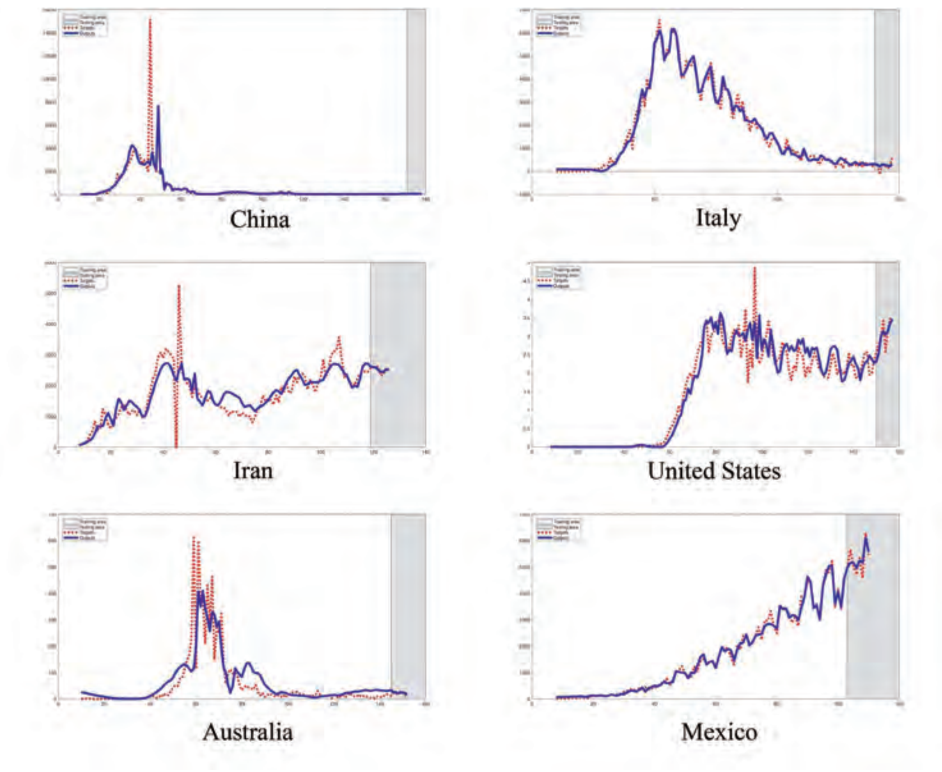

FIGURE 17.5
Prediction results of the COVID-19 confirmed cases for six countries.

TABLE 17.1
List of detailed information about inputs and results of prediction in 14 counties.

Country	Train RMSE	Test RMSE	CWT	DWT	Periods
Australia	61.6852	4.23448	bump	db1	2.72- 4.41 9.46- 40.54
Brazil	2094.0814	6800.2734	amor	rbio1.1	2.72- 3.34 3.58- 5.43 6.69- 7.68 21.72- 43.45
Canada	154.2365	30.5101	morse	bior1.5	2.72- 4.12 8.23- 13.37 26.74- 53.49
China	1101.6565	8.70	bump	coif1	2.72- 4.41 5.43- 16.46 17.64- 40.53 65.85
Germany	356.2333	81.2454	amor	coif3	2.72- 6.69- 10.86 13.37- 15.36 53.49
India	208.8657	1329.085	morse	bior1.5	2.72- 2.91 3.58- 5.07 6.24-7.17 8.82-20.27
Iran	456.87	82.5656	amor	sym9	2.72-3.84 6.24-11.64 14.33-21.72 46.56
Italy	219.5788	329.0488	bump	db6	2.72- 3.58 6.69- 9.46 37.82-46.56 53.49
Mexico	135.006	329.0488	bump	coif5	2.72- 2.91 3.84-4.12 6.69- 13.37 17.64-30.72
Russia	162.9836	145.0177	bump	rbio2.4	2.72-3.84 6.69-18.91 20.27- 30.72 53.49
South Korea	625.2626	12.3547	morse	sym9	2.72-3.58 4.12- 4.73 5.07-7.17 28.66- 43.45
Spain	411.7153	83.6592	amor	db2	2.72- 3.34 5.82-6.24 7.17- 8.23 13.37- 49.91
Turkey	77.9651	297.4952	morse	db5	2.72- 3.84 4.41-5.82 7.68- 9.46 18.91-37.82
United States	3631.1439	2264.9258	bump	fk22	2.72- 3.12 4.12-6.69 768- 28.66 43.45- 57.33

17.3.4 Extraction of hot/cold spot patterns

Finally, the COVID-19 pattern maps were prepared with the STHCSA at different periods. The neighborhood time step must be specified in the preparation of this map. The neighborhood time step is the number of time-step intervals to be used in the neighborhood of analysis. This value specifies which features are evaluated together to determine local clustering in space-time cube [28]. Hot/Cold spots of the COVID-19 confirmed cases in the world countries with one-day neighbors until March 21, 2020 are presented in Figure 17.6.

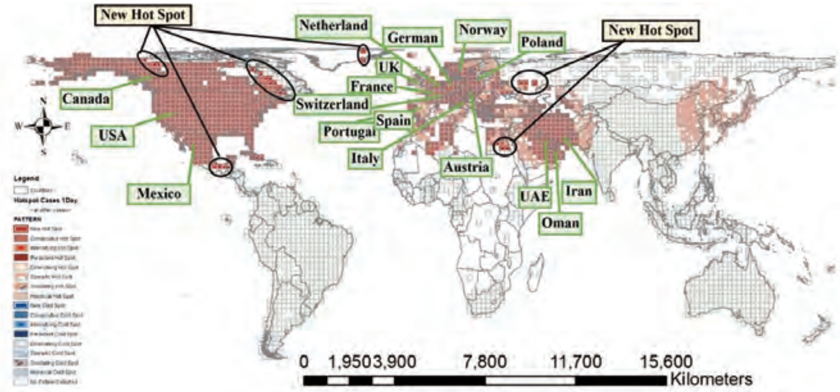

FIGURE 17.6
The STHCSA results for confirmed cases with a day temporal neighborhood steps.

The spatiotemporal patterns were identified with respect to the number of confirmed cases, the area, the spatial and temporal neighbors of each country. Countries such as the USA, Italy, Germany, France, Portugal, Mexico, Iran, Poland, Austria, Switzerland, Netherlands, and UAE have consecutive hot spots according to the results in Figure 17.6. The consecutive hot spot is a location with a single continuous run of statistically notable hot spot bins in the final time-step intervals. New hot spots in countries like Canada, Mexico, Cuba, Egypt, and Russia were also identified. Other countries were recognized as the oscillating hot spot or without a pattern. The new hot spot area is a location that is statistically significant for the final time step and has never been a statistically significant hot spot before. The oscillating hot spot is a region with high temporal oscillation patterns. With the temporal neighborhood increasing to three days, parts of Australia and Venezuela had been identified as historic cold spots and western China as oscillating cold spots. New hot spots had been detected in Brazil, Mexico, Russia, and Australia based on data until March 21, and after this date, there was a huge increase especially in Brazil and Russia.

Then, the spatiotemporal patterns were re-examined and shown in Figure 17.7 by entering all the data until June 24. The temporal neighborhood steps were entered as 3, 6, and 66 days according to the important periods extracted for the whole world and results are shown in Figure 17.7.a, 17.7.b, and 17.7.c, respectively. With increasing temporal neighborhood steps from 3 to 66 days, oscillation and consecutive hot spots have increased by 14% for Asian and European regions and about 10% for the United States. Countries like India, Brazil, Mexico, and Russia have become oscillation and consecutive hot spots. According to the results, many parts of the southern hemisphere have been identified as persistent and intensifying cold spots due to their low confirmed cases and cold spots have also increased by 20%.

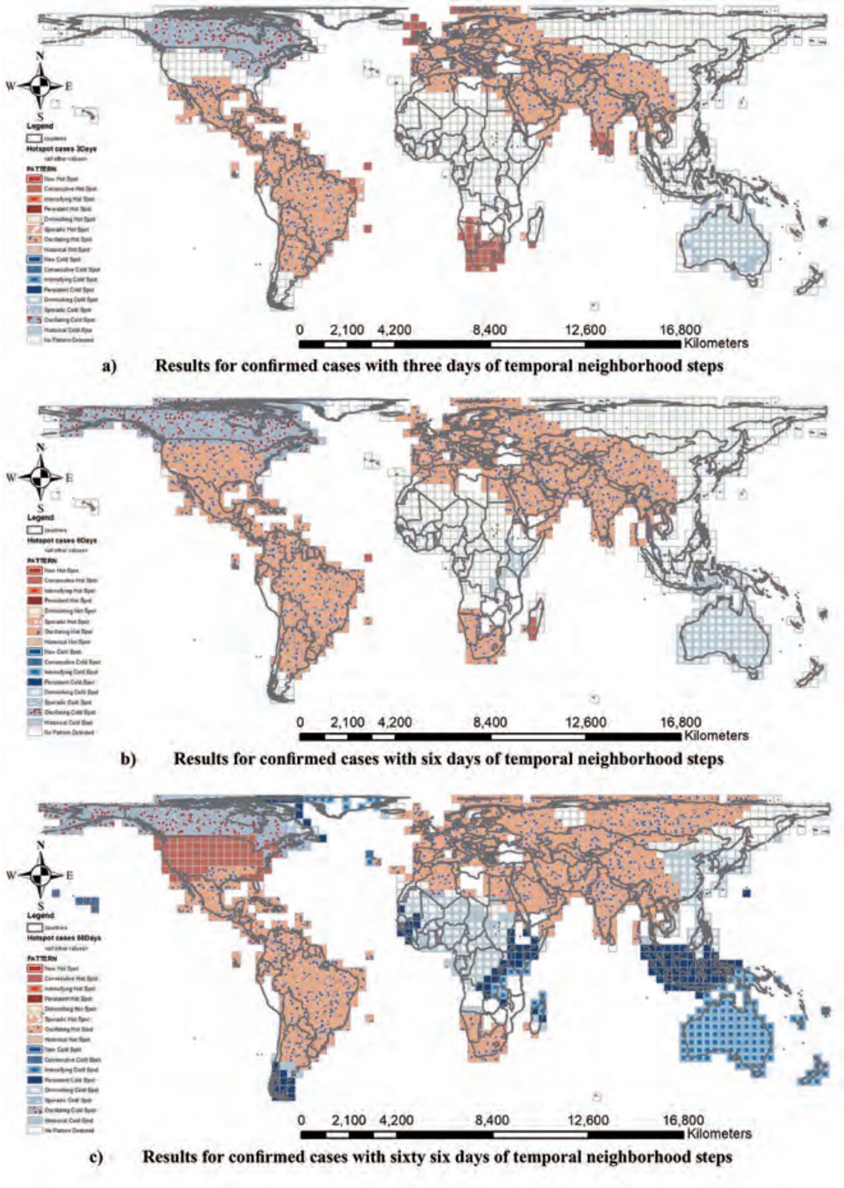

FIGURE 17.7
The STHCSA maps.

17.4 Discussion

The (2-7)-day period had a large magnitude in the results of this research, which had also been highlighted in clinical research. Results also highlighted periods greater than 25, 40, and 65 days which should be considered, whereas clinical trials had recorded only periods about 25 days. It seems that if the time series data are recorded correctly in terms of number and time, the higher the rate of infection and the incubation period of the diseases, the more possible it will be to extract important periods from them. The 3, 6, and 66-day periods with a large magnitude are shown in Figure 17.8. The size of the symbols indicates the normalized magnitude of the periods and their colors show the importance of the classes that are classified by the k-means.

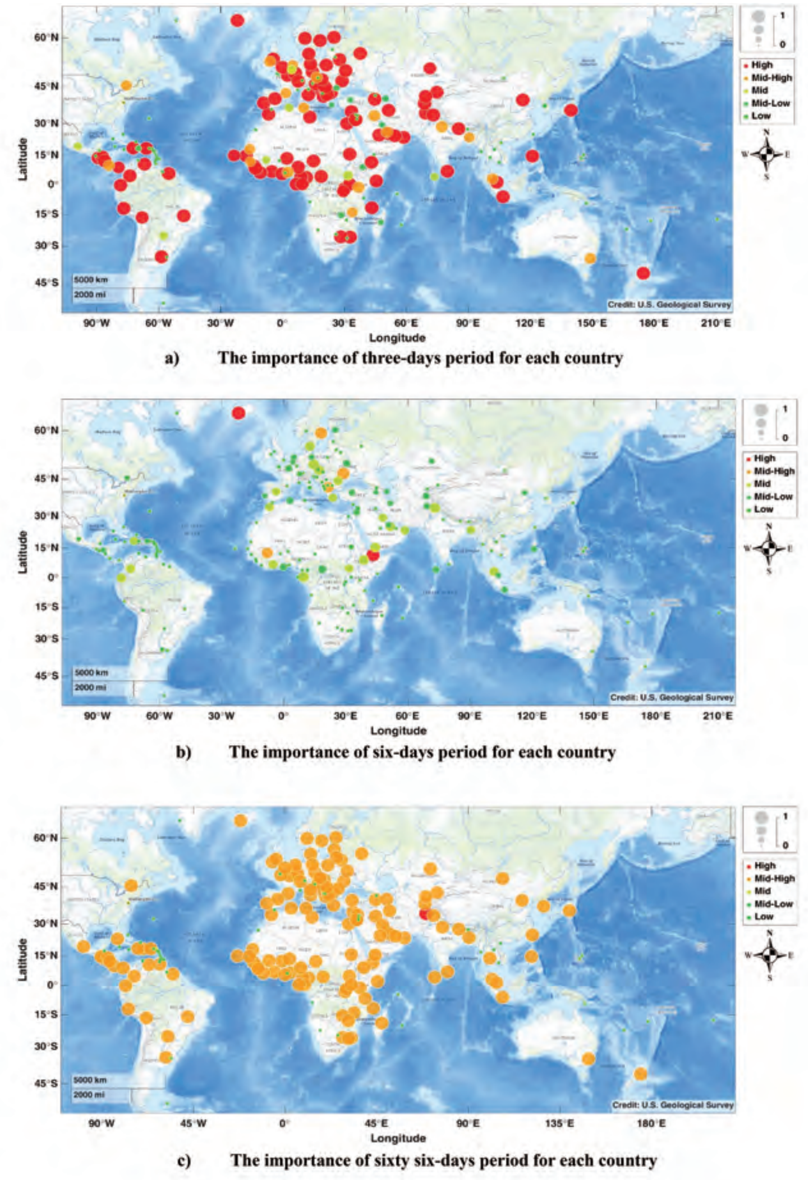

FIGURE 17.8
The important periods of the COVID-19 with their magnitude.

There have been periods of 3 and 66 days in many countries, but the magnitude of three days periods was much greater than 66 days. Periods of six days have been observed in many parts of Europe, some parts of Africa, and South America. Neighboring countries may have an impact on the similarity of the importance of periods.

In the COVID-19 prediction for each country, the performance of the proposed model was investigated in different situations based on the test and train RMSE, and the DWT and CWT mother wavelet functions were determined as well as an optimal network was built. Since train data was larger than test data and there had been significant changes and sudden increases in the train data, test accuracy was higher than train accuracy in many countries. Therefore, the train data was much more irregular than the test data.

Due to the different populations, confirmed cases and periods of infection in different countries, the RMSE is not sufficient to compare the accuracy of prediction for various countries. RMSEIQR can be more compatible to compare different data sets through IQR normalization. It has been determined for train and test data in all countries and the best and worst values are shown in Figure 17.9. According to the proposed model and the train data, Russia with RMSEIQR of 0.018 was the best, and Mauritania with 54.2689 was the worst prediction of this study.

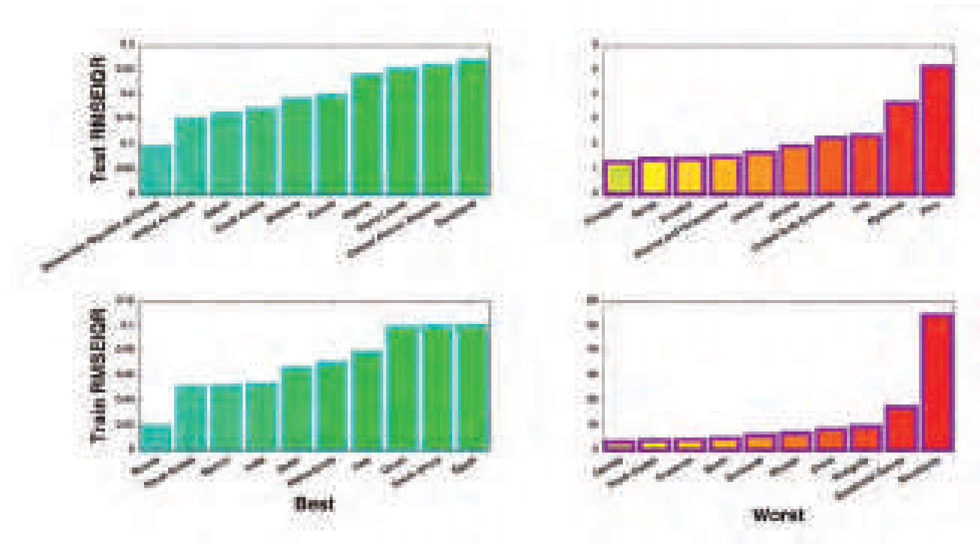

FIGURE 17.9
Comparison of test and train RMSEIQR.

Based on the test data, the Democratic Republic of Congo with RMSEIQR of 0.095 was the best, and Peru with 5.14 was the worst. The results indicate that the performance of the prediction was sufficient for almost all countries. In particular, the networks of countries such as Russia, Mexico, Italy, the United Kingdom, India, Saudi Arabia, and the Congo were the most efficient.

17.5 Conclusion

In this chapter, daily reports of the COVID-19 cases through different countries of the world were used to discover important periods of the disease. The results indicate that the COVID-19 has different short-term and long-term periods in different countries of the world, but in general, the main important periods were between 2 and 7 days, which had been demonstrated by clinical study for limited countries. Significant long periods, such as 66 days and 41 days, have also been detected by CWT. Then, by DWT, the features were extracted and important periods were used as a delay on the main signal and the extracted features. The neural network was then built based on the results of the previous steps and the COVID-19 cases were predicted. Results were acceptable with an average train and test RMSEIQR equivalent to 1.2785 and 0.6695, respectively.

Finally, hot/cold spots were identified by analyzing spatiotemporal patterns. The existence of 48.78% and 13.20% of oscillation and consecutive hot spot patterns around the world indicate the widespread spatiotemporal distribution of this epidemic. Prediction and analysis of hot/cold spots are useful for finding high-risk areas. Accurate predictions of cases and deaths can help politicians and decision-makers to legislate until the COVID-19 vaccine is discovered. A comparison of various neural networks and their tunes with optimization methods may be discussed in future research. Also, effective environmental and social factors in the COVID-19 and the impact of neighboring countries will be extracted which are recommended for further study in this field.

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Part III

Regional, Country and Local Applications

18

London in Lockdown: Mobility in the Pandemic City

Michael Batty, Roberto Murcio, Iacopo Iacopini, Maarten Vanhoof and Richard Milton

This chapter looks at the spatial distribution and mobility patterns of essential and non-essential workers before and during the COVID-19 pandemic in London, and compares them to the rest of the UK. In the 3-month lockdown that started on 23 March 2020, 20% of the workforce was deemed to be pursuing essential jobs. The other 80% were either furloughed which meant being supported by the government to not work, or working from home. Based on travel journey data between zones (983 zones in London; 8,436 zones in England, Wales and Scotland), trips were decomposed into essential and non-essential trips. Despite some big regional differences within the UK, we find that essential workers have much the same spatial patterning as non-essential for all occupational groups containing essential and non-essential workers. Also, the amount of travel time saved by working from home during the Pandemic is roughly the same proportion – 80% – as the separation between essential and non-essential workers. Further, the loss of travel, reduction in workers, reductions in retail spending as well as increases in use of parks are examined in different London boroughs using Google Mobility Reports which give us a clear picture of what has happened over the last 6 months since the first Lockdown. These reports also now imply that a second wave of infection is beginning.

18.1 The 2020 Pandemic in Britain

On 23 March 2020, Britain locked down to protect its population against what by then was widely recognised as a global Pandemic. Its population watched in horror the reports from Northern Italy of rising deaths and a health system that was simply overwhelmed with serious cases requiring intensive care. Spain was not far behind while the rest of Europe was catching up fast. COVID-19 had overwhelmed the city of Wuhan where the virus was first detected in a wildlife market in early November 2019 but the serious nature of the disease was not appreciated until it was literally on our doorstep. By March, it was clear that the disease was particularly serious for older age groups whose mortality rates for those above 80 who were admitted to hospital were close to 50%. The Lockdown introduced in late March was designed to stop the spread of the disease, using the time honoured method of keeping people apart until the disease could be contained which was generally assumed to have occurred when the so-called R number – its rate of change – dropped below 1. Although the Lockdown was reviewed every three weeks, in fact it lasted some three months to mid-June when it became apparent that the virus had been contained. It was then deemed 'safe' to open up parts of the economy again to social interactions, notwithstanding fairly strict measures of social distancing that mandated people to keep 2 metres apart from one another, wear masks to avoid spreading the virus through respiratory means, and to wash hands frequently to remove any traces of the virus that might have been picked up from surfaces.

The restrictions imposed by the Lockdown were designed to protect the UK National Health Service which to some extent, is the most revered public service in Britain, the only function of government to have survived the dismantling of the Welfare State that proceeded apace as Britain emerged from its industrial past. The key elements of the Lockdown involved staying at home to stop the disease spreading between households. To this end, the only exceptions were shopping for basic necessities, one form of exercise a day, medical needs, care for the vulnerable, and travelling to or from work to carry out essential services. These mandates meant no household mixing, no meeting friends or family members living in separate homes, no gatherings of more than two people in public, and no social or sporting events. Schools and churches were closed. These were Draconian measures by peacetime standards and essentially put the economy and social life into cold storage. The summer months saw a gradual opening up of the economy but in a dramatically constrained way. However by the late summer in September, it was clear that a second wave could be detected through a rapid increase in testing for the virus [1]. Hospital admissions began to rise and at the time of writing (end October 2020) half the country is now back in some form of Lockdown, a little less severe perhaps than the original with some hospitality, schools, shops and work still open, but with strong advice to continue working from home wherever possible and with no household mixing in the most infectious hotspots. With winter approaching, the predictions are that although the shows no signs of loosening its grip and becoming less virulent, there are vaccines on the horizon whilst our medical knowledge of how to combat the disease with pharmaceutical inventions has increased. The hope is that although the number of cases may well outstrip the peak earlier in the year, the overall impact will be less severe. However assuming a vaccine becomes available by early 2021, it will take a Herculean effort to mass vaccinate an entire population.

If you lockdown an economy in the way many governments have to combat the spread of this disease, the impact on where people work, live, and entertain is dramatic. The effect of the Pandemic has and continues to have largely destroyed our quest to travel using public or group transport. Although our focus here is not on the economic impact, there are obvious changes to the locations which we traditionally visit or frequent where we engage in the routine activities of working, shopping, educating ourselves, socialising and so on, all activities that usually require us to gather together in groups of all sizes and at all scales. The mandates of social distancing operate at the most local level but these translate themselves into how we might travel more globally throughout the metropolitan area, regionally, nationally and internationally for we need to observe the mandates for keeping apart when we use public transport of any kind [2].

In this chapter, we will illustrate the impact of COVID-19 on changes in mobility in both the UK and in a world city where changes in where and how we travel have been dramatic. London has one of the biggest central areas of any city worldwide, diversified into financial, retail, and government functions in several distinct cores all of which have been emptied of workers since the hit. In the financial quarter – the 'square mile' or the City – which is the traditional heart of the metropolis, half a million people usually work largely in financial and legal services and cognate activities but most have been absent, working from home, for the last 6 months since the Pandemic began. In the inner part of the metropolis, the Greater London Authority (GLA) area, home to a population of some 8 million, about 40% of all those travelling use public transport and these services have been operating at little more than 30% capacity. It is estimated that 16% of the 5 million workers in this GLA area were classed as 'key' or 'essential workers, with permission to work during the first Lockdown. There has been an exodus of population to the outer suburbs and to the countryside, just as happened in the last great plague that hit London in 1665 when Parliament moved to Oxford. Retail activity within the City has all but ceased and many outlets have closed, reportedly more than 1,000 in the GLA area with little sign that these closures are anywhere near complete.

In some respects, a full analysis of a city under a Pandemic is an impossible task until the Pandemic ends because the restrictions on normal life are continually changing. Here, however, we will focus on mobility examining the extent to which the patterns of movement we have already noted have been disrupted by the need to social distance on all spatial scales. We will begin by examining the location patterns of essential and non-essential workers in London which are defined in terms of occupations and which are assumed to separate workers who have remained at their place of work during the Pandemic from those who are either furloughed and supported by the government (to not work) or are working from home. We will extend this analysis to how different types of workers travel between home and work under the Pandemic.

Although our analysis is largely inconclusive with respect to defining distinct differences between essential and non-essential workers in terms of their geospatial attributes, we then follow up this analysis by examining a more detailed picture of changes in travel patterns using Google's Mobility Reports. These reveal significant differences between movements associated with several physical activities ranging from transit to the use of parks and using this type of data, we can easily demonstrate how mobility varies systematically across the metropolis illustrating quite profound differences between the city core, the inner area and the outer suburbs. In fact a full analysis of all this data for cities and regions in the UK is still to be attempted but the particular case of London does provide a focus for informed speculation about how the Pandemic might end with respect to possible changes in mobility. From this data too, because it relates to how visits to different activities vary throughout the Pandemic starting in mid-February 2020 providing data each day until 18 October (the time of writing), we can see detailed change in the time series and in this way, detect the rise of the second wave and the difficulties of bringing the economy back until a vaccine is in sight. Last but not least, we will use this particular analysis to hint at ways in which London might transition to a new normal different but similar to the old normal once the Pandemic ends.

18.2 Defining Essential Workers

When the government locked the country down, it first defined a group of 'key' or 'essential' workers whose endeavours were required to keep the country running. It produced a list of such workers defined in terms of the proportion of the numbers of persons in the 9 occupational classes defined by the Office of National Statistics and used in the Population Census. By applying the proportions to the numbers in each of the occupational classes, it is possible to derive the numbers of essential workers in each class and it is possible to do this at the level of the standard regions in the UK of which there are 12. This is the finest level of granularity we have for occupational classes at the level of the resident population which we need to work with because we need to disaggregate our trip patterns for the journey to work by occupational class so that we can generate the distribution of such classes at the workplace end of the trip. In short, our basic data involves the flows of workers from their place of residence to their place of work, data collected by the UK Population at the census year, the latest of which is 2011, updated to 2019 by proportional factoring. As all this data is grounded at the place of residence, we need to work backward by disaggregating trips by occupation at the residence and then computing occupational classes at the workplace end of the trip. This then enables us to calculate the number of essential workers at both ends of the trip.

To indicate how we generate this data, trips between a workplace i and a residential location j are first defined by mode of travel k as T_{ij}^k from the updated Census data. This is consistent with employment E_i in workplace i and working population P_j at residential location j defined from $E_i = \sum_j \sum_k T_{ij}^k$ and $P_j = \sum_i \sum_k T_{ij}^k$. As we know the proportions of occupations o at the residential end of the trip ρ_j^o, we can apply these first to generate a disaggregate pattern of trips $T_{ij}^{ko} = \rho_j^o T_{ij}^k$ from which we can compute both the working population and the employment by occupational group at the residential and workplace ends of the trip $P_j^o = \rho_j^o P_j = \rho_j^o \sum_i \sum_k T_{ij}^k$ and $E_i^o = \sum_j \sum_k \rho_j^o T_{ij}^k$. We also need to divide employment, working population and trips into essential (es) and non-essential (ne) workers. We have this for the residential end of the trip from more aggregate data where we define $\rho_j^o = \rho_j^o(es) + \rho_j^o(ne)$ and we then use these proportions to generate the essential and non-essential workers and working populations as

$$\left.\begin{array}{c} E_i^o(es) = \sum_j \sum_k \rho_j^o(es) T_{ij}^k \quad , \quad E_i^o(ne) = \sum_j \sum_k \rho_j^o(ne) T_{ij}^k \\ P_j^o(es) = \rho_j^o(es) \sum_i \sum_k T_{ij}^k \quad , \quad P_j^o(ne) = \rho_j^o(ne) \sum_i \sum_k T_{ij}^k \\ E_i^o = E_i^o(es) + E_i^o(ne) \quad , \quad P_j^o = P_j^o(es) + P_j^o(ne) \end{array}\right\} \tag{18.1}$$

We now need to consider the volumes of essential workers from the data before we embark on our first foray into examining the distribution of those who are still working during the first

Lockdown. To get some sense of the variation in the distribution of essential and non-essential workers, we can aggregate the employment and working populations given in equation 18.1 to the UK and then to Greater London. In Table we show $E^o = \sum_i E_i^o$ and $E^o(es) = \sum_i E_i^o(es)$ and $E_{GLA}^o = \sum_{i \in GLA} E_i^o$ and $E_{GLA}^o(es) = \sum_{i \in GLA} E_i^o(es)$ and it is clear that there are substantial differences between different locations as well as between the volume of different occupations for different levels of spatial aggregation.

The way the government defined essential workers was based on particular subcategories of occupation whose families required support such as child care [3], and these subcategories varied in size for each occupational class in different areas and were defined from the Standard Occupational Classification (SOC) which has a very detailed breakdown of the 9 basic occupations. The percentages of workers in each basic occupation determined to be essential are illustrated in Table 18.1 for the UK and for London. It is immediately clear that the proportion of essential workers in London is much smaller than in the whole UK, 16% compared to 24% and although we do not have space here to examine these variations over the whole country, they are significant and thus make a big difference to the sheer volume of mobile workers during the Lockdown for the entire country. In fact in this project we have extended our analysis to England, Scotland and Wales using the Census geography of the middle-layer super output areas (MSOAs) of which there are 8,436 in Great Britain (where we use the term Britain as a short hand for the three countries involved) but here we will focus only on London. Our figure of 24% working in essential services in the UKL compares well with the figure of 22% from the Institute of Fiscal Studies which is also based on the list of key occupations provided by government [4] but applied slightly differently.

In Table 18.1, where we show total and essential workers by occupational categories for the UK and London, we first note that the relative importance of managerial and professional groups (the first three categories) which are much greater for essential workers in the UK than in London. The table also shows that the proportions of carers acting as essential workers in the UK is twice that of London. If we look at the last two columns in Table 18.1 where we have computed the proportions of non-essential and essential occupational groups for the UK and London in terms of the total employment of each area, we see that proportions of non-essential and essential managerial-professional groups is a little higher in London with skilled trades a little lower and caring and leisure services somewhat higher. A closer analysis of Table 18.1 suggests that London is weighted more to managerial occupations and service occupations than the UK in general but that in these occupations there are less proportions in the essential workers category than the UK in general. This bears out in very broad terms the fact that there are less non-essential workers in London with the implication that is non-essential are likely to be working from home, mobility levels will be a lot less than other parts of the country.

Our preliminary analysis of this data involves examining the relative distributions of essential and non-essential workers at their place of work and at their place of residence. In the analysis, we aggregated the occupational data, thus, working with essential and non-essential workers at their workplace and residence. These are defined from the above employments as

$$\left.\begin{array}{l} E_i(es) = \sum_o E_i^o(es) \\ E_i(ne) = \sum_o E_i^o(ne) \\ P_j(es) = \sum_o P_j^o(es) \\ P_j(ne) = \sum_o P_j^o(ne) \end{array}\right\} \tag{18.2}$$

We initially speculated that essential workers would travel less distances to work than non-essential, especially in London and this would be reflected in their work and home locations. We would expect non-essential to be more clustered towards the centre of the city although the complications of the London housing market could well obscure such a clear pattern because central and inner London are now so highly priced. Therefor we might also be able to detect some evidence that essential workers might actually travel further to work so that they can access lower priced housing. The trade-off in London between house price and travel cost however is complicated and the data to measure this is problematic. If we first look at the correlations between essential and non-essential workers at their place of work for the UK aggregated now over occupations, this is 0.981 in comparison with their place of residence where it is 0.882. However the correlations between essential and non-essential between workplace and home are very low. In short, there is a very dramatic difference in the UK between where workers live and work which is perhaps somewhat greater than what one might have expected. Correlation is one of many measures we can use to look at this covariance and it does not tend to pick up the autocorrelation in these data but it does bear out the fact that there are big differences particularly in London where people live and work for both essential and non-essential workers. These bear out similar correlations to the UK.

TABLE 18.1
Total and Essential Workers by Occupational Categories for the UK and London (Source: [3])

UK	Employment	Essential	Ess/ Emp	NEss/ Total	Ess/ Total
1 Managers, directors & senior officials;	3,149,600	168,800	0.054	0.127	0.007
2 Professional	5,532,200	1,170,300	0.212	0.186	0.050
3 Associate professional, technical occupations;	3,854,300	919,600	0.239	0.125	0.039
4 Administrative and secretarial occupations;	2,050,900	312,100	0.152	0.074	0.013
5 Skilled trades	2,932,400	570,800	0.195	0.101	0.024
6 Caring, leisure & other service occupations;	1,700,900	973,200	0.572	0.031	0.042
7 Sales & customer service occupations;	719,700	71,800	0.100	0.028	0.003
8 Process, plant & machine operatives;	1,754,200	796,200	0.454	0.041	0.034
9 Elementary	1,752,400	542,500	0.310	0.052	0.023
Total	23,446,600	5,525,300	0.236	0.764	0.236
LONDON	Employment	Essential	Ess/ Emp	NEss/ Total	Ess/ Total
1 Managers, directors & senior officials;	617,300	14,800	0.024	0.130	0.003
2 Professional	1,230,000	242,900	0.197	0.213	0.052
3 Associate professional, technical occupations;	870,100	120,000	0.138	0.162	0.026
4 Administrative and secretarial occupations;	412,100	52,100	0.126	0.078	0.011
5 Skilled trades	317,800	46,000	0.145	0.059	0.010
6 Caring, leisure & other service occupations;	328,200	80,200	0.244	0.054	0.017
7 Sales & customer service occupations;	265,300	10,900	0.041	0.055	0.002
8 Process, plant & machine operatives;	210,700	98,000	0.465	0.024	0.021
9 Elementary	377,500	76,700	0.203	0.065	0.017
Total	4,629,000	741,600	0.160	0.840	0.160

Our data represent counts of workers in the small zones called MSOAs which on average have some 2,378 employees at their workplace and the same working populations at their residences. In fact the standard deviation for workplaces is much bigger than for residences (5,360 compared to 760) and this shows the very skewed distribution of the workplace data compared to the residential areas. To generate normalised distribution which are somewhat more comparable, we have defined densities as follows $E_i(es)/L_i$, $E_i(ne)/L_i$, $P_j(es)/L_j$, and $P_j(ne)/L_j$ where L_i,L_j are the land areas of the zones in question. We have also correlated these variables for the UK and London and this shows a slightly different pattern; all these are shown in the heat maps in Figure 18.1 which, for counts and densities of the data in MSOAs, show almost exact correlations between essential and nonessential workers at their workplace and very strong correlations at their residence (home). Only for essential and non-essential workers at their residence is there any clear and obvious difference, and this is with respect to counts data where the absolute non-normalised size effect is more dominant.

To complete this preliminary picture of how locations of essential and non-essential workers at their workplaces and residences are spatially distributed, we begin with the counts data that we show in Figure 18.2 for the UK and Figure 18.3 for London. Because these distributions are so skewed with very few large values and many small, we plot the logarithms of these data. The distinction between correlations associated with workplaces and residential areas in terms of essential and non-essential workers is reflected in these maps, first for the UK in Figure 18.2.

It is clear that at the workplaces the UK distributions of essential and non-essential are very close as reflected in the correlations in the Heatmaps in Figure 18.1(a) and Figure 18.1(c). When we examine the home-based data in Figures 18.2(b) and 18.2(d), the biggest differences between essential and non-essential areas are in rural locations where travel times are much longer to reach workplaces and homes. Essential workers tend to be a little less concentrated near the bigger cities. We map the same distributions for London (the GLA area) in Figure 18.3 and the same sorts of conclusion emerge.

From Figure 18.3, the workplace distribution of essential workers is quite close to the non-essential for London and there is little to suggest any real spatial differences. In terms of the distribution of these same employments at the home-residence locations, the non-essential appear to be more clustered than the essential with the essential living a little closer to the centre. To explore these differences further, we can generate the same maps for the density distributions. As before, we first map the national density distributions of essential and non-essential workers at their workplace and home in Figure 18.4. From this first analysis, we can conclude that the spatial distributions of essential employment differs very little from non-essential at their place of work, as much because these distributions are very highly skewed and follow power laws. This is the reason we have been plotting them as logarithmic transforms to get rid of extreme variations and make them as comparable as possible, visually. At the home location, there is more variation but in terms of the UK and then London, it is more difficult to generalise other than saying that non-essential appear to be more randomly distributed than essential which are lower in rural and remote areas.

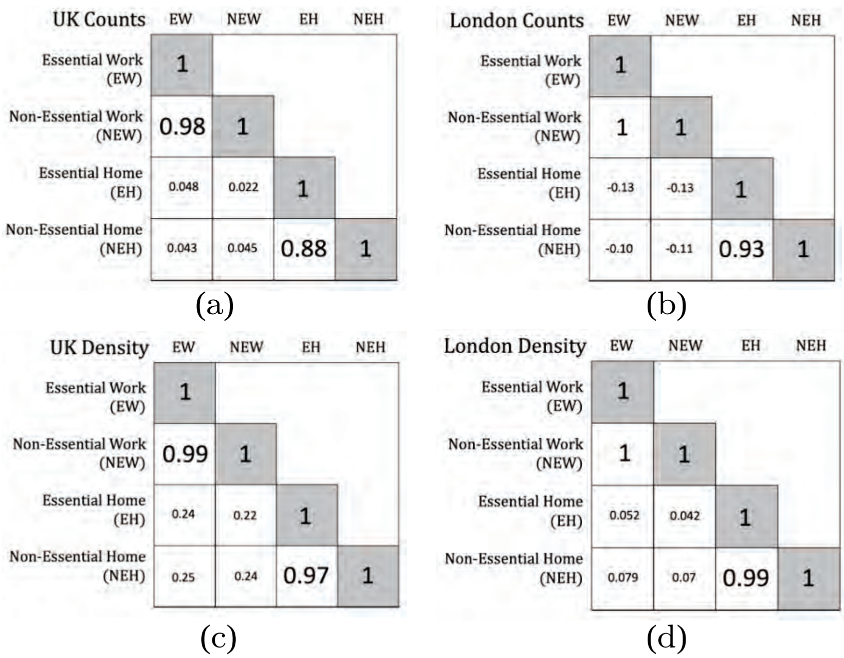

FIGURE 18.1
Heat Maps Showing the Correlations for the UK and London For Count and Density Data a) UK Count Data, b) London Count Data, c) UK Density Data, and d) London Density Data

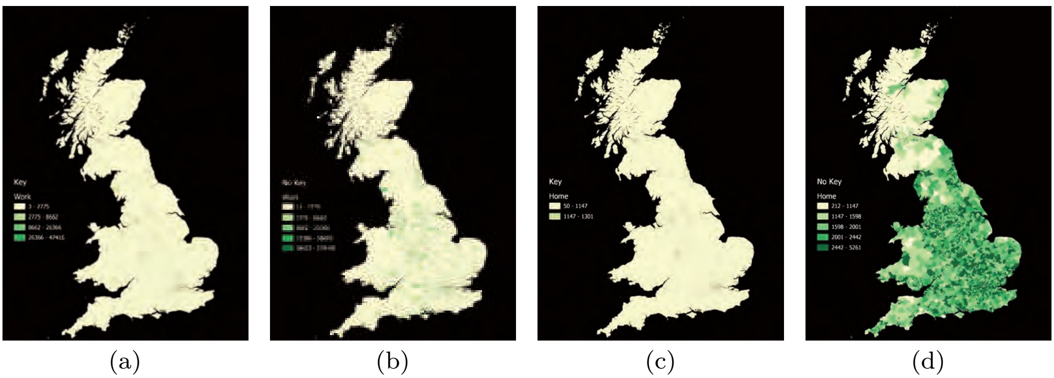

FIGURE 18.2
UK: Essential and Non-Essential Employment at Workplace (a and b) and at Home (Residence c and d)

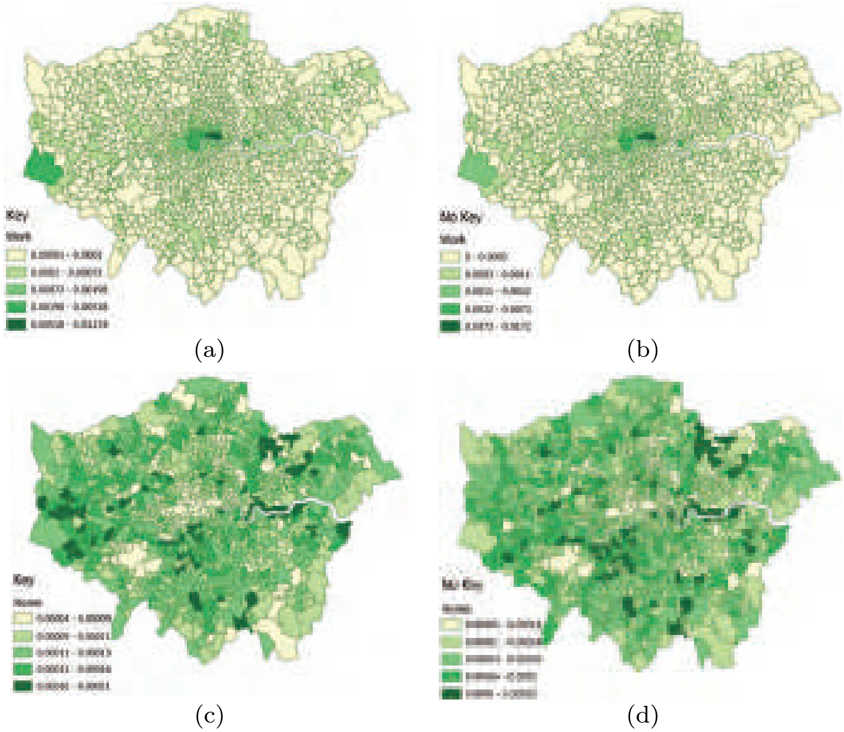

FIGURE 18.3
London: Essential and Non-Essential Employment at Workplace (a and b) and at Home (Residence c and d)

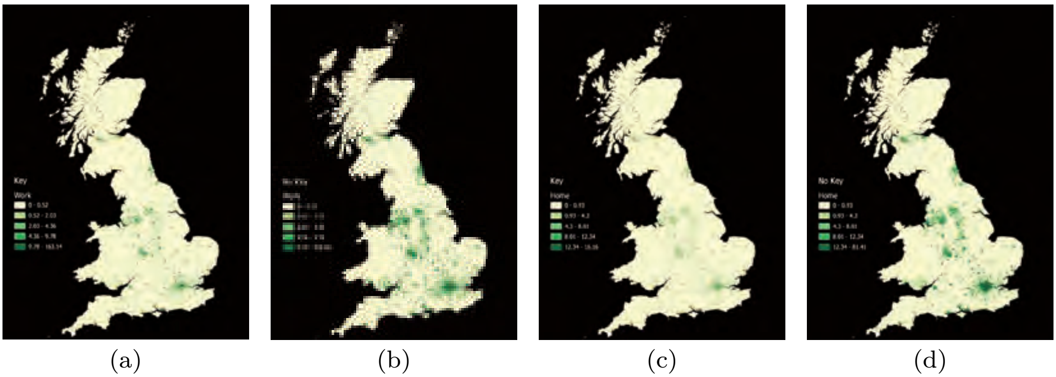

FIGURE 18.4
UK: Essential and Non-Essential Employment Densities at Workplace (a and b) and at Home (Residence c and d)

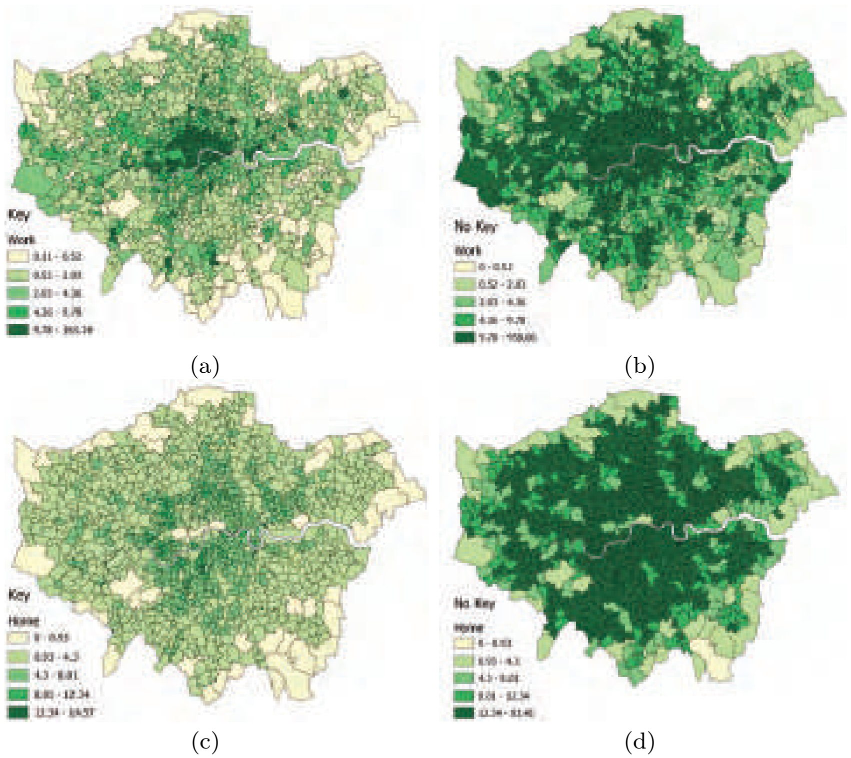

FIGURE 18.5
London: Essential and Non-Essential Employment Densities at Workplace (a and b) and at Home (Residence c and d)

18.3 The Movement Patterns of Essential and Non-Essential Workers

Rather than simply focussing on how different are the location patterns for essential and non-essential workers, a more important aspect of the analysis is to examine the different trip lengths for the basic variable T_{ij}^{ko}. We do this for the overall distribution and then for the aggregations that we have introduced above. The mean trip length C over the entire system measured in minutes is

$$C = \sum_i \sum_j \sum_k \sum_o T_{ij}^{ko} d_{ij}^k \ \ / \ \ \sum_i \sum_j \sum_k \sum_o T_{ij}^{ko} \tag{18.3}$$

and then for the overall aggregations for occupations, modes and occupations by mode, these means are

$$\left.\begin{aligned} C^o &= \sum_i \sum_j \sum_k T_{ij}^{ko} d_{ij}^k \ \ / \ \ \sum_i \sum_j \sum_k T_{ij}^{ko} \\ C^k &= \sum_i \sum_j \sum_o T_{ij}^{ko} d_{ij}^k \ \ / \ \ \sum_i \sum_j \sum_o T_{ij}^{ko} \\ C^{ko} &= \sum_i \sum_j T_{ij}^{ko} d_{ij}^k \ \ / \ \ \sum_i \sum_j T_{ij}^{ko} \end{aligned}\right\} \tag{18.4}$$

We can also aggregate these to workplace zones and all sub-aggregations to occupations, modes and occupations by mode

$$\left.\begin{array}{r}C_i = \sum_j \sum_k \sum_o T_{ij}^{ko} d_{ij}^k \ \ / \ \ \sum_j \sum_k \sum_o T_{ij}^{ko} \\ C_i^o = \sum_j \sum_k T_{ij}^{ko} d_{ij}^k \ \ / \ \ \sum_j \sum_k T_{ij}^{ko} \\ C_i^k = \sum_j \sum_o T_{ij}^{ko} d_{ij}^k \ \ / \ \ \sum_j \sum_o T_{ij}^{ko} \\ C_i^{ko} = \sum_j T_{ij}^{ko} d_{ij}^k \ \ / \ \ \sum_j T_{ij}^{ko}\end{array}\right\} \tag{18.5}$$

and then to residential destinations

$$\left.\begin{array}{r}C_j = \sum_i \sum_k \sum_o T_{ij}^{ko} d_{ij}^k \ \ / \ \ \sum_i \sum_k \sum_o T_{ij}^{ko} \\ C_j^o = \sum_i \sum_k T_{ij}^{ko} d_{ij}^k \ \ / \ \ \sum_i \sum_k T_{ij}^{ko} \\ C_j^k = \sum_i \sum_o T_{ij}^{ko} d_{ij}^k \ \ / \ \ \sum_i \sum_o T_{ij}^{ko} \\ C_j^{ko} = \sum_i T_{ij}^{ko} d_{ij}^k \ \ / \ \ \sum_i T_{ij}^{ko}\end{array}\right\} \tag{18.6}$$

We need to note that the variable d_{ij}^k is the travel time between origin i and destination j on the modal network k of which there are three – bus, rail and road – but this does not include travel time at the trip ends. It is solely the travel time on the mode of transport – the time spent on the bus, in the train, or in the car. It is very likely that these times would double if the trip end times were added to them.

The breakdown of total modal trips into essential $T^k(es) = \sum_i \sum_j \sum_o T_{ij}^{ko}(es)$ non-essential $T^k(ne) = \sum_i \sum_j \sum_o T_{ij}^{ko}(ne)$, and total $T^k = \sum_i \sum_j \sum_o T_{ij}^{ko}$ is shown in Table 18.2 where it is clear that the percentage divisions for each mode do not differ very much from the 20-80 split which is roughly the overall split advised by government. In terms of the trip lengths, these are shown in Table 18.3 for each mode and overall and they differ very little between essential and non-essential. The minor differences in terms of proportions are such that what this probably means is that essential and non-essential trips patterns are very close to each other across all modes and this is echoed throughout this analysis. The aggregate mean trip length for the whole UK system C is 15.89 minutes. When we disaggregate these into modes C^k, the longest is the rail at 30.63 minutes ($C^{(k=2)}$), followed by bus at 26.64 ($C^{(k=1)}$), and then there is a large drop to road (largely meaning car) with 12.46 minutes travelled on average ($C^{(k=3)}$). In terms of the modal split, the proportions in each mode are

$$\rho^k = E^k \ / \sum_k E^k = \sum_i \sum_j \sum_o T_{ij}^{ko} \ \ / \ \ \sum_i \sum_j \sum_o \sum_k T_{ij}^{ko} \tag{18.7}$$

and these are calculated approximately as 10% for bus, 11% for rail and 79% for road.

TABLE 18.2
UK Total, Essential and Non Essential Workers $T^k(es)$, $T^k(ne)$, T^k

Total Workers	**Essential Workers $T^k(es)$**	**Non-Essential Workers $T^k(ne)$**	**Total T^k**	**% Essential**	**% Non-Essential**
Road	3105661	12717370	15823031	0.2	0.8
Rail	353080	1833292	2186372	0.16	0.84
Bus	383304	1667827	2051131	0.19	0.81
Total	**3842045**	**16218489**	**20060534**	**0.19**	**0.81**

Although we examine the trip lengths by mode in Table 18.2, we should also note the division of the country into its standard regions – namely Wales (W), Scotland(S) and 9 English regions – East Midlands (EM), East of England (EE), London (L), North east (NE), North West (NW), South East (SE), South West (SW), West Midlands (WM) and Yorkshire/Humberside (YH). The variations in trip lengths across modes still dominate the regional variations although there are some large deviations from the overall means. For example, in terms of road travel, the shortest travel times are in London (9.25) and the largest are in Wales (14.43) while rail travel is also smallest in London (22.98) and largest in Wales (45.82), the East Midlands (50.09) and the South West (64.88). The bus times are pretty even across all the regions with the largest being London but this is only 29.62 minutes compared to the average of 26.62, 11% more. Note that it is easy to confirm these statistics in that we can show if we add the mean trip lengths together for the three modes and weight them in the way we have shown in equation (18.7) above, then it is clear that

$$\sum_k \rho^k C^k = \left\{ \rho^1 \frac{\sum_i \sum_j \sum_o T_{ij}^{10} d_{ij}^1}{\sum_i \sum_j \sum_o T_{ij}^{10}} + \rho^2 \frac{\sum_i \sum_j \sum_o T_{ij}^{20} d_{ij}^2}{\sum_i \sum_j \sum_o T_{ij}^{20}} + \rho^3 \frac{\sum_i \sum_j \sum_o T_{ij}^{30} d_{ij}^3}{\sum_i \sum_j \sum_o T_{ij}^{30}} \right\} = C \qquad (18.8)$$

A brief examination of the variances between these three modes between the 11 regions suggests that for bus, the standard deviation is about 6.68 minutes, followed by rail where it is 5.42, and then road which is 4.80. We can casually interpret these deviations as being due to the fact that most travellers have less control of the timing of their use of bus compared to rail and that the greatest control, hence the lowest variance, is for car use where the user has most control. However as all these effects are compounded across many zones and many travel times in different regions, it is not clear whether we can attribute such variation simply to the spatial differences across the nation or to the modes themselves.

When we examine the overall trip lengths by occupation and by region C^o, we find that managers and professionals travel some 33% more in time than the average while less professionally qualified occupations such as sales, technicians and some caring services travel some 25% less. London is a massive outlier where the managerial and professional occupations tend to have much less variation than in the regions but the less professional travel more than 40% of the national average. The North West and West Midlands tend to have lower travel times over most occupations than other regions. The singly-biggest difference with respect to occupations and regions is between an average travel time of some 20 minutes for professionals in all regions with the exceptions of the North West, West Midlands and Yorkshire-Humberside. The caring occupations only commute some 10-11 minutes while London is again the outlier and more peripheral regions such as Wales and Scotland do not appear to be dramatically different from the average. It is hard not to conclude from this brief analysis that London is dramatically different from the national average largely because of its size and the fact that its housing market and its transport systems are so different from the rest of the country.

We have one further disaggregation that we need to focus on and that is our basic distinction between essential and nonessential workers. In fact we can explore these through the occupations but as this would involve us in too much detailed analysis here, we will aggregate these essential and nonessential occupations into a total of essential and nonessential at the zonal, then the regional and the national levels. We will thus produce the same analysis that we have already developed for the essential and non-essential aggregates. Noting that we define the essential trips and non-essential as $T_{ij}^{ko}(es)$ and $T_{ij}^{ko}(ne)$, the mean trip lengths by mode as $C^k(es)$ and $C^k(ne)$, and by occupation as $C^o(es)$ and $C^o(ne)$, it is immediately apparent that the orders of magnitude of all these variables are very similar in values to C^k and C^o. In fact, the essential and non-essential mean trip lengths for occupations and regions hardly reveal any differences from the combined distributions of all populations: the main difference is in the overall mean trip lengths $C(es)$ and $C(ne)$, which are 15.63 and 15.95, respectively, which is a difference of only about 2%. These are shown in Table 18.3 for the modes as well.

TABLE 18.3
UK Mean Trip Lengths $C^k(es)$, $C^k(ne)$, C^k

Mean Costs	Essential Workers $C^k(es)$	Non-Essential Workers $C^k(ne)$	Total C^k
Road	12.52	12.44	12.46
Rail	31.23	30.52	30.63
Bus	26.48	26.68	26.64
Total	**15.63**	**15.96**	**15.89**

In short, this means that on average, essential workers only travel about 2% less than nonessential workers over all modes. The occupation data suggests all changes are less than 2% and these do not vary much within regions. In fact each of the 9 categories of worker by occupation has essential and non-essential workers and in general over all occupations, the essential travel is only very slightly less than the nonessential. In terms of modes, there is no more difference than between regions and occupations and it would appear that the essential workers are distributed in a very similar way to the nonessential across the country, probably due to the fact that to keep the system running, one has to have roughly the same pattern of workers everywhere. This is particularly pronounced for London as Table 18.4 reveals. In short the differences are hardly worthy of comment and our anticipation that essential workers differ in their journey patterns radically from non-essential is not borne out. In fact it is more likely that essential and non-essential differ in their spatial locations than in the amount of time spent in travelling but what we require is a new framework to handle all these variations so that we can apportion the relative importance of minor differences between category types.

TABLE 18.4
London Mean Trip Lengths $C^k_{GLA}(es)$, $C^k_{GLA}(ne)$, C^k_{GLA}

Mean Costs	**Essential Workers $C^k(es)$**	**Non-Essential Workers $C^k(ne)$**	**Total C^k**
Road	9.12	9.28	9.25
Rail	22.98	22.98	22.98
Bus	29.76	29.95	29.62
Total	**18.86**	**19.16**	**19.12**

If we now look at the total amount of travel, rather than the trip lengths, we can begin noting that we can multiply the mean trip lengths by the total trips for whatever aggregation of the trips we are dealing with from $T^{ko}_{ij}(es)$ and $T^{ko}_{ij}(ne)$. First, we will look at total travel in the essential and non-essential sectors and these are defined as $T(es) = \sum_i \sum_j \sum_k \sum_o T^{ko}_{ij}(es) d^k_{ij}$ and $T(ne) = \sum_i \sum_j \sum_k \sum_o T^{ko}_{ij}(ne) d^k_{ij}$ which add to the total travel in the system as

$$T = \sum_i \sum_j \sum_k \sum_o T^{ko}_{ij} d^k_{ij} = \sum_i \sum_j \sum_k \sum_o \left[T^{ko}_{ij}(es) + T^{ko}_{ij}(ne) \right] d^k_{ij} = T(es) + T(ne) \quad (18.9)$$

These statistics suggest that before the Pandemic, the total amount of travel for work during the day was about 5.31 million hours per day in the UK as shown in Table 18.5. If we look at essential workers, the number of hours travelled after the lock down was about 1 million hours which means that some 4.31 million hours has been saved by persons working from home. This is a fall of some 81% in travel time which reflects the number of essential workers in the whole economy. It is worth saying that this is not the total reduction in travel because people working from home still go shopping and take exercise. Note that if we divide these total travel times by the respective total trips, then this gives the mean travel times, in this case of $C(es) = 15.63$, $C(ne) = 15.95$, and $C = 15.89$.

TABLE 18.5
UK Total Hours Spent in Essential Travel and Saved in Home Working $C^k T^k/60$

Hours	**Essential Workers**	**Non-Essential Workers**	**Total**
Road	648,048	2,636,735	3,285,916
Rail	183,778	932,535	1,116,143
Bus	169,165	741,627	910,702
Total	1,000,853	4,314,118	5,312,698

18.4 Drilling Down Into Individual Locations in London

So far, we have only examined the aggregate pattern of essential and non-essential workers at their workplace and home where the distribution of workers has been mapped prior to the Pandemic. Then those who are furloughed and work from home who are deemed non-essential are subtracted from the total leaving those who are essential workers dominating the journey to work during the 3 months period from 23 March 2020 when the country was first locked down. However, we are able to approach the problem of the fall in travel in a more oblique manner using Google Mobility Reports [5] which collate data from anyone who users Google services on mobile devices such as Google Maps and who has switched on their Location History (which is off by default). This is available for many places around the world and in the UK is available for all local authorities. In London, this means that we have good data on the changes in trips day by day from 10 February 2020 to 18 October 2020 for six categories of activities: residential occupancy, workplace volumes, visits to parks, volumes of workers using transit which in the case of London is overground and underground rail and buses, retail sales, and then grocery store volumes of visits. What these data show is the decrease or increase in volume from the baseline. In this case for the UK, it is some 37 days before Lockdown and covers the period from then to our cut-off date when we retrieved the data giving us a series of 247 days. The horizontal axes of the trajectories that we show below in Figures 6 to 9 span these 247 days on a scale from 0 to 250. In fact, the baseline is the median value of activity volumes in the 5-week period from 3 January to 6 February 2020. The data continues to be collected.

For each place and aggregation thereof, the data provides a detailed time series of the level of activity before the Lockdown with the baseline data as 10 February. Then the subsequent change in activity which at the beginning of the period is a massive drop in visits due to the fact that people were mandated not to travel (as we noted in the introduction) suggest a slow recovery towards the baseline. In the case of the UK, and London in particular, there is no return to the baseline and there has in fact been a levelling off and even a slight drop in some activities in the last 40 or so days as a second wave of infection appears to be beginning. There is a wealth of data here but with all the caveats of course pertaining to its representativeness for only if you have Location History on and access to Google services can any such data be collected. The representativeness of the data is thus unknown and only if the data were integrated with other sources would we be able to say very much about its overall quality. What we can say, however, is that the data is accurate in terms of its geo-positioning.

Our analysis in this paper merely touches the surface of what we can do with data such as this and as yet we have not embarked on a full scale analysis of all areas of the UK and any aggregation thereof. What we do here is begin with the data for the UK and use this as our spatial baseline, thence comparing three different parts of the Greater London Authority with this baseline and with each other. These locations are the City of London – the so-called dead heart of the metropolis [6], the more prosperous borough of Richmond-on-Thames in west London and the less prosperous borough of Newham in east London. The average income/wage of those in the City is about £27 per hour (ph), in Richmond it is £20 ph and in Newham £13 ph, all compared with a London average of £15 ph and a UK average of £13 ph. This gives a very crude idea of the relative prosperity of these places and we might expect this to have some effect on the degree to which mobility patterns might have altered during the Pandemic. There are many other estimates of income but these appear to be the least controversial (see [7] and [8]).

We show the profiles of the change in the six activities for the UK in Figure 18.6 and the same for the three London boroughs – the City in Figure 18.7, Richmond on Thames in Figure 18.8, and Newham in Figure 18.9. For the UK, the growth in those working at home peaked early in the Pandemic at about an additional 30% staying home to work or furlough, then gradually falling back to about 10% more than the baseline. There is no data for the City of London as only 8,000 people live there and many only do so during the working week but the richer borough of Richmond had up to 50% and this has fallen back to some 25% now. Newham is similar to the UK baseline. The only other activity which has seen any real increases in activity are in parks, which fell nationally in the early and then quickly increase to a peak of 150% about average through the summer months well above the baseline. This has fallen back to some 25% above the baseline. Richmond is similar to this profile but in Newham there has been massive increase up to 500% of above the baseline of people visiting parts where in the City of London where half a million workers use pocket parks during the day, volumes have fallen by over 90% rising back to some 60% below the baseline but now back down to 70% as winter approaches.

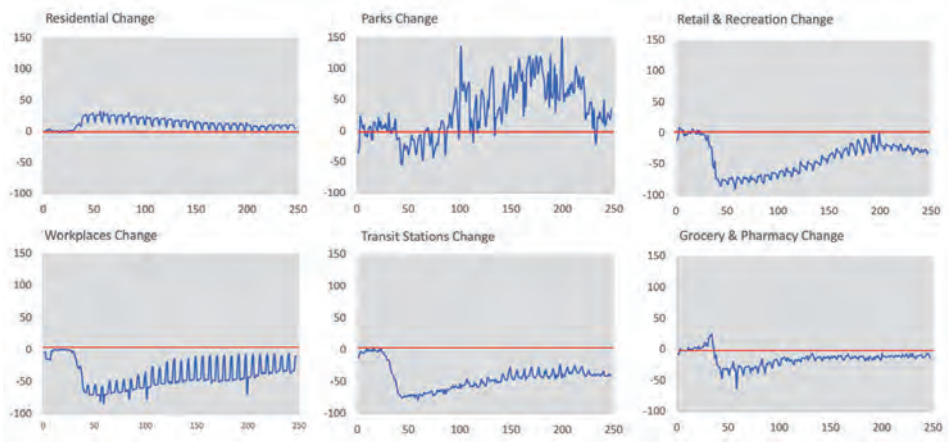

FIGURE 18.6
National UK Percentage Changes in Use of Activities from the February Baseline

The horizontal axes relate to the number of days from the 10$^{\text{th}}$ Feb and the vertical axes are the negative or positive percentage shifts in activity volumes from the baseline. This applies to all subsequent figures.

The other four activities – retail, workplaces, use of transit and grocery shopping – all show a big drop when Lockdown took place and then a gradual recovery but only in the case of grocery shopping has this recovered almost to the baseline – the old normal. This is apart from the City where grocery shopping is mainly based on office workers who are no longer at work. Retail change is startling with a national fall by about 90% at the beginning of the and then a steady rise back to about 20% below the baseline by the late summer but with a distinct fall back to about 35 percent below the line during the last 50 days. There is evidence here of a second peak but this is compounded by a drop in income and as yet the picture is unclear. Richmond and Newham are fairly similar to the national UK profile apart from two massive spikes in Richmond on 23rd February and 7th March which relate to key Rugby matches at Twickenham where England played Ireland and Wales in the 6 Nations Cup in the days before the Lockdown occurred. The same picture occurs in transit usage with spikes in Richmond but quite dramatic falls in usage in all four examples. In the UK, volumes using transit fell to about 70% below the baseline but then have recovered to about 50%, while in the City these have fallen even more by about 95% but have only recovered to within some 70 percent of their normal baseline. Richmond and Newham have a similar profile to the UK but have only recovered to about 60% of their previous normal volumes. This is a major problem in that public transport is being completely subsidised by government and local authorities throughout England and is effectively bankrupt. National Rail have more or less been re-nationalised and Transport for London is in negotiation with the UK government. Congestion charging has been increased already in London and fare rises much greater than inflation have been suggested but not yet agreed. The public transport picture is much confused and at the time of writing, where a new national Lockdown is under discussion, the picture for transit looks bleak.

The key changes of course with respect to the focus here on essential and non-essential workers pertain to change in workplace volumes which imply changes to those working in their traditional workplace and those who have elected to work from home. When we look at the national picture in Figure 18.6 for workplace change, the profile is fairly typical of other declines: the national fall is

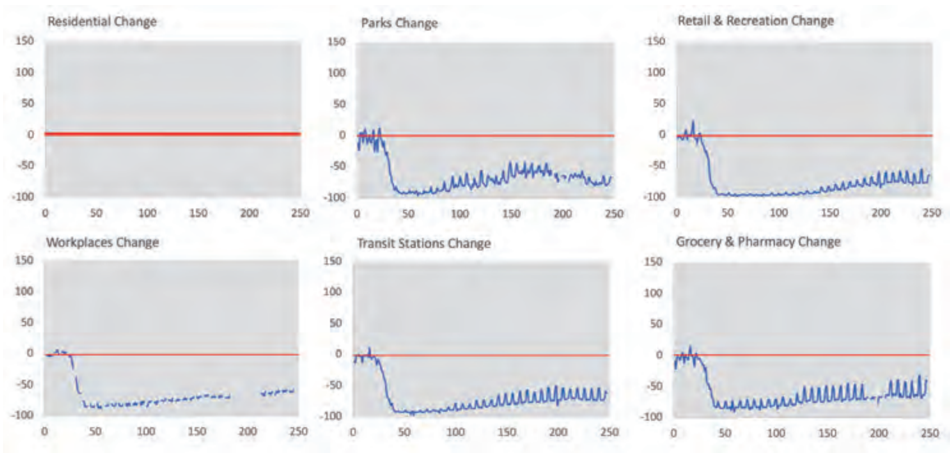

FIGURE 18.7
The City of London Percentage Changes in Use of Activities from the February Baseline

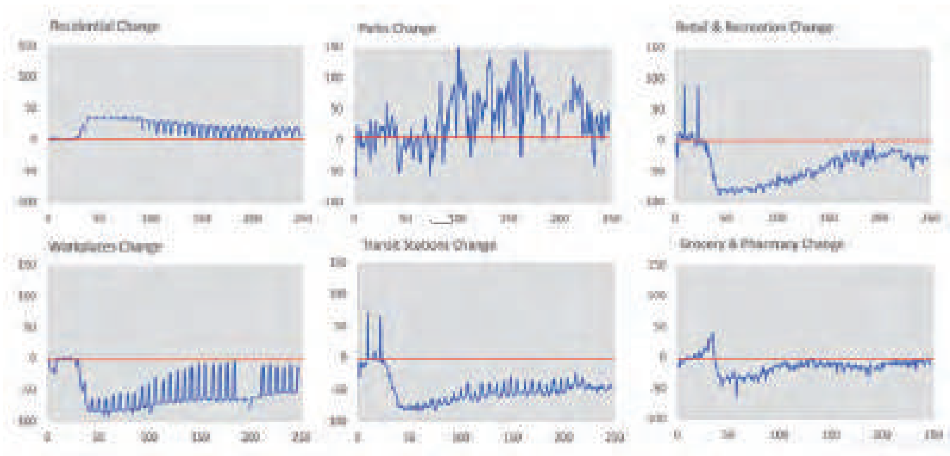

FIGURE 18.8
The Borough of Richmond on Thames Percentage Changes in Use of Activities from the February Baseline

about 70 precent which then recovers to some 30% less than the baseline. In Richmond, the decline is similar to the UK and to Newham but the decline in the City of London is much more fractured due to gaps in data collection during the weekends while in the three other cases the impact of the weekend versus the weekday is very pronounced. In short, the succession of spikes along the trend from a big fall and then recovery back towards the baseline marks the way the weekend and weekdays impact on work journeys to places of work. Without more information, it is difficult to precisely gauge these movements but these are quite pronounced in Richmond where the impact of the weekday seems to generate many less workers than the weekends.

The last activity we need to examine is very local – grocery shopping which drops the least of any activity after Lockdown – to no more than 50% of normal activity. In all but the City, this recovers to near normality by the end of the period. In fact, there is spike at the onset of the Pandemic with grocery shopping increasingly above the baseline, largely we suspect when people were stocking up on products ready to shop far less in the early months of the Pandemic. This is the case for three of our cases but not the City of London where there is a pronounced drop to about 90% of normal activity which slowly climbs back but to no more than 50% less than the

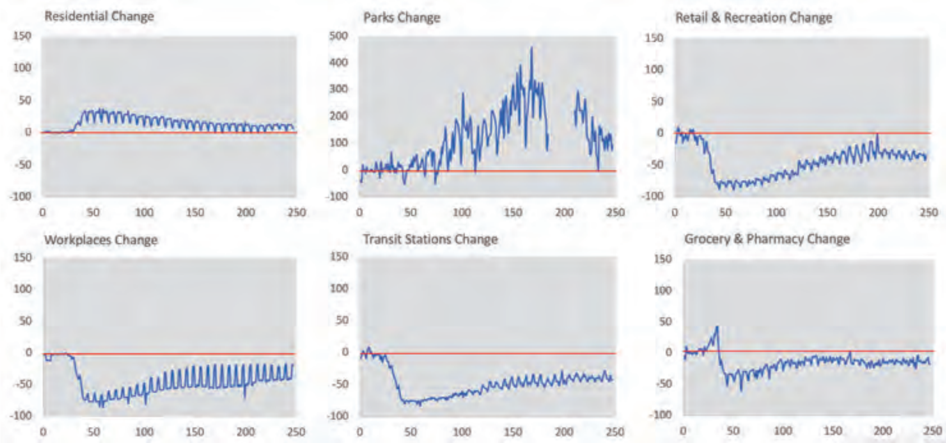

FIGURE 18.9
The Borough of Newham Percentage Changes in Use of Activities from the February Baseline

baseline. This is largely due to the fact that most grocery shopping in the City is by workers from their place of work, not their home and it is interesting that these features are reflected in the data. This is also true of the spikiness of the trajectories which reflect differences between home and work with the distortions posed by working from home, affecting this drop in activity much more on weekdays than is represented on weekend days.

Overall, these trajectories confirm what we know from our casual experience of the Pandemic, but what is interesting is that they do give us some insight into changes in activities even though they only come from one source, Google. We cannot prove that this data is representative but little differences such as the impact of sporting events which show up in the data are likely to show up in similar activity patterns from other mobile operators. Moreover, what is of current interest is in how these patterns will be reflected in another Lockdown. As we have had a series of partial Lockdowns of varying severity in the UK during the last 3 months, it may be possible to trace the impact of these once the full Lockdown becomes active on 05 November. Although this data is useful, it is hard to tie it to independent data sets, and during the Pandemic it is difficult to mount special surveys to examine more conventional flow data, notwithstanding the work that the Office of National Statistics are undertaking.

18.5 Conclusions and Next Steps: A More Integrated Analysis

The most surprising conclusion from the analysis involves the dramatic differences between the regions of the UK with respect to average travel times on different modes of transport, and the minimal differences between average travel times between essential and non-essential workers in each region. To an extent, this may be due to the fact that the way the government has defined essential workers is close to the distribution of non-essential workers and if this is the case, the transport networks and modal split will not make any real difference to the patterns of distribution which essentially are the same for these two groups.

A key issue which is raised by this paper is data. From data prior to the Pandemic, which is the only detailed data we have on flow patterns and locational volumes, it is of little surprise that we cannot generate many new insights into spatial differences that might be exploited in handling the Pandemic. To this end we need much better data on the spatial progression of the Pandemic, and we need to tie the sort of data produced by Google (with equivalent mobility data from IT platforms such as Apple [9] from their map products, and Amazon Web Services, etc.) to more conventional transport data such as traffic counts from sensors, data from smart card ticking systems and so on.

What we need to do now is to regionalise the country into localities and regions that might be highly clustered with respect to similarities (and differences in an alternative analysis) so that we can examine where there are significant differences that might be exploited in countering the Pandemic. In part of the country where people travel more or travel less than the average, this has implications for how we might lockdown certain areas. Currently, many governments in Western Europe are moving towards a total Lockdown to combat the second wave but these kinds of blunt instrument approaches are too crude to effectively exploit the differences in the way the wave of infections is diffusing. In this work, what we urgently need, as in all work on the spatial, is some way of linking the location of the incidence and intensity of the disease to human behaviours pertaining to location and mobility. This is essential and probably requires moving to a much more individual scale where we can tie health data to the location of workers and the population. This will require us to disaggregate our data down to the individual and household level so that we can then associate this with the diseases and susceptibility to disease, before we then aggregate this back up so we can link these attributes to those we have explored in this paper, which focus on how people move and how movement is connected to location.

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19

Americas' Geospatial Response to COVID-19

Rosario Casanova, Paloma Merodio Gómez, Álvaro Monett Hernández and Andrea Ramírez Santiago

In the Americas region, the Regional Committee of the United Nations for Global Geospatial Information Management (UN-GGIM: Americas) in a joint work with the Economic Commission for Latin America and the Caribbean, have been facilitating exchange of good practices and monitoring geospatial tools to respond to the pandemic. This exchange has conveyed an analysis of the different institutional arrangements, data management and technological approaches taken by countries in the region to control the outspread of COVID-19. This chapter provides an overview of the regional geospatial response to COVID-19. We analyze the implementation and use of UNGGIM global frameworks in the geospatial response to COVID-19. Through the regional meetings and consultations carried out in the context of the pandemic, we have been able to verify that countries, to a greater or lesser extent, have knowledge on methods and geospatial tools to face critical situations such as the COVID-19 pandemic. However, some gaps and challenges have also been identified that must be addressed. From a regional perspective, we encourage countries to take full advantage of these guiding frameworks, through a collective and collaborative approach.

19.1 Introduction

In December 2019, a new virus called SARSCoV-2 causing severe acute respiratory syndrome coronavirus disease (COVID-19) emerged in Wuhan, China, and rapidly spread to other parts of the world [1]. March 11, 2020, the World Health Organization (WHO) officially declared the COVID-19 outbreak a pandemic [2]. The disease is characterized by a long incubation period, high infectivity, and difficulty in detection, which has contributed to the rapid outbreak and development of the epidemic [3].

This situation has required that experts in different areas like doctors, disease trackers, modelers, logisticians, and supply chain experts are designing and implementing measures to stop the transmission and spread of the virus. In this way, it is essential for the exchange of information and the development of tools, to deliver data in real time on websites and via messaging networks, identification of locations to establish additional hospitals, quarantine bases and virus testing locations, and effective communication on the situation.

The COVID-19 pandemic is full of unknowns, and many of them have a spatial dimension [3], in this way, GIS has become a vital tool in analyzing and visualizing the spread of COVID-19 [4]. Modern GIS technologies center around web-based tools, improved data sharing and real time information to support critical decision-making, an example of these are online dashboards have been extremely popular to sharing and understanding the spread of COVID-19, since they offer accessible information to people around the world, improves data transparency and helps authorities disseminate information [1]. The most notable example is the online dashboard developed by John Hopkins University Centre for Systems Science and Engineering [5].

In this way, this chapter provides an overview of the regional use of geospatial data and GIS tools to support the response measures and manage the containment of COVID-19, based on the outputs of the Virtual Geospatial Summit, the webinar "COVID-19: Strategies for a Geospatial Response in the Americas" and the regional questionnaire on geospatial support to COVID-19 in the Americas. Furthermore, we analyze the role and implementation of UNGGIM global frameworks in the geospatial response to COVID-19.

Available Global Frameworks to Support the Geospatial Response to COVID-19

The geospatial response to COVID-19 at country level can be supported by sound global guidelines provided by the United Nations Committee of Experts on Global Geospatial Information Management (UNGGIM [6]). This committee has the objective to make joint decisions and establish directions on the use of geospatial information within national and global policy frameworks.

In this chapter, we will show how the geospatial response to COVID-19 -being conducted by member states is transiting to the alignment with these frameworks and how these frameworks can help so that .an improved geospatial response to this emergency and others that may occur in the future is sustainable.

The first one is the Integrated Geospatial Information Framework (IGIF [7]) that provides a guide for developing, integrating, strengthening, and maximizing geospatial information management and related resources in all countries [8]. The IGIF has been proven to be integrative and of practical implementation. Any of the nine IGIF strategic pathways have been implemented by member countries in the Americas, by establishing institutional arrangements and governance agreements, referencing policies to protect privacy and confidentiality of data, promoting partnerships between stakeholders from different sectors (public, private, and academy), leveraging innovation to deliver better technological platforms, and creating communication tools to reach the wide spectrum of users that need this geospatial resources for different purposes.

The second framework endorsed by UNGGIM and the Statistical commission of the United Nations Statistics Division that has proven to be usefully implemented to monitor COVID-19 is the Global Statistical and Geospatial Framework (GSGF [9]) which enables a range of data to be integrated from both statistical and geospatial communities and, through the application of its five Principles and supporting key elements, permits the production of harmonized and standardized geospatially enabled statistical data. The resulting data can then be integrated with statistical, geospatial, and other information to inform and facilitate data-driven and evidence-based decision making. The integration of statistics and geospatial has been vital in this pandemic. Sociodemographic variables such as age, health status, have been analyzed even at block level to detect vulnerable populations.

And the third one is the Strategic Framework on Geospatial Information and Services for Disasters [10], elaborated by the UN-GGIM Working Group on this topic, which aims to bring all stakeholders and partners involved in Disaster Risk Reduction and/or Emergency Management together to ensure that quality geospatial information and services are available and accessible in a timely and coordinated way to support decision-making and operations within and across all sectors and phases of disaster risk management. The strategic framework draws from the principles included in the Sendai Framework for Disaster Risk Reduction [11]; the UN General Assembly resolution on international cooperation on humanitarian assistance in the field of natural disasters, from relief to development; the 2030 Agenda for Sustainable Development; and the UN-GGIM Global Statistical Geospatial Framework [9].

19.2 Overview On the Regional Geospatial Response to COVID-19

As reported in the abstract of this article in a joint effort between the United Nations Regional Committee for Global Geospatial Information Management (UN-GGIM: Americas) and the Economic Commission for Latin America and the Caribbean (ECLAC [12] with the support of the Secretariat of UN-GGIM at a global level, two regional webinars and a regional consultation on regarding geospatial response to COVID-19 were conducted, in order to collect information and share experiences and knowledge from different approaches ranging from institutional to technological.

In order for geospatial data users and providers across governments, the private sector, academia, students and the general public could know and shared how the global community of geospatial scientists have been leveraging geospatial, Earth Observation and statistical data, creating innovative tools to support response measures and manage the containment of COVID-19, was made the Virtual Geospatial Summit 2020 under the theme "GIS Response to COVID-19", in which they showed some of the geospatial tools that have been developed in different countries including the Americas region, as well as the good practices that have been implemented, including the challenges in collecting geospatial health data.

The seminar COVID-19: Strategies for a Geospatial Response in the Americas was held on May 15, 2020, facilitated by UN-ECLAC and UN-GGIM: Americas. Through this activity an enriched exchange of experiences in Member States on how they have met the challenge of COVID-19 was conducted, reviewing progresses, and identifying the challenges being faced. Demonstrations on developing national dashboards and tools were also shared, highlighting data needs and available resources. The seminar helped the discussion on how to optimize resources to respond in the short and medium-term impact of COVID-19, while preparing for the long-term implications of public health and safety crises or emergencies.

The regional consultation was carried out by UN-GGIM: Americas and ECLAC to promote dissemination actions and exchange of practices and experiences around the use of geospatial information, to support the management of the COVID-19 pandemic.

In this consultation, information was collected from national geospatial data infrastructures or from national cartographic agencies in collaboration with other public bodies. Information regarding data integration, development of indicators and implementation of platforms, among others was reported. The identified use cases and good practices were disseminated on the UN-GGIM: Americas website [13], and on the COVID-19 Observatory [14] in Latin America and the Caribbean.

Overview On the Regional Geospatial Support

The following section presents the response approach, from different countries in the region, regarding institutional aspects and the use of geospatial data.

Governance and Institutions

A central component of geospatial support for disaster management is governance. This is established by the UN-GGIM Strategic Framework on Geospatial Information and Services for Disasters, assigning institutional agreements, collaboration, and coordination a fundamental role. In this context, through this consultation it was possible to identify various forms of governance and participation in the countries that responded to the regional consultation, basically through the formation of multisectoral work teams to support decision-makers and the entities in charge of disaster management.

In order to articulate national organizations and to make geospatial information available for decision-making, several countries have activated protocols to support to the entities in charge of disaster management, like the National Emergency Response System in Jamaica, the Emergency Operations Center in Sint Maarten or the National Risk Management System in Honduras. These protocols organize the collection of spatial information, the integration of statistical and geospatial data and the way in which this information is processed to help the decision making.

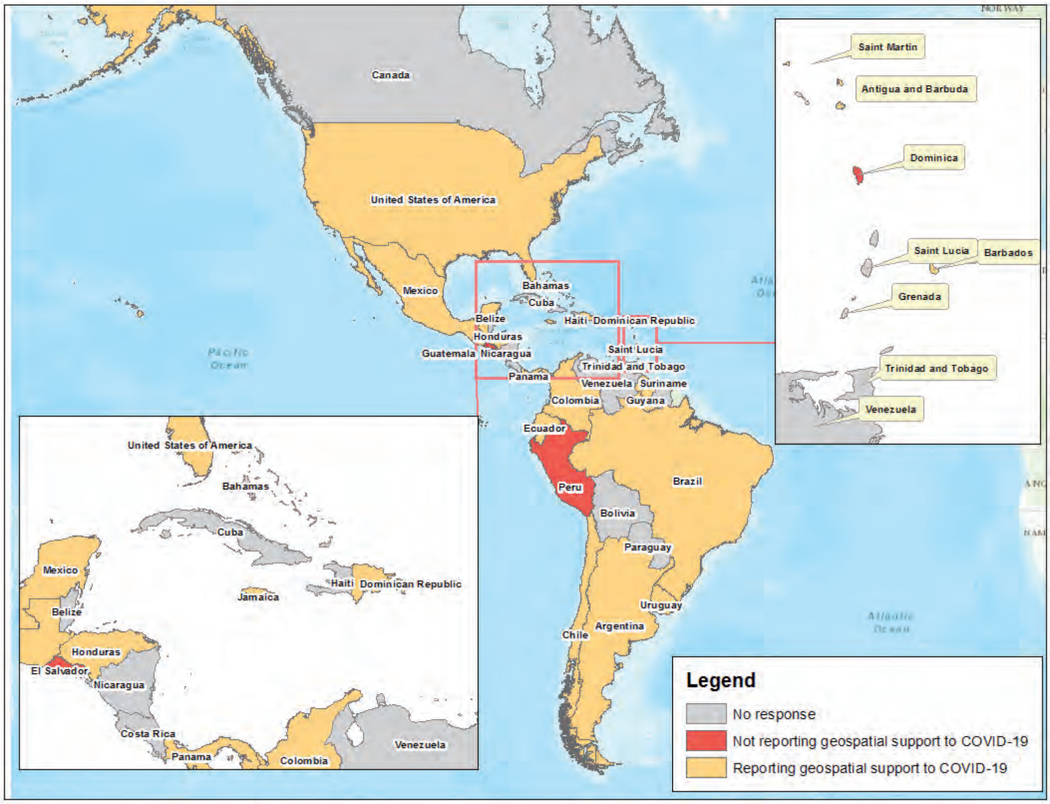

FIGURE 19.1
Map representing the geospatial response to COVID-19 of Americas countries. Source: Regional consultation carried out by UN-GGIM: Americas-ECLAC Regional consultation, 2020.

Other frequent institutional arrangement observed in the region is the creation of special working committees and/or groups to assist the national geospatial response to the pandemic. This allows to collect information from various sources, keep the inter-institutional communication permanently opened and generate added value products helping to implement logistical actions and carry out territorial analysis regarding the advance of the pandemic. These working groups in some cases also examine political issues affecting employee activities, travel, and public events, among others.

In this regional overview, the institutions that most frequently participate in geospatial support are the ministries and institutes of statistics and geography of each country. An example of the above is Mexico, where statistical data on COVID-19 is provided by the Ministry of Health, and then these are processed by the National Institute of Statistics and Geography (INEGI), to be displayed on platforms for presentation to the public; Chile follows a similar process, but in this case it is through the country's Spatial Data Infrastructure (IDE-Chile) that collects and disseminates the information provided by the different associated Ministries or Institutions.

Following the foregoing, in many countries emergency systems or institutions are the first access route in geospatial support, an example of this is Uruguay, where the National Emergency System (SINAE) is the body in charge of being in contact with all institutions from which you can receive information; In Antigua and Barbuda, the National Disaster Office (NODS) performs a similar function, coordinating the collaboration of geospatial information from different Ministries or offices such as the statistical office. Also, national / civil defense institutions are organizations that have been mentioned as organizations that deliver information to the coordinating entity, as is the case of Guyana, Barbados, the Dominican Republic and Jamaica. Finally, to a lesser extent, agencies, private entities, or foundations are independent organizations that have valuable information useful for the country, for which they work collaboratively. This is the case of Brazil, where data provided by the Oswaldo Cruz Foundation is disseminated; or in the Dominican Republic, where support is obtained from private geomatic companies.

The integration of statistical and geospatial information has been made explicit through the examples mentioned above, where countries are using geocoded health and population data referenced to a specific location and the information is being displayed in geospatial dashboards. This use of fundamental geospatial infrastructure and geocoding in a data management environment, using common geographies for the dissemination of statistics in an accessible and usable platform is the core of the five principals of the GSGF [15].

Data and Technology

From the collected information through the different activities and consultations carried out in the region, it was possible to realize that the most frequent technological resources being utilized to disseminate COVID-19 statistics, are geospatial dashboards. Secondly, interactive websites with maps, charts and dynamic statistics. Most countries are using GIS to disseminate statistics related to confirmed cases, active cases, recovered cases, and deaths, at different levels of disaggregation, such as political-administrative divisions, gender, or age groups. A first group of countries report that they are using GIS to prepare distribution maps, networks and flows of people to access health services, or other services that offer basic goods. Others have informed to be carrying out spatial analysis of vulnerable groups, such as the elderly, the chronically ill or areas of high population density. There are also cases of mapping households with confirmed cases, quarantined areas and isolation centers, as well as constant monitoring of confirmed and suspected cases.

In the case of the regional consultation, it was informed that, from a total of 20 countries that answered the questionnaire, fifty percent declared that they had public access platforms for the dissemination of data regarding COVID-19. In general terms, the information is disaggregated to the second or third hierarchical level of the political-administrative division and the topics represented are diverse: confirmed cases, examinations, intensive care patients and deceased patients, vulnerable population disaggregated by age ranges, information on employability, poverty and population at risk, tests carried out and results, among others.

Regarding some specific country examples in the use of national platforms and dashboards, the National Institute of Statistics and Geography of Mexico developed a geoportal called “Analytical Visualizer for COVID-19”, which allows information on COVID-19 how number of confirmed, negative, suspected cases and deaths to be seen at the municipal and state levels. Information that is aligned to the information issued by the Ministry of Health.

In addition to this information, the displayed integrates information of others 8 themes: population, ethnicity educational characteristics, economic characteristics, health services, households, hospital infrastructure and deaths due to various registered conditions 2018. Each one of the topics has its corresponding indicators for a total of 28, some of the indicators that can be viewed are density (inhabitants per square kilometer), total population, population over 60 years of age, population affiliated with health services, average number of occupants per dwelling, dwellings that do not have piped water and risk diseases.

Other interesting experience is that conducted collaboratively between the National Planning Department, the Institute of Technological Evaluation in Health and the National Administrative Department of Statistics (DANE) of Colombia, which collaborated with the Ministry of Health and Social Protection and the National Institute of Health to provide statistical information and build tools[1] that facilitate senior government to make decisions with greater certainty for emergency response caused by COVID-19.

In this case, the demographic characteristics of the population and their conditions of health helped to determine who may have more complications in case of getting COVID-19. This, by taking into account, among others considerations, the identified epidemiological criteria, based on information from the 2018 National Census of Population and Housing, administrative records of the National Identification File, the Civil Birth Registry, the National Registry of Marital Status, the Unique Database of Health Affiliation and the individual records of provision of Health services.

[1] Reference: http://visor01.dane.gov.co/visor-vulnerabilidad/

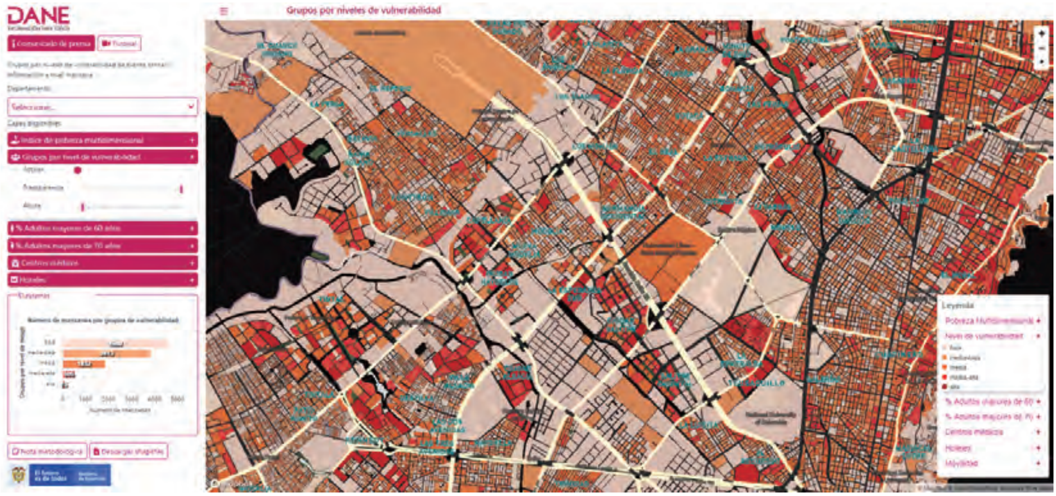

FIGURE 19.2
Viewer of vulnerability levels in Colombia Source: National Administrative Department of Statistics of the Republic of Colombia, 2020.

In the Caribbean subregion, it can be mentioned the work carried out by the GIS unit of the Survey and Mapping Division, which has been providing geospatial support to the National Emergency Operation Center, mainly through the development of GIS solutions and data gathering. This work has been conducted in coordination and collaboration with the National Office of Disaster Services, the Ministry of Health, Wellness and the Environment, the Central Board of Health and the Statistics Division. As a result, a geospatial hub is in the public domain to disseminate data on the timeline of cases and basic associated information, primarily focused on the local level, but complemented by a section regarding regional response efforts. Internally, a monitoring dashboard is still being setup to effectively manage the operations and coordination between all stakeholders.

In Central America, the National Geographic Institute Tommy Guardia (IGNTG) of Panamá formed a work team to support with cartographic information and mapping, two relevant government initiatives to confront COVID-19. The first on is the plan "Protégete Panamá" led by the Ministry of Health in collaboration with the Social Security Fund, WHO experts, and national and international Health experts. The second one is the "Solidarity Plan", in charge of the Economic Advisory Council led by the Ministry of the Presidency and integrated by several institutions. Both programs seek to mitigate the impact of the pandemic and guarantee that Panamanians affected by the health crisis can obtain essential products.

The IGNTG, leading the Panamanian Spatial Data Infrastructure, has facilitated data cooperation to integrate information from different sources, for example, on educational centers location (provided by the Ministry of Education) and a wide range of statistical data made available by the Institute of Statistics and Censuses, which has been combined with other geospatial information.

The committee prepared a special map of the republic with presidential indications for the Solidarity Plan for food delivery logistics and solidarity bonds to affected families: Route maps for garbage collection; Maps to assist aid distribution and logistics for municipalities; Statistical information to generate information layers of housing areas for people over 60 years, beds by province, chronic diseases, location of health centers and hospitals; Maps for aircraft landing areas and secondary collection centers.

19.3 Gaps and Challenges

The outcomes from the regional consultation show that countries have been able to capitalize the power of geospatial tool to respond to COVID-19. Nevertheless, challenges persist in the region and further work needs to be done in order to have an integrated geospatial response and to be prepared for future disasters.

- The most urgent gap detected by the regional encounters and consultations is related to data accessibility. To respond geospatially to the pandemic countries have faced challenges in: accessing updated real time data; lack of access to quality data and satellite images; unavailability of disaggregated fundamental data at different levels (political-administrative divisions, sex, age, etc.). Moreover the low interoperability between statistical and geospatial data, the absence of regulation regarding the use of information, and the need to create a national address systems are the most frequent challenges among the countries that responded the questionnaire conducted by ECLAC/UN: GGIM-Americas.

- Farther, there is an urgent need to improve the GIS technical capacities of current personnel. Some of the weaknesses, that have been exposed in this pandemic, refer to the lack of technical and professional resources available to make appropriate use of geospatial data, as well as lack of knowledge about the accessibility to free geographic data and applications.

- Raising awareness of authorities regarding the importance of GIS can promote its effectiveness in capturing, analyzing and disseminating spatial information. Countries recognize the challenge to support software financing and human resources. Finally, it is important to have an appropriate Spatial Data Infrastructure (SDI) that allows them to collect data from the different institutions, to have a cadaster and organize national information.

On the other hand, two major advancements identified in the regional consultation are related to dissemination geospatial tools and partnerships.

- The urgent need to access high quality data has been enabled through geospatial dissemination tools. The public visibility of geographic data, gained during this pandemic, has made geographic information take on unexpected relevance. Fact that opens some opportunities and challenges for the geomatic community. Moments in which the relevance of geographic data, as a tool for processing and making analysis, is an unquestionable fact open opportunity to promote and raise awareness of the importance of having upgraded and good data quality of the information. Data that should be accessible at the national level and acquired with the specific needs of each country. An aspect that should be included, in the current agenda, refers to the use of geospatial information in support of the new "normality", in which sustained physical distance is the only way to minimize the effects of the pandemic. Now it is time to move from response to recovery and reopening. Once, commercial life, educational centers, recreational spaces, etc. have been reestablished, the relative distance between the inhabitants begins to take on a leading role in the new way of life. And it that place is where geomatic tools have a lot to contribute.

- The wealth of professional exchanges carried out in these times has been one of the most outstanding aspects of this pandemic. As stated in the ninth pathway of the IGIF, cross-sector and interdisciplinary cooperation, coordination and collaboration with all levels of government, the geospatial industry, private sector, academia, and the international community is a premise to developing and sustaining an enduring response to disasters [8]. The collaboration and partnership generated by various professionals, from different countries, has resulted in the use of good practices that have no frontiers and are being applied in different parts of the continent. As geospatial professionals, practitioners and stakeholders strategic actions reinforcing the power of collaboration and true humanity.

19.4 Conclusions

In the previous sections, valuable experiences in the use of geospatial information to support the response to COVID-19 in countries of the region have been described,. Various institutional arrangements to coordinate the actions of the different national actors, to establish the links between geospatial agencies, ministries of health, and other relevant actors, with the offices in charge of emergency management. We also provided an overview of methodologies for the integration and analysis of geospatial data and its dissemination through accessible platforms for decision-makers and citizens.

Through the regional meetings and consultations carried out in the context of the pandemic, we have been able to verify that the countries, to a greater or lesser extent, have knowledge on methods and geospatial tools to face critical situations such as the COVID-19 pandemic. However, some gaps and challenges have also been identified that must be addressed, regarding to interoperability, data access policies, higher levels of disaggregation, capacity building, increased awareness at the level of authorities and availability of greater financing, among other.

Considering the above, in the region of the Americas there are strengths which support future crises of this or another nature. We also have weaknesses and challenges that open the way to strengthen our geospatial response. The crucial question then is, what should we do to capitalize our strengths, address gaps and achieve a comprehensive and sustainable geospatial response over time?

From UN-GGIM: Americas and ECLAC, we recognize a great opportunity in the new guidelines delivered by the working agenda of the UN-GGIM Initiative, and the need to bring down global frameworks in the countries of the region. These frameworks would make it possible to take advantage of and strengthen the response that we have today, provide cross-cutting work elements to the countries' management in geospatial matters, and prepare roadmaps with concrete actions to cover the existing gaps.

The Integrated Geospatial Information Framework (IGIF) and the Implementation Guide for its nine strategic pathways -governance and institutions, legal and policy issues, financing, geospatial data, innovation, standards, partnerships, education/capacity building, and communication-exhaustively and didactically provides a vision of what actions can be carried out to strengthen geospatial information management.

In particular, the Implementation Guide provides valuable guidance to address the five priorities of action of the Strategic Framework on Geospatial Information and Services for Disasters, which are connected and aligned with the IGIF's strategic pathways. For example, for the Disaster Framework Governance action priority, the IGIF explains how to establish working groups, define strategies, develop action plans, and monitor their progress, among other.

The same applies to other priorities of action such as data management, where the IGIF implementation guide suggests on the application of inventories (in this case to support disasters management), the development of geospatial data profiles, the analysis of gaps, the formulation of roadmaps for thematic data, and the generation of guidelines for the maintenance and custody of data, among others.

On the other hand, the Global Statistical Geospatial Framework (GSGF) provides tools for the territorial disaggregation of data, a fundamental requirement to have accurate diagnoses and to effectively guide the activation of alerts and decision-making for the management and recovery of this health, social and economic crisis. The GSGF highlights the importance of geocoding processes and the fundamental geospatial dataset that support it, for example, geo-referenced postal addresses, buildings, cadastral parcels, and other highly granular data.

From the regional level, we encourage countries to take full advantage of these guiding frameworks, through a collective and collaborative review among all public, private and academic actors, and then put them into operation on the basis of institutional agreements, intersectoral alliances, capacity building plans, and sustainable communication mechanisms over time.

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20

Spatio-Temporal Information Management to Control the COVID-19 Epidemic: Country Perspectives in Europe

Marije Louwsma and Hartmut Müller

The COVID-19 pandemic puts a heavy burden on populations, health care systems and governments alike. Europe has been one of the first epicenters of the pandemic, with a huge number of reported cases and fatalities. National governments in Europe applied a range of measures to mitigate the impact of the outbreak. Infectious diseases such as COVID-19 spread from person to person and thus in space and time. Local outbreaks occur frequently and different spatial distribution patterns can be observed. Therefore, policy makers and health care services have to respond to regional dynamics of new infections on a local basis. Theis chapter illustrates the state-of-the-art of providing COVID-19 information using selected EU countries as examples. From a supranational perspective, it can be stated that the most up-to-date data at national and sub-national level can be found in national dashboards, at the most detailed NUTS 3 level or even more detailed. The integrated view and analysis of COVID-19 data from different sources reveals a wide variety of difficulties, such as timeliness of reporting, ambiguous definitions of cases and fatalities, to name a few. In Europe, the potential of an integrated system is not yet fully exploited due to the obstacles identified. It remains to be seen to what extent and when this situation will improve in the future.

20.1 Introduction

After having recently published a Global Influenza Strategy 2019-2020 [1], on 11 March 2020, the World Health Organization WHO 'made the assessment that COVID-19 can be characterized as a pandemic' [2]. On 13 March 2020 WHO stated that 'Europe has now become the epicenter of the pandemic, with more reported cases and deaths than the rest of the world combined, apart from China'. On 19 March 2020 UN Secretary-General stated that 'the coronavirus pandemic is a crisis unlike any in the UN's 75-years history'. Apart from the people that contracted the disease, the epidemic put a heavy burden on health care and governments the like. Early detection, laboratory testing, isolation, contact tracing and referral of patients had to be managed. Furthermore, the demands of responding directly to COVID-19 while maintaining essential health service delivery had to be balanced.

20.2 Spatiotemporal Spread of Infectious Diseases

Infectious diseases spread from person to person and thus by their very nature in space and time. Depending on the characteristics of the disease, different spatial distribution patterns can be observed [3]. Since COVID-19 was not known before the start of the outbreak, little information was available about the circumstances that influence contamination and consequently the spatial distribution by infected people. The limited amount of information available from the first epicentres in China had to be used as the best assumption. From a global perspective, the influence of long-range airline traffic which shapes the spatiotemporal pattern of a global epidemic by forcing infections due to multiscale processes in the disease dynamics [4] is also of particular interest [5]. Experience with COVID-19 in China [6] suggests that in many cases the disease spreads under particular circumstances related to specific local environments. This results in spatially very heterogeneous distribution patterns in larger geographical areas.

To assess the impact of COVID-19 the British Health Foundation has compared the nationwide excess mortality rates in several European countries to the excess mortality rates in the COVID-19 hotspots of these countries [7, 8]. The parameter excess mortality was chosen because the number of registered deaths in all countries can be considered as one of the most reliable statistics, which is for various reasons regarded more reliable than the figures related to the dissemination of the disease itself. Many countries do have a longstanding registration system for census data, contrary to the registration of COVID-19 patients and related casualties. There is no risk of misrepresentation due to different definitions used, as is the case with the number of deaths registered with COVID-19 as the cause of death (see discussion below).

Spatiotemporal heterogeneous distributions of disease cases demand for analyses with special consideration of the spatiality of the underlying phenomena. The national figures might not be representative for the local and regional situation, due to uneven spreading of the disease. A first step to analyze the geographical distribution of the disease is to visualize diagnosed cases on maps. Meanwhile, distribution maps as a medium of COVID-19 representation can be found all over the world in a mass of official publications, newspapers, on social media platforms, in dashboards etc. A list of resources can be found at the website of the Open Geospatial Consortium [9].

Data visualization of territories, mostly at country level, through mapping, dashboards and other techniques, is a valuable tool to present the characteristics of spatiotemporal phenomena. Geospatial analysis of the underlying geospatial data can do much more. Trends in outbreaks over time and space, hotspots of infection, applicable rules and regulations, and available resources for medical treatment can be identified and disseminated to a wider public. In times of a pandemic such as COVID-19 a global view is needed to take appropriate action at all governance levels; global, supranational, national, and local.

In health context, individual humans represent the basic unit of spatial analysis. However, publicly available data are regularly being aggregated to a sufficient extent to adhere to privacy standards and regulations to protect individuals in their right for privacy [10].

An integrated statistical and geospatial framework [11] can be used as an excellent basis for managing such aggregated health data. Once a harmonized framework of spatially referenced territorial units is given, health data can be aggregated to the predefined territorial units and be used for presentation and further spatiotemporal analysis. In fact, many national health authorities already take advantage from these possibilities by providing national COVID-19 data within their national framework used for managing statistical national data. The following section will start by describing the reference system NUTS (Nomenclature des Unités Territoriales Statistiques) used for managing statistical information in Europe. After that, a number of use cases presenting COVID-19 related epidemic data by using the NUTS system will be briefly discussed.

20.3 NUTS (Nomenclature Des Unités Territoriales Statistiques), the European Union's Spatial Reference for Statistical Data

The Nomenclature of Territorial Units for Statistics (NUTS) provides a breakdown of the economic territory of the European Union into territorial units. It has been used in EU legislation since 1988, and it was converted to a formal Regulation of the European Parliament and the Council in 2003 [12]. While the national level of Member States is above NUTS, the NUTS classification consists of three hierarchical levels: each Member State is divided into NUTS 1 regions, then divided further into NUTS 2 regions, which in turn are subdivided into NUTS 3 regions. The NUTS regions regularly coincide with existing administrative units within the Member States, because the statistical data of the Member States are available for these units. A legislative procedure is in force to renew the classification, following changes in the Member States' administrative units. At EU level, the NUTS serves as a reference for the collection, development and harmonization of the European Union's regional statistics, for socio-economic analyses of the regions, and for the framing of EU regional policies.

The current NUTS nomenclature subdivides the territory of the European Union into 104 regions at NUTS 1 level, 281 regions at NUTS 2 level and 1,348 regions at NUTS 3 level. The NUTS Regulation defines the population size as a key indicator for comparability, laying down minimum and maximum thresholds for the population (Table 20.1).

TABLE 20.1
Population Size of the European Union's Administrative Units (Source: [12])

Level	Min. number of inhabitants	Max. number of inhabitants
NUTS 1	3 million	7 million
NUTS 2	800.000	3 million
NUTS 3	150.000	800.000

Following the heterogeneous population density across the EU territory this definition results in a wide span of both area size and population number: the largest NUTS 1 region is Manner-Suomi (Finland), covering 336,859 km^2, the smallest region, Région de Bruxelles-Capitale (Belgium) covers 161 km^2. At NUTS 2 level, Pohjois-ja ltä-Suomi (Finland) covers 227,150 km^2, Ciudad Autónoma de Melilla (Spain) 13 km^2, at NUTS 3 level the figures are Norrbottens län (Sweden), 105,205 km^2 and again Ciudad Autónoma de Melilla (Spain), 13 km^2.

20.4 COVID-19 Pandemic Data Using the NUTS System

20.4.1 EU Level

Eurostat, the statistical office of the European Union situated in Luxembourg, concentrates on providing relevant statistics to tackle the implications of the Covid-19 outbreak. Eurostat maintains an interactive dashboard regarding Covid-19 developments within Europe, based on the data provided by its member states (Figure 20.1).

Note: The map in Figure 20.1 is based on information provided to ECDC by the EU/EEA Member States and UK on their subnational levels of COVID-19 transmission (NUTS 2 regions) according to the categories defined by the World Health Organization. When no information has been provided by the countries on the level of COVID-19 transmission, the region is marked as 'not reported'.

The European Union is a union of sovereign states. The EU design gives the maximum respect for the sovereignty of its member states. At the same time, it ensures that the system is operational

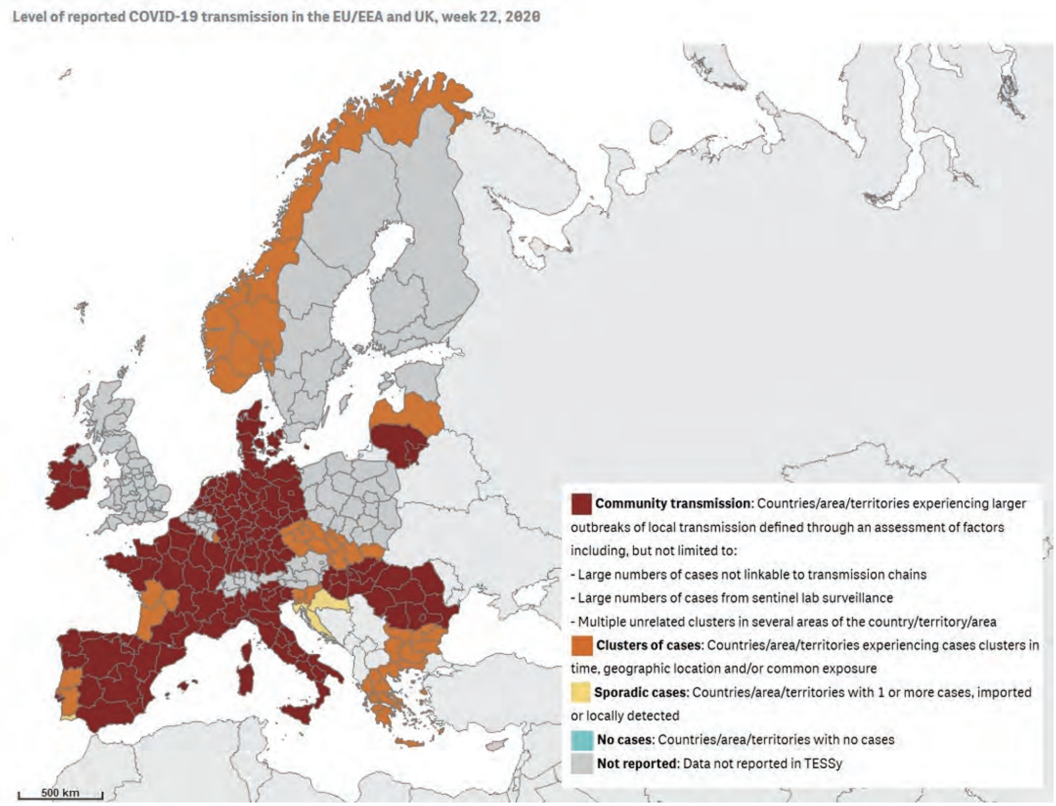

FIGURE 20.1
Country Level Information on COVID-19 in Europe (Source: [13])

and decisions can be taken. The role of EU institutions has evolved over time, but national institutions also continue to play key roles by performing their traditional functions at the national level. This fact became very evident again in the initial phase of the COVID-19 outbreak, when political decisions were predominantly taken by the national member governments. From a certain level, this also applies to the provision of information, including geospatial health information. In the following sections, this will be illustrated using selected EU countries as examples.

20.4.2 National and Sub-National Level

Providing up to date information about the distribution of the virus and prevailing measures is key to make informed decisions on the one hand and on the other hand to inform citizens and organisations to comply with the policy within a country (awareness raising or sensitization). Most up-to-date data at sub-national level, either at NUTS 3 level or even more detailed, can be found in national dashboards. Some use cases will be presented here.

20.4.2.1 France

The French government has published a dashboard on the internet that presents COVID-19 related information geographically. It is possible to retrieve the information on a particular date. Hence it is possible to consult the course of the disease geographically. Various information is included: the current level of precautionary measures based on the number of detected cases (Figure 20.2), the transfer of patients within France and Europe, test sampling locations and their status and the test results per administrative unit.

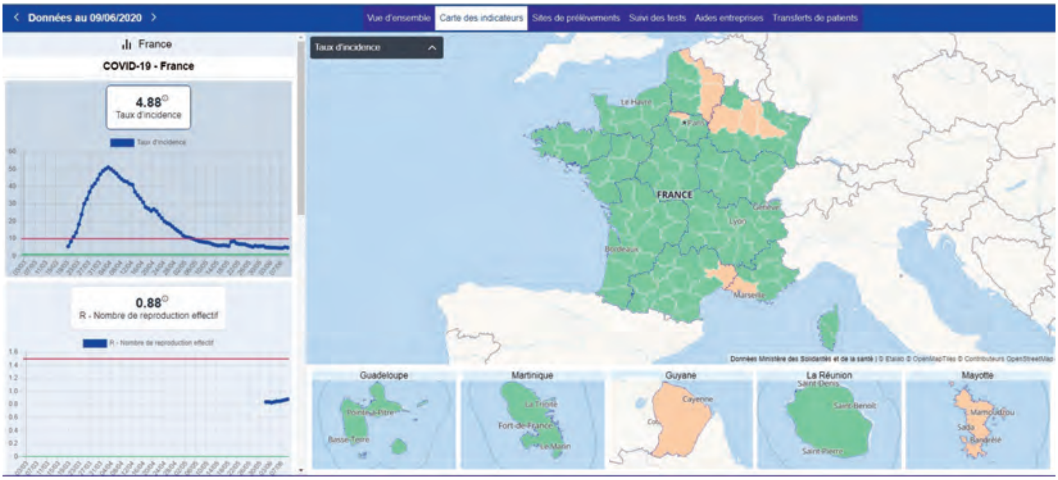

FIGURE 20.2
Vigilance Map for France on 9 June 2020 (Source: [14])

20.4.2.2 The Netherlands

After the crisis team became operable, the national insitute for public health and the environment (RIVM), operating under the Ministry of Health, Welfare and Sport, became responsible for dissemination of Covid-19 related data and figures. The government in the Netherlands chose to publish most Covid-19 related information in traditional graphs instead of mapping it. Only the relative number of Covid-19 cases and hospitalized people per 100,000 inhabitants per municipality were visualized geographically. Compared to absolute numbers, this relative number allows to compare between municipalities with varying population densities. The media mapped the confirmed hospitalized patients over time at municipality level to show the spreading of the disease of the country over time [15]. Here, one can see that the disease was spread across the country from the south to the west and north due to various events, e.g. spring holiday and carnival, and movements of people between the regions. The three most norther provinces were hardly affected, most likely due to their remote character relative to the location of the big cities in the west and south.

20.4.2.3 Germany

At March 2020, Germany had introduced consistent measures to combat COVID-19 that were implemented nationwide. Over time, it became clear that the spread of infection is mainly concentrated in local hotspots, without it being possible to predict such locations precisely. Therefore, on 6 May 2020 policy makers agreed to respond to regional dynamics of new infections on a local basis, using the NUTS 3 level administrative units as the spatial reference. It was decided that in districts or urban municipalities, the German NUTS 3 level units, with a cumulative rate of more than 50 new cases of infection per 100,000 inhabitants within the previous seven days, restrictions adapted to the local situation will immediately be implemented. A cumulative rate of more than 35 new cases of infection per 100,000 inhabitants within the previous seven days was set as threshold for early warning [16].

Figure 20.3 shows the temporal dynamics of infections over time including the numbers as of 12 June 2020, with one NUTS 3 unit surpassing the intervention threshold of 50 infections per 100,000 inhabitants within the previous seven days (LK Aichach-Friedberg, 59 cases), and five units reaching the early warning limit of 35 infections per 100,000 inhabitants within the previous seven days (LK Cuxhaven 44 cases, SK Bremerhaven 41 cases, LK Sonneburg 41 cases, LK Göttingen 37 cases, LK Coburg 35 cases).

The Robert-Koch-Institute, Germany's public health institute, collects data on, among others, 12 Dynamics of infections.png

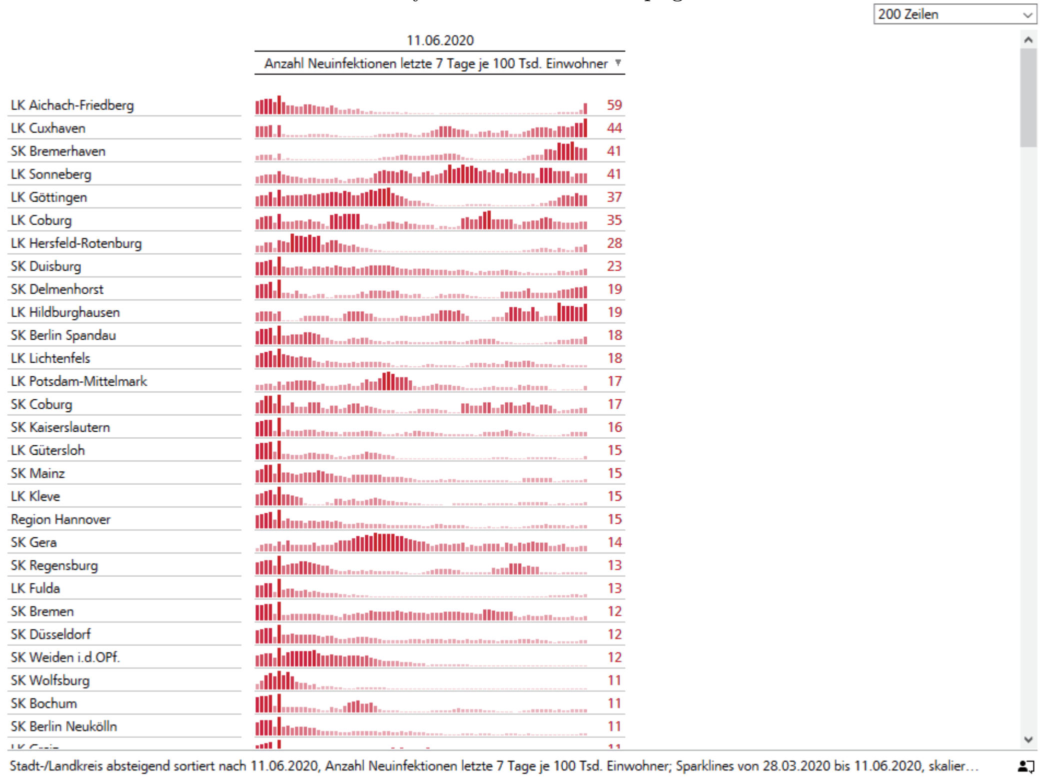

FIGURE 20.3
Dynamics of Infections per 100,000 Inhabitants in Germany at the Nuts 3 Level (Source: [17])

infectious diseases; it communicates information by a COVID-19 specific dashboard and offers the underlying data to the general public on a daily updated basis. The data can be downloaded in different formats. Retrieving the data via an ESRI ArcGIS Feature Service is a very versatile way to get direct access to the attributes and geometries of the layers. Geospatial data retrieved via a Web Feature Server make it possible to use the complete set of GIS tools for comprehensive spatiotemporal analyses. For example, the period of time and further spread of local outbreaks can be tracked. At the same time, using such spatially aggregated data preserves data protection and data privacy.

A major event illustrating the benefits of locally adapted measures occurred in June 2020, when a COVID-19 outbreak was detected at a German meat processing plant in the week ending 21 June 2020 [18]. The outbreak near Gütersloh (see Figure 20.4, prism in red) was first reported on Wednesday 17 June, when 400 workers tested positive. By Friday 19 June, that number had doubled to 803 and it climbed further to 1,331 by Sunday 21 June. The number of confirmed infections for the corresponding NUTS 3 unit LK Gütersloh rose to 264 per 100,000 inhabitants within one week, thus far exceeding the intervention threshold of 50 infections. Seven days high incidences in neighbouring districts are linked to the outbreak in Gütersloh [19]. The now localised lockdown strategy permitted the local authorities to limit the quarantine order to the 5,500 employees of the plant and their families, rather than imposing a broad lockdown affecting the social and economic lives of many millions of people in the whole country.

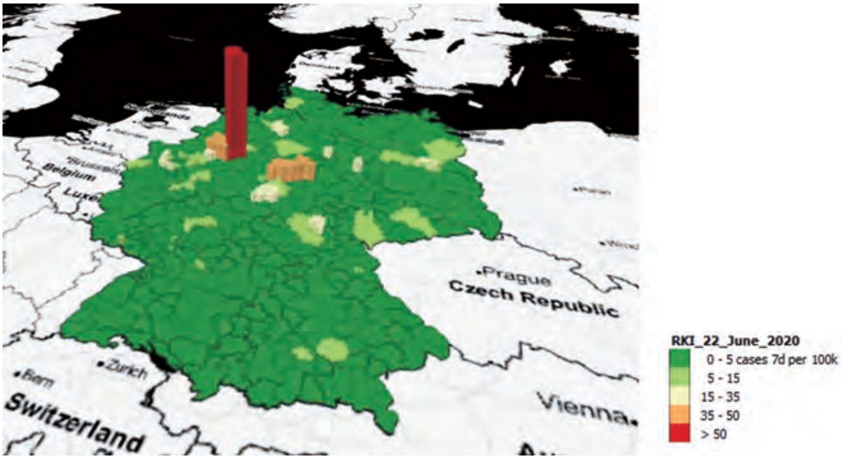

FIGURE 20.4
Visualization at Nuts 3 Level of a Major Local COVID-19 Outbreak in Germany, June 2020. Source: Own Representation, Data Based on Robert Koch-Institut (Rki), DL-de/by-2-0, Map Tiles by Stamen Design, Under CC by 3.0. Data by Openstreetmap, Under CC by SA

20.5 Shortcuts and Challenges of COVID-19 Data Provision

Data problems in providing COVID-19 data are manifold. The Washington Post expresses the facts in this perfect, concise statement: 'Case counts are consistently inconsistent. Reporting practices differ from country to country, state to state, even county to county' [20].

The Johns Hopkins University, Baltimore, Maryland, USA, maintains a coronavirus resource center [21], a globally intensively used resource for better understanding of and information about the virus. The researchers of Johns Hopkins University are doing very valuable work by collecting data and, at the same time, by managing a list of open issues [22]. At the time of writing this article, the list consists of 1,344 open issues, with 899 issues already closed. A comprehensive review of the existing data problems is beyond the scope of this article. For illustration purposes, however, some relevant exemplary problems shall be addressed briefly.

1. The Quest for Reliable Data
   The number of confirmed cases depends largely on the number of conducted diagnostic tests: the more laboratory tests are conducted, the more positive cases are discovered. A lack of test material or testing capacity hampered some countries to produce reliable data regarding the number of positive tested persons. As an alternative other data were used to monitor the progress of the disease, such as the number of hospitalized people.

2. The Timeliness of Reporting
   There is no obvious reason why both the number of confirmed cases of disease and the number of disease-induced deaths should be lower on weekends than on working days. However, this is exactly what most country statistics display. It seems to be much more likely that a smaller number of cases are registered at weekends because fewer diagnostic tests are conducted at weekends, or because there are delays in reporting due to staff at health offices not being on the job, or for other reasons. The timeliness of the data therefore fluctuates without this being precisely documented in many cases.

3. The Need for Unambiguous Definitions
   Differences in the definition of diagnosed and reported cases, even changes in the definition occur. For illustration purposes, some application cases shall be mentioned.

China reported 15,132 new cases for a single day, February 12 2020. The reason for this spike was a change in how cases are diagnosed and reported in Hubei province starting on the same day. In the Hubei province only, medical professionals can classify a suspected case of COVID-19 as a clinically confirmed case, without having to have a laboratory confirmation. Of the 15,132 new cases reported, only 1,820 were new laboratory confirmed cases, all others were due to the changed counting method of the cases [23].

In a similar way the U.S. moved from counting only laboratory confirmed cases to counting 'confirmed and probable cases and deaths' [24].

In early April, France reported 17,827 additional cases and 532 plus 884 additional deaths from nursing homes, that had not previously been included in the official counts. Similarly, the daily figures for COVID-19 deaths in one country might, for example, only include those dying in hospitals, while other countries include deaths in nursing homes in their figures [23].

20.6 Discussion

Due to the epidemic character and unfamiliarity with the disease, no standardized methodology to collect data was available. This makes it difficult to compare between countries and to provide decision-makers and the public with reliable information. For logic reasons, each country drafted their own procedures and policy regarding the testing strategy, and these might have been altered over the course of the epidemic. Many variables influenced the strategy, for example the availability of testing material, the capacity of health care to treat patients, and political viewpoints. Some countries (initially) ignored or underestimated the impact of the infectious disease, which led to a more severe outbreak. The country examples show nicely which data was collected and were regarded 'reliable' enough to be published.

Apart from variations in the type of data collected, also the purpose of geospatial data – i.e. the use case – differed. On the one hand, geospatial information played an important role to inform the public about the severity of the outbreak, the spatial distribution and possible measures that applied in particular local regions or municipalities. Graphics and maps in a complementary dashboard are an important means for communication.

The other role of geospatial information relates to analytical purposes. Governments need reliable information to decide how to respond to the crises. Of course, with a new disease, much is unknown, and politicians have few resources to rely on, except for knowledge and expectations from the experts. However, over the course of the epidemic, it is essential to collect data to monitor progress and effectiveness of imposed measures, such as the closure of facilities and restrictions to travel.

The purpose for which geospatial information is used, should relate to how the geospatial information is presented and which means are used. Can it best be presented in a simple graph or is a map better? And how to include specific spatial developments related to spread of the disease across the country, or across the region? The level of detail provided should be considered and related to the purpose as well. A comparison between countries or between continents requires a different presentation of data, e.g. more accumulation is needed, then a detailed location-specific analysis for decision-makers.

20.6.1 The Data Problem

Every presentation and analysis of geospatial information is a result of the underlying data. Responding to a global epidemic requires coordinated action at all levels, both global and supranational, as well as national and local. As discussed in section 'Shortcuts and challenges of COVID-19 data provision', there is a lack of internationally harmonized standards for data collection and data provision of COVID-19 data. This limitation makes it difficult, if not impossible, to compare data collected in different countries and thus hinders information and possibly informed joint political action at the international level.

Other global issues, such as achieving the Sustainable Development Goals (SDG) 2030, face similar data problems. In July 2017, the United Nations General Assembly adopted a Global Indicator Framework consisting of 232 statistical indicators designed to measure the SDG goals and targets [25]. Populating those indicators poses enormous challenges, which is even described as an 'unprecedented statistical' challenge [26]. MacFeely [27] distinguishes two different groups of SDG indicators: Indicators that are conceptually clear, have an internationally established methodology, and for which standards are available, and indicators, for which internationally established or standards are not yet available, but are being (or will be) developed or tested.

20.6.2 Public Health Data and Statistical Information

As discussed above, health data are regularly provided by national health authorities in an aggregated form within the same national framework that is used to manage statistical national data. For this reason, a globally well-defined integrated statistical and geospatial framework could serve as an excellent basis for managing not only relatively low-dynamic statistical data, but also highly-dynamic health data, such as those generated in the event of a global epidemic. In this way spatiality of statistical information [28] and dynamic health data could go hand in hand. INEGI, the National Institute of Statistics, Geography and Informatics of Mexico [29] implemented one of the first geostatistical dashboards presenting COVID-19 data and statistical indicators in an integrated form [30]. The analysis of confirmed, suspected, negative COVID-19 cases and COVID-19 deaths in the context of statistical indicators at both state and municipality level (population density, population aged 60 and over, educational and economic characteristics, health services, hospital infrastructure, etc.) makes it possible to assess the level of vulnerability of the population (see [31]).

20.6.3 Public Health Data and Spatial Data Infrastructures

By definition, a pandemic is 'the worldwide spread of a new disease' [2]. Consequently, a pandemic requires a worldwide coordinated response. Due to global dependencies and exchange of goods and people, there is a need to coordinate actions to limit further spreading of the disease. However, each country has its own authority and powers to take decisions. In Europe, countries developed their own strategy to counteract the disease despite a shared understanding of the potential impact of the outbreak on society. A parallel can be drawn with the management of geospatial COVID-19 data. Each country made their own decisions regarding which data to collect, how to measure and monitor progress of the outbreak, and how to display and disseminate the information to the public.

At the beginning of this century, a similar situation existed with regard to the Spatial Data Infrastructures (SDI) of the EU Member States. To overcome the unsatisfactory situation of lack of interoperability between the different National Data Infrastructures (NSDI), it was decided to create a European Spatial Data Infrastructure to enable the sharing of environmental geospatial information among public sector organisations, to facilitate public access to geospatial information across Europe and to support policy-making across national borders. In 2007 the INSPIRE (INfrastructure for SPatial InfoRmation in Europe) Directive came into force, with full implementation required by 2021 [32]. INSPIRE is based on the National Data Infrastructures established and operated by the Member States of the European Union.

Although long-established standards for a European Spatial Data Infrastructure are available, it does not currently seem possible to provide a high-quality European dashboard capable of disseminating COVID-19 data from individual Member States in a standardized form. Part of the reason lies in the novice nature of the disease in combination with the diverse institutional settings in each country. Most of these institutions are not oriented towards geospatial information, but deal with healthcare, public health and public order and safety.

Murgante et al. [33] publish the results of a comprehensive research on the COVID-19 outbreak in Italy, in which health, geographical and planning aspects were equally considered and integrated. The aim of the study was to conduct a fine and disaggregate analysis at the local level. The analysis demonstrated the spatial diffusion and the distribution of the COVID-19 outbreak in Italy by referencing some major groups of variables: land use, air quality, climate and weather, population, health and life expectancy. Many high-resolution data on land use, air quality, climate and weather, population, health and wellness were needed as input data for such detailed analyses. The authors report that they had to collect data from many different sources, COVID-19 data from the Italian Ministry of Health, from regional administrations, from local health agencies, even from newspapers. Socio-economic and demographic data came from the Italian Statistical Institute, environmental data and indicators had to be collected from different sources, such as the Higher Institute for Environmental Protection and Research, the World Health Organization, the European Environmental Agency, the Italian Automobile Club. Weather and wind data had to be retrieved from other websites, data on air quality and weather conditions from special dashboards.

Considerable preparatory work was needed to integrate those data so that could be used as input for analyses. Most of this data could be provided within a well-defined spatial data infrastructure, directly and instantly accessible, clearly linked to georeferenced statistical, health and other relevant information.

20.6.4 Integration of Public Health Data, Statistical Data and Basic Geospatial Data

To take full advantage of the wealth of information available in the various institutions it is necessary to develop and implement solutions for the integrated management of public health data, general statistical data and basic geospatial data.

Since 2016, the global 'integration of spatial, statistical and other related information' has been explicitly on the agenda of the UN Committee of Experts on Global Spatial Data Management [34, 35]. The COVID-19 epidemic demonstrates in a perhaps unparalleled way the need to provide globally integrated spatial, statistical and health-related information, adapted to the needs of very diverse users.

20.7 Conclusions

A pandemic, a worldwide-spread of a new disease, requires a worldwide coordinated response. An infectious disease spreads over space and time at different speeds and can cause local outbreaks. A new disease calls for new insights, which must be gained through synoptic observations from different perspectives, medical, social and economic. Spatio-temporal analysis can help to gain such new insights by relating disease-related data, such as case numbers, hospital occupations, fatality rates, etc. which evolve over time, to statistical indicators and to the locations to which they refer.

In order for spatio-temporal information systems to develop their full potential, the characteristics of the data they contain must be clearly defined and the underlying spatial reference units must be consistently defined. Such high-quality and trusted information can help decision-makers to intervene at the right time and at the right place, rather than relying on general figures. More than that, a quality controlled spatiotemporal database can support post-pandemic analysis in many different areas of interest.

Much groundwork has already been done in the domain of spatial data infrastructures, both at national and supranational level. At this stage, committees and working groups are concentrating on the development of solutions for the integration of statistical information into such infrastructures, which will then be implemented by the individual countries.

The epidemic demonstrates the urgent need for an integrated spatial and statistical information system at the global level, but also at the country level and beyond. This chapter showed how various countries implemented a system at the national level, which led to a range of diverse solutions, interfaces, and management information. This pluralism in national solutions was integrated at the European level into a data platform based on the input from individual member states and their systems. After some initial hick-ups, the information was used to discuss interventions at the European level and feed these back into national actions, e.g. regarding cross-border travel regulations between countries. However, the potential of an integrated system at the country level and the European level is not fully taken advantage of yet due to mentioned barriers. Once the systems at the country level have matured and aligned, it will leverage the benefits for both government and societal resilience at the country level and at European level.

An integrated system providing basic geospatial data, statistical data, and public health data in one and the same framework would make it possible to retrieve georeferenced information in near real time at all levels – global, supranational, national and local – in a timely and user-oriented manner.

It remains to be investigated to what extent and how the organizational, technical, and legal challenges of such an initiative can be mastered.

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21

Practicing Online Higher Education Facilitated by ICT in China: In the Context of COVID-19 Pandemic

Zhixuan Yang

The impact of COVID-19 pandemic on higher education pushes forward the transformation of traditional in-class education to fully online education. The chapter analyzes the experience of online education firstly in literature, particularly, the external and internal elements that influence learning outcomes in flipped classrooms and Massive Open Online Courses (MOOC). Besides, the chapter also touches base on the learning behavior change in online higher education to reveal the internal driving force of self-regulation in the distancing learning environment. The results of a survey in the course of GIS for Real Estate to analyze the importance of the crucial elements in the learning practice suggest that COVID-19 pandemic has a crucial influence on the teaching-learning process. It has been also noticed that the resilience of the community to the shock of health disaster and the speed of reaction to the preparedness for the change in the broader sense is meaningful to the success of the practice of higher online education.

21.1 Introduction

COVID-19 pandemic is a devastating global crisis which has caused millions of confirmed cases and hundreds of thousands of death. It is the most serious global epidemic since the Spanish pandemic 100 years before. In China, the pandemic is a nationwide epidemic, reshaping social activities as well as causing changes in higher education. The online higher education has become a teaching-learning routine since the spring semester in 2020, influencing approximately 32 million students studying in colleges and universities. The fully online higher education causes the transformation of such a vast amount of students studying remotely from home.

There is limited information on online higher education in practice. Different from theoretical research, practical research requires a solid investigation of operations in online education, particularly, the ICT preparedness, the monitoring process, and the evaluation of performance. In general, the prerequisites of the practice influence the most in terms of successful implementation. That means the following three points are important. First, ICTs should be ready and accessible. Teachers and students have access to the internet as well as mobile devices. Second, mobile devices and online applications can be applied to the learning management system. Users' devices can access learning management systems and online applications. Third, sufficient and informative online courses should be available. Teachers have recorded teaching videos and calibrate digital materials for teaching purposes.

The practice of online higher education officially started on 1st March 2020 when the spring semester began. Up till the end of the semester in July, it has shown that the practice was generally successful. It is necessary to introduce the experience in practice and analyze the pros and cons. Therefore, the chapter focuses on the current practice of online higher education facilitated by ICT to illustrate the crucial elements of maintaining the performance in the context of the COVID-19 pandemic in China.

21.2 Literature Review

21.2.1 ICTs and Online Accessibility

It has been a long history of discussion of online higher education in theory. By definition, online education refers to educational activities in cyberspace which are facilitated by the internet, information communication technology (ICT), and geospatial information system. Due to the innovative way of remote teaching and distancing learning, online education creates the virtual reality of study anytime, anyplace for anyone. To be exact, the virtual environment bases on the internet and ICT, leveraging the advantages of flexibility, accessibility, content diversity, scalability, and cost-effectiveness in modern education. In that sense, ICTs are the fundamental instruments in the knowledge delivery, engaging teachers together with learners in problem-solving and critical thinking [1].

As remote teaching and learning require the accessibility of online courses, the ICT facilitation is critical regarding the successful performance of distancing education. It also matters the engagement of students in the technology-enriched learning environment which is important to identify and evaluate the students' needs and help teachers to calibrate the teaching content to the knowledge in their need.

Apart from the facilitation of ICT, online higher education also requires students to have strong self-directed and self-regulated inner drives. In that sense, the design of an online learning environment is crucial. The supportive online learning environment includes three layers, i.e. participants, micro-level and macro-level environments [2]. The layers overlap and cooperate in the creation of a satisfactory and accessible virtual learning environment. In the three layers, the participants are the central roles as instructors, responders, and actors; the micro-level environment refers to the learning management system (LMS) that forms the digital interactive platform; the macro-level environment consists of the cyber and digital environment and ICTs' facilitation.

As the online learning environment is important regarding course performance, the previous researches reveal the elements that foster a good environment. For example, researchers find that the appropriate instructional design of prediction, observation, explanation, and evaluation (POEE) is necessary for the inquiry learning process. Besides, the course design in the scaffolding modular structure is meaningful to a better understanding environment and it can also provide support for self-learning [3, 4]. In addition, the online self-assessment toolbox in the learning management systems (LMS) and the virtual learning environment (VLE) interface facilitates leaning performance as well [5]. Furthermore, the design of sociable environments can enhance learners' social presence and interaction, which enables confidence in the learning process [6].

21.2.2 Experience Learned from Flipped Classroom and MOOC

As discussed, the readiness of digital infrastructure is crucial regarding the preparation of online education. The ICT infrastructure requires high-speed digital signals, mobile smart devices as well as environment friendly leaning management systems (LMS). Before the pandemic, the online higher education facilitated by ICT has been prevalently used in blended learning (BL), such as flipped classroom and Massive Open Online Courses (MOOC), which is known as one of the major trends in higher education [7]. In the face of the epidemic, the former experience of flipped classroom and MOOC is beneficial to teachers as it is helpful in terms of appropriate online resources and adjustable video courses to different levels of learners.

21.2.2.1 Flipped Classroom

The flipped classroom is a model that the in-class teaching course is deliverable outside the classroom via virtual online LMS, leaving the time in the classroom effective for questions and discussions [8]. The flipped classroom is regarded as an advanced teaching method due to the power of online teaching technology, driving the significant contribution to efficient learning outside the classroom, and leaving the time in class open for the innovative collision of deep thoughts.

There are arguments about the pros and cons of flipped classroom and experiences can be referential to online education. As the teaching content is taught in the video course, the well-designed video course is crucial to efficient learning outside the classroom. Besides, knowledge, skills, engagement with students' satisfaction, and advanced organization via e-learning management system (LMS) are the fundamental dimensions of the flipped classroom [9].

The flipped classroom emphasizes the teacher's ability of course control regarding the course design in terms of the percentage of the video course and in-class interaction, the skill of instilling various knowledge in class monitoring, the organization's ability as well as the engagement of students in the teaching-learning process. However, the flipped classroom is not the fully-online education as the part of education is still conducted in the classroom. The teachers and students still have the chance of face-to-face interaction, so traditional ways of the class organization such as group discussion can be fulfilled. The outside and inside classrooms are complementary to the goal of good performance of the learning process. Even if the failure of teaching outside the classroom fails, there are still chances of monitoring teaching outcomes. In contrast, MOOC has more common features with fully-online higher education.

21.2.2.2 MOOC

The MOOC stands for Massive Open Online Course and represents an instructional approach that provides students access to online courses from places anywhere around the world [10]. Alhazzani [11] reveals that MOOCs have a significant direct impact on higher education as it improves education outcomes [11]. Besides, studies of MOOC are contributable to online higher education as the MOOC can be the fully-online and outside the classroom. Generally, the researches touch base on the advantages of MOOC in practice regarding the sharing of high-quality education resources as well as flexible self-study via portable ICTs. In a sense, MOOC has become global evaluation criteria regarding the level of the university.

However, the difficulties of monitoring the performance of MOOC is also of great concern as it requires high self-regulation and remains uncertain of students involvement via distancing education. Researchers find that good performance of MOOC requires concerns on students' engagement in the learning process as the vast majority of students may drop out before completing courses when the loose engagement undermining learning performance [10].

Teachers' facilitation can foster a positive environment by offering informative course materials, which enables the students' engagement. Besides, the teachers' facilitation improves the efficiency of knowledge transmission and quality of interaction, which enhances the engagement, motivation, and satisfaction of students. But importantly, the students' confirmation, satisfaction, and attitude have directly or indirectly influenced the intention to continue using MOOCs [12].

It is suggested that the intention of use, interaction, engagement, motivation, and satisfaction, are the five pillars of MOOC [13]. Among those, the quality of interaction is regarded as the paramount element in solving the problem of learning retention. For example, Dai et al found that there was no direct relation of interaction quality and satisfaction with the learning experience, but the learning habit of MOOCs as a learning model could significantly increase continuance intention [14]. In addition, the interaction can promote students' attitudes and enhance their persistence. Besides, the interaction enables motivation and self-regulation, which is a positive impact on the MOOC performance as well [15].

In contrast to the flipped classroom, MOOC emphasizes the promotion of students' inner drive on learning performance through teachers' facilitation as well as mediation. The practice of two innovative educations, reshaping students' learning behavior, bring forward the valuable experience of online higher education.

21.2.3 Learning Behavior Change

The learning behavior change is an unavoidable challenge of fully online higher education. The open and distance online learning environment changes the traditional face-to-face mode. And the most apparent change from the students' side is the learning behavior change. Such change also causes a change in teacher's instruction and mediation in learning activities [16].

In the time when the teaching is in class, the students' learning behavior is easy to predict, observe, explain, and evaluate (POEE), while online education is on the contrary. Students' learning behavior relies on the instructions given by teachers through virtual interaction, but importantly, the inner drive of self-learning behavior plays vital roles in the learning process, which directly affects education outcomes.

Typically, the importance of learning behavior regarding the performance of online education has been illustrated by the technology acceptance model (TAM). According to the original TAM [17], the external variables function the perceived usefulness and perceived ease of use, which impact on the attitude towards behavior, and influence the behavior intention to use, and lastly the actual system use.

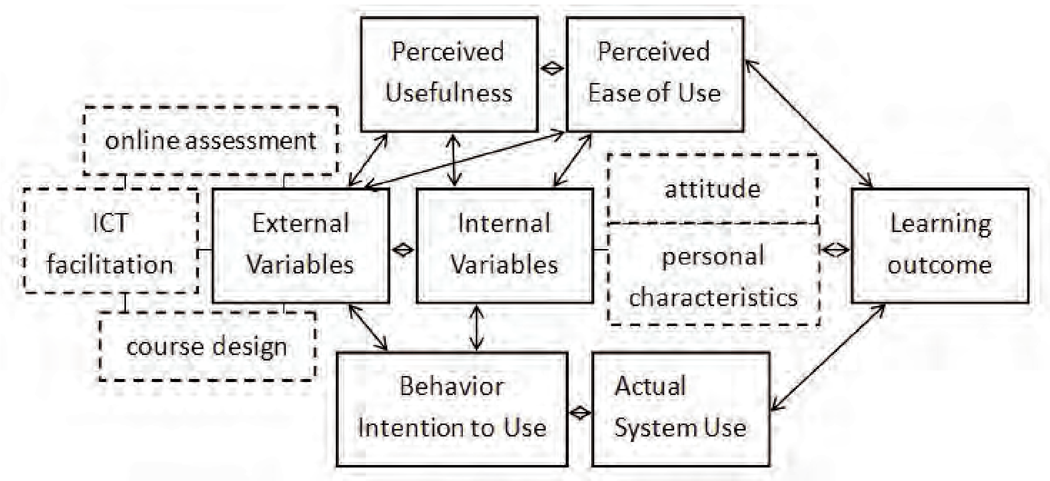

FIGURE 21.1
Modified TAM (Based on original TAM [17])

The external variables consist of ICT facilitation, course design, online formative assessment as well as course monitoring. Taking the online course design affecting learning behavior, for example, [18] finds that a course design enticing students' behavior, emotional and cognitive engagements can promote achievement [18]. Among the different types of engagements, behavior engagement is relatively easier to measure and collect, especially with the help of learning management systems (LMS). [3] highlights that the learner-centered course design helps the collaborative learning and social inclusion, widening participation in education. It is also suggested that the scaffolding modular structure of the learning environment is convenient for observation and evaluation [3, 19]. Also, as regards the performance of online higher education, the online formative assessment is in need. As effective online formative assessment can foster a learner's assessment centered focus through "formative feedback and enhanced engagement with valuable learning experiences" [20].

The internal variables, such as personal characteristics, are also focused on relevant research. For example, the learners' characteristics have a strong influence on learning behavior, such as note-taking behavior, and the impact on learning performance during a fully online course [16]. The strong self-determination and persistence in the learning process can assist the learning behavior and so forth [21].

21.3 Practice of Online Higher Education in China

21.3.1 Background

China started early as a certified distancing higher education. Back in 1998, the Ministry of Education officially approved Tsinghua University, Beijing University of Posts and Telecommunications, Zhejiang University, and Hunan University as the first batch of National Modern Distancing Education Pilot Universities (NMDEPU). And 68 universities have been officially approved by the Ministry of Education regarding the certified online higher education by 2019.

Meanwhile, China has a good foundation of cyber technology. The internet and mobile technology are prevalently used by Chinese entities, universities as well as individuals. And the level of digital infrastructure and the popularity of broadband has been continuously improved. The users of bandwidth 100M have surpassed 60% in 2018. Also, the 4G network coverage is remarkable. In 2019, the total number of 4G users reached 1.23 billion, covering nearly 98% of users, ranking first in the world. At the same time, the construction of new infrastructure, 5G, and gigabit optical fiber networks is in acceleration.

As the key support for the development of digital society, the leading role of broadband network and 4G fiber network becomes increasingly prominent. It provides strong support for the smooth development of online education.

21.3.2 Online Learning Environment in Practice

The learning management system (LMS) supports the online learning environment. There are three modules in the system, they are, administration module, teaching module, and learning module. And LMSs are embedded in the intranet of certain universities. The design of the learning environment is versatile due to the verified needs of users. Recently, commercial online education platforms are gradually established, which is encouraged by the Ministry of Education in the 13th five-year plan. But the commercial platforms are open to the education market and independent from universities' LMSs. Those functions of modules are slightly different as the commercial platforms emphasize more on technical services as well as flexible unified learning modules.

During the period of the pandemic, the commercial online educational platforms are in great popularity as the learning materials and video courses are enriched and well-established before the incident. Thus, the market shows a strong demand for merging the internal LMS in universities with commercial online open courses. Therefore, that type of cooperative online higher education is in rapid development.

Accordingly, the commercial platform adopts an updated marketing strategy during the epidemic, including free use and open learning resources, which attracts massive users to register in the open platforms, providing chances for the teachers to integrate video courses into their curriculum construction.

The commercial platforms support either recorded course or live broadcasting course. Table 21.1 showed the features of popular platforms ICourse, Chaoxing, Yuketang, Zhihuishu, Wechat, and Tencent Meeting. They have different publishers, but all have open access to end-users. Most of them have enriched course resources, such as pre-recorded courses and sufficient learning materials. Besides, they all support desk-top and cell phone apps. But the technical maturity is slightly different. For example, not all of the platforms support live broadcasting.

21.3.3 Case Study

For the analysis of users' experience as well as the online education performance in the incorporated LMS, the chapter elaborates on a survey in this section. The course GIS for Real Estate is the investigated case.

TABLE 21.1
Commercial learning platform (Based on this research)

Name	Publisher	User access	Curriculum resources	Convenience of use	Live broadcasting	Curriculum construction	Desktop app	Mobile phone app
ICourse (https://www.icourse163.org/)	Higher Education Society & Netease	Open access (limited time)	☆☆☆☆☆	☆☆☆☆☆	Yes	☆☆☆☆☆	Yes	Yes
Chaoxing (http://erya.mooc.chaoxing.com/)	Beijing superstar company	Open access (limited time)	☆☆☆☆	☆☆☆☆☆	Yes	☆☆☆☆☆	Yes	Yes
Yuketang (https://www.yuketang.cn/)	Tsinghua Uni	Open access (limited time)	☆☆☆☆	☆☆☆☆☆	Yes	☆☆☆☆☆	Yes	Yes
Zhihuishu (https://www.zhihuishu.com/)	Shanghai Zhuoyue Ruixin Digital Technology Co., Ltd	Open access (limited time)	☆☆☆	☆☆☆☆☆	Yes	☆☆☆☆☆	Yes	Yes
Wechat (https://weixin.qq.com/)	Tencent group	Open access	☆	☆☆☆☆☆	Yes	☆☆☆	Yes	Yes
Tencent Meeting (https://meeting.tencent.com/)	Tencent group	Open access	☆	☆☆☆☆☆	Yes	☆☆☆	Yes	Yes

Notes: ☆ represents for the level of readiness of the curriculum on different online platforms, The marks base on the observation of users in general in this research.

The course was a selective course open to the sophomore in the major of Real Estate Development and Management. The teaching weeks were 18 weeks for 2 credits. Students needed to finish the entire online course, weekly assignment, and participate in the final exam to get the full credit. Due to the situation of the pandemic, the course had been pre-recorded in videos and uploaded to the Chaoxing Platform according to the weekly teaching schedule. The learning system recorded students' learning behavior and marked individual scores accordingly. The weekly course opened from Monday to Friday to students. The flexible learning arrangement was encouraged as a test of self-management. The teacher used an online discussion whiteboard for questions and answers of weekly learning content. Besides, the teacher also interacted face-to-face with students in the Tencent Meeting and Wechat. The final exam was conducted in the universites' LMS.

The course focused on the application of GIS analysis in real estate industry in terms of market analysis, real estate development, and property analysis. The pre-recorded videos were the main learning resources for students, which was convenient to use as a digital interpretation of the textbook. But it was not easy to trace the GIS operation online. In that case, the course gave weekly instructions in the text before the assignment, so the students could follow the instructions step by step in the GIS tool operation. The evaluation of the assignment based on the analysis outcome of the work. Also, the course used ad-hoc online meetings and group chat devices to solve students' problems.

For evaluating the performance of students, the chapter delivered a survey at the end of the semester. The class was divided into two groups. Each of them consisted of 29 students, with 58 students in total. A survey was delivered to students online at the end of the semester. The purpose of the survey was to test significant elements that influence students' performance in their learning experience.

The survey included 13 question items, those were, Satisfaction of online learning platform, Satisfaction of fully online course, Habit's influence, ICT facilitation, Personality influence, Attitude and persistence influence, Behavior influence (taking notes), Modular design, Course management, Weekly assignment, Time flexibility, Final exam, and Barriers of the online course. Among those, the first twelve questions were in a Likert 5 scale (full score 100) for the evaluation, and the last question was a structural deigned semi-open question. The survey was distributed to students via the back-to-back method to ensure respondents to have no communication. The valid responses were 58. The survey result is shown as follows (Table 21.2).

TABLE 21.2
Factor loading matrix for self-evaluated online education performance (Based on the survey in this research)

No.	Question Item	Satisfaction/Importance (Score)	
		Group 1 (mean)	Group 2 (mean)
1	Satisfaction of online learning platform	82.11	88.42
2	Satisfaction of fully online course	62.91	65.91
3	Habit's influence	83.65	86.33
4	ICT facilitation	81.54	91.58
5	**Personality influence**	**45.76**	**59.48**
6	Attitude and persistence influence	81.6	86.8
7	Behavior influence (taking notes)	81.58	83.68
8	**Modular design**	**89.49**	**94.74**
9	Course management	82.14	89.99
10	Weekly assignment	85.27	91.03
11	Time flexibility	70.53	81.03
12	Final exam	84.22	81.58
13	Barriers of online course	-	-

The mean score in both groups was homogenous, without apparent variance. The top five question items (basing on the mean score) were No. 8, 10, 4, 9, and 1. The observation showed that the top items were external variables that influenced students' learning performance. In contrast, the lowest two items were No. 5 and 3, which were internal variables influencing students' performance.

Besides, the students highlighed barriers of the online course in the regard of self-regulation, eye-contact and interaction, focus and concentration of video course, in-class monitoring, learning atmosphere and efficiency, internet congestion, time management, pop-up advertisement disturbance, and reading inconvenience of the digital document.

21.4 Conclusion

COVID-19 pandemic is an overwhelming health disaster. The shock of the epidemic causes the reconsideration of building community resilience in the field of online higher education. Due to the closure of the campus, millions of university students receive online courses remotely. The fully online transformation changes the face-to-face learning process to distancing online self-study mode. The transformation is not merely a temporary change in educational evolution. It is influencing the revolution of higher education deeply.

Practicing online higher education is a predominant issue facing the epidemic. The experience shows the readiness of online education, such as ICT facilitation, video courses, online learning materials, LMS and commercial platforms, etc, is the prerequisite. Meanwhile, the external drives for interaction and engagement of students in the teaching-learning process are vital.

The lessons learned from flipped classrooms and MOOCs are that crucial elements for the improvement of learning performance are both external and internal. A good combination of external and internal drives can enhance students' learning behavior.

The case study in the chapter shows that external elements, such as modular design, weekly assignment, ICT facilitation, course management, and convenient online LMS, are the most significant elements influencing respondents' performance. Whereas, the internal drives, such as personality and learning habits, have insignificant influence. Besides, the step-by-step technical instructions to GIS operation and sufficient online interaction are crucial in the online learning environment.

The continuation of on-going research of online higher education in the reaction of health disaster will be in need, particularly, regarding building community resilience. The experience that the research learned from the practice in China shows the preparedness of ICT facilitation, flexible structure of the organization, the readiness of online course resources, effective communication of participants as well as the clear instructions to students in the GIS-related course are crucial to the successful implementation of the online higher education.

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Time-Series Analysis of COVID-19 in Iran: A Remote Sensing Perspective

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This chapter reports on a national study of COVID-19 using remote sensing (RS) indicators in Iran. Time-series analysis is performed on RS indicators (n=12) including wind speed, temperature, evaporation, carbon monoxide (CO), nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), ozone (O_3), formaldehyde (HCHO), cloud cover, precipitation, air pressure and soil moisture (SM) to identify remotely sensed products that may contribute to COVID-19 transmission. Mann-Kendall test is employed to summarize time-series observations. Further, a correlation analysis is performed between Z-scores obtained from the Mann-Kendall test and the number of COVID-19 cases. Findings indicated that the precipitation, NO_2, and SO_2 have high correlations with number of COVID-19 cases with Spearman correlation coefficient of -0.39, -0.33, and -0.31, respectively. Findings may provide useful insights for public health decision makers by improving the accuracy of predicative models.

22.1 Introduction

As of 1 July 2020, Iran has been identified as one of the top ten countries with the highest number of reported COVID-19 cases. Several neighboring countries such as Bahrain, Iraq, Georgia, Kuwait, Oman, Afghanistan, Lebanon, and Pakistan reported that their first cases of COVID-19 was imported from passengers traveling from Iran [1]. As of 3 September 2020, over 381,000 confirmed cases and almost 22,000 deaths had been reported from Iran. However, the real figure is largely underestimated [2]. It is predicted that the country will face several waves of the pandemic due to ineffective controlling strategies such as early reopening and ease of restrictions.

Several studies have identified associations between environmental indicators and COVID-19 transmission. For instance, in China, Yongji et al. (2020) examined the relationship between ambient air pollution and daily (confirmed) COVID-19 cases using generalized additive models. They found a positive association between COVID-19 and particulate matter 2.5, carbon monoxide, nitrogen dioxide, and ozone, while Sulphur dioxide was negatively associated with the disease [3]. Ma et al. (2020) modeled the relationship between daily COVID-19 mortalities and temperature and relative humidity variations using time-series analysis. They found a positive association with temperature and negative association with relative humidity [4].

Epidemiological investigations of infectious diseases mostly concentrate on medical aspects and infection control and disregard the geographic components of the diseases [5–7]. Geospatial technologies such as Remote Sensing (RS) and geographic information system (GIS) have been identified useful in monitoring a variety of infectious diseases when they are coupled with data-driven techniques [8, 9]. GIS and RS have been utilized in the study of COVID-19 across the world. For instance, Liu et al. (2020) used RS data such as nighttime light and air quality index to assess the impact of COVID-19 lockdown on human lives in Mainland, China. Their results suggested that with the implementation of lockdown policies, the nighttime light radiances generally decreased in the entire Mainland, and a significant decline was observed in commercial center regions. Meanwhile, air quality significantly improved [10]. In a GIS-based study in the United States, Mollalo et al., (2020) utilized multi-scale geographically weighted regression to explain the variations of COVID-19 incidence at the county level across the country. They compiled a geodatabase of 35 explanatory variables, including environmental, behavioral, and socio-economic factors. Their results indicated that socio-economic variables, particularly income inequality, could explain more than 68% of variations of disease incidence compared to environmental factors [11, 12].

To our knowledge, there are limited studies that have utilized remotely sensed data to monitor COVID-19 in any region of Iran, especially at the national level. To bridge the gap, we examined the applicability of RS coupled with time-series analysis in Iran as our study area.

22.2 Materials and Methods

In this section, we describe the study area, data used and methodology for identifying time-series relation among COVID-19 and environmental indicators obtained from satellite observations.

22.2.1 Study Area

The study area covers Iran. This country with the area of 648,195 km^2 is considered as the 17th largest country in the world. Iran is divided into 31 provinces (Figure 22.1). Two types of datasets including the number of COVID-19 cases and remotely sensed data were compiled. Figure 22.1 shows the geographic location of study area together with the normalized number of COVID-19 cases by the population.

22.2.2 Disease Dataset

The number of COVID-19 cases in each province was obtained from the Ministry of Health and Medical Education. The data were only available for 22 provinces, excluding Alborz, Isfahan, Qom, Razavi Khorasan, Semnan, and Tehran provinces, which are shown in Figure 22.1. The actual number of cases is presented in NCD column of Table 22.2. The number of COVID-19 cases is registered from 20 February 2020 to 19 April 2020, which is about 53000 cases.

22.2.3 Remotely Sensed Data

In this study, various satellite data sources and products were obtained from Google Earth Engine (GEE) platform (https://earthengine.google.com/). GEE is an efficient cloud computing tool that provides georeferenced and calibrated RS data of a variety of satellite imagery [13]. It allows researchers and users to simultaneously process, visualize, and analyze time-series geospatial data in a simple and quick way [14]. GEE was utilized to provide 12 spatial indicators including wind speed, temperature, evaporation, carbon monoxide (CO), nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), ozone (O_3), formaldehyde (HCHO), cloud cover, precipitation, surface pressure, and soil moisture (SM) (Table 22.1). The selection of parameters is based on literature review and available RS indicators [3, 4, 10–12].

In order to extract time-series RS indicators (n=12) from GEE, Terra Moderate Resolution Imaging Spectroradiometer (MODIS), Sentinel-5 Precursor (Sentinel-5P), Global Precipitation Measurement (GPM), Soil Moisture Active Passive (SMAP), National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR), and Global Land Data

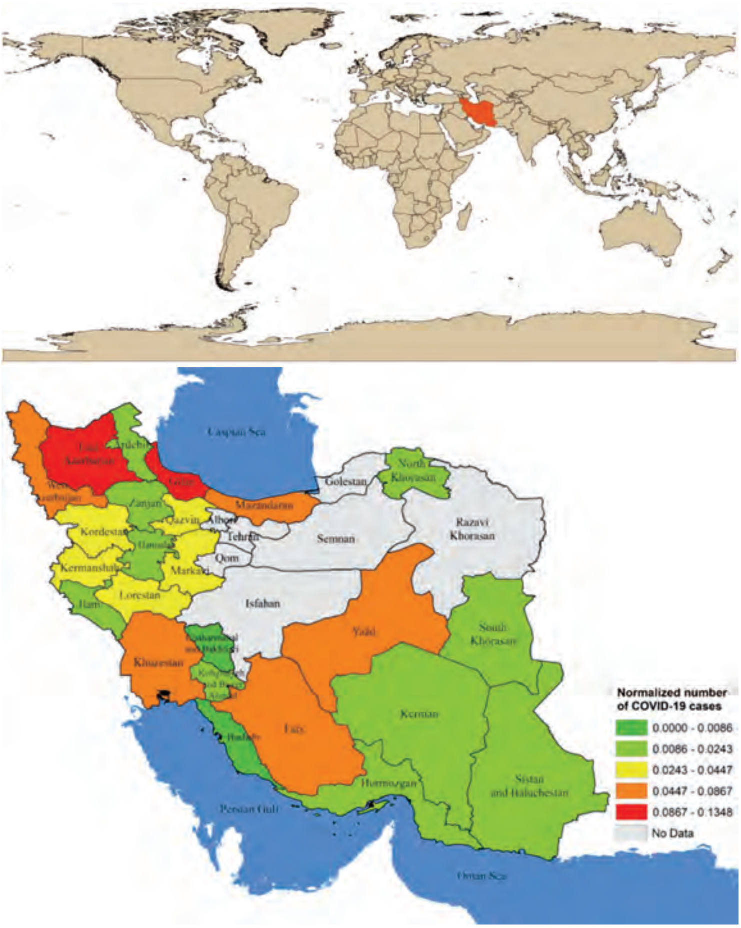

FIGURE 22.1
The geographic location of Iran in world map, and the normalized number of COVID-19 cases obtained until 19 April 2020 for each province

Assimilation System (GLDAS) were used. These data were acquired from February 20, 2020 (starting date of COVID-19 outbreak in Iran) to 19 April 2020.

22.2.3.1 MODIS Data

According to previous studies, the number of COVID-19 cases may be influenced by the changes of temperature and evaporation [15, 16]. Terra MODIS MOD11A1 Collection 6 (C6) product provides daily daytime, and nighttime land surface temperature (LST) at a spatial resolution of 1 km [17]. We selected Terra MODIS data, because the atmosphere is more stable at the early hours of the day. Atmospheric instability can influence dispersion of aerosols, pollutants, and smoke plumes in some areas [18, 19]. This product is vastly used and evaluated by many researchers across the world [20, 21]. The MOD11A1 with scientific datasets (SDS) name of "LST-Day-1km" (^oK) was obtained from GEE data catalog during the study period.

Terra MODIS level 4 MOD16A2 C6 product, which provides land surface total evapotranspiration (ET) (kg/m^2) datasets in 8-day at 500 m resolution, have also been used [22]. ET product can be used to calculate regional water and energy balance. Provinces with high ET values may have high COVID-19 cases, therefore researchers believe that ET may be an effective indicator. Hence, change of ET and its effect on COVID-19 are investigated. The MOD16A2 product with SDS name of "ET-500m" was also downloaded from GEE data catalog. This product has been applied, evaluated, and validated by many researchers [23, 24].

22.2.3.2 GPM Data

Previous studies indicate that precipitation is an important indicator that may lead to an influence on microbial pollution which may effect on the number of COVID-19 cases [25]. For this reason, this indicator is incorporated in the dataset. GPM is an international earth's precipitation observation science mission that measures amounts of rainfall and snowfall (mm/hr) for every three hours at a spatial resolution of 0.1 arc degrees ($\approx$ 11.1 km). GPM data products can improve analyzing climate data all over the world [26, 27]. The data were previously validated by some researchers [28–31]. GPM version 6 with SDS name of IR (Infrared) precipitation was utilized.

22.2.3.3 NCEP CFSR Data

Surface pressure (SP) is an indicator that effects some respiratory diseases such as chronic obstructive pulmonary disease, therefore it is employed in this study [32]. NCEP CFSR, one of the global reanalysis datasets, designed to compute an estimation of the global interaction between atmosphere, ocean, sea ice, and land surface [33]. Surface pressure (Pa), albedo (%), sea surface temperature (^oK), soil temperature (^oK), snow depth (m), vegetation cover (%), relative humidity (%), planetary boundary layer height (m), and surface roughness (m) were available variables in the datasets at 0.2 arc degrees ($\approx$ 22.2 km) resolution. These reanalysis datasets were widely used and evaluated in many studies [34, 35]. Among these, surface pressure with SDS name of "Pressure-surface" was the only variable used in this study.

22.2.3.4 SMAP Data

Soil Moisture (SM) is an environmental indicator that can be provided by RS data. Change of SM may influence COVID-19 cases. Hence, this indicator is included in this study. SMAP measures surface values and subsurface SM (mm) every 3 days at 0.25 arc degrees ($\approx$ 27.75 km) resolution with the combination of passive (radiometer) and active (radar) instruments [36]. Scientists can use SMAP data products to better investigate different environmental applications, such as drought monitoring, climate change analyzing, flood prediction, and monitoring of agricultural crop growth [37–39]. These data were evaluated and validated in some research projects [40, 41]. In this study, level 3 surface soil moisture (SSM) with SDS name of SSM was acquired.

22.2.3.5 GLDAS Data

Similar to surface pressure, wind speed can be an influential factor that may be associated with the transmission of respiratory diseases [42]. GLDAS utilizes different earth observation satellites and ground-based data. It is mainly used to generate wind speed (m/s), albedo (%), and soil temperature (^oK). These data are provided at 0.25 arc degrees ($\approx$ 27.75 km) resolution every 3 hours, which are used and evaluated in many research projects, such as water resource management, drought monitoring, weather forecasting, and flux cycle studies [42, 43]. In this study, wind speed (WS) was extracted from GLDAS data products using GEE platform.

22.2.3.6 Sentinel-5P Data

Copernicus program provides some environmental parameters that can present appropriate information about diseases [44]. They can show crowded and industrial areas that people have a high interaction. Hence, it is employed to extract some environmental indicators and the their effects on COVID-19. Sentinel-5P sensor called TROPOspheric Monitoring Instrument (Tropomi) is designed to monitor the atmosphere, climate, air quality, and solar radiation, at a spatial resolution of 0.01 arc degrees ($\approx$ 1.11 km), and a spectral range of (270-495), (675-775), and (2305-2385) nm [45]. In this study, Near Real-Time (NRTI) air pollutant concentrations, including CO, NO2, SO2, O3, and HCHO were obtained. Also, cloud cover fraction data among NRTI level 3 cloud products of Sentinel-5P was extracted from GEE data catalog and utilized as explanatory variable.

TABLE 22.1
Remotely sensed data used in this study together with spatial resolution and sources.

Source	Indicator	Spatial resolution	Citation
MODIS	LST	1 km	[15–17, 46]
	Evaporation	500 m	
GPM	Precipitation	11 km	[47]
NCEP CFSR	Surface Pressure	22 km	[32]
SMAP	Soil Moisture	27 km	[40, 41, 48]
GLDAS	Wind Speed	27 km	[32, 49]
Sentinel-5P	CO, NO_2, SO_2, O_3, HCHO, Cloud Cover	1 km	[44]

22.2.4 Methodology

In the proposed method, time-series analysis of 12 spatial indicators including wind speed, temperature, evaporation, NO_2, SO_2, CO, O_3, cloud cover, HCHO, precipitation, surface pressure and SM obtained from GLDAS, MODIS, Sentinel-5P, GPM, NCEP CFSR, and SMAP satellites/datasets. Pre-processing tasks including some scale factors were performed. Further, the average of each indicator was estimated. Mann-Kendall test was employed to produce Z score maps of time-series observations for each indicator. Mann-Kendall test was used to indicate the general trend of a variable resulted from the processing of time series data. Finally, correlation between Z values and the number of COVID-19 cases was calculated to identify the most effective indicators. Figure 22.2 depicts the workflow of the research.

22.2.4.1 Mann-Kendall Test for time-series Analysis

Mann-Kendall test was utilized to study time-series changes of the selected environmental RS indicators. The main advantage of this test is that it is not influenced by observations with the drastic changes [50, 51]. Mann-Kendall test was also employed for two main reasons: 1- To study severe time-series and changes of spatial indicators in the study area, 2- since the number of registered COVID-19 cases have been registered in period of two months, we need to make a parameter from daily and weekly satellite observations to compare it with the number of COVID-19 cases. Z score of Mann-Kendall test provides a change of an indicator in period of two months, therefore it is possible to perform a correlation analysis among them.

Suppose n observations in accordance with x_1,x_2,. . . ,x_n in the Mann-Kendall test, S variable is calculated based on Equation (22.1):

$$\mathrm{S} = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k) \tag{22.1}$$

where, sgn (x) is calculated as:

$$sgn(x) = \begin{cases} 1 & if x > 0 \\ 0 & if x = 0 \\ -1 & if x < 0 \end{cases} \tag{22.2}$$

The variance of S is calculated as:

$$\operatorname{var}(\mathrm{S}) = \frac{[n(n-1)(2n+5) - \sum_{i=0}^{m}(t_i(t_i-1)(2t_i+5)))]}{18} \tag{22.3}$$

where m is the number of groups with similar values and t_i is the number of points in group i. After calculating the variance, the Z score is calculated using the Equation (22.4). Positive Z scores indicate positive changes in the variable trend, while negative Z scores indicate decreasing trend of the studied variable. Values greater than 1.96 and smaller than -1.96 indicate significant changes

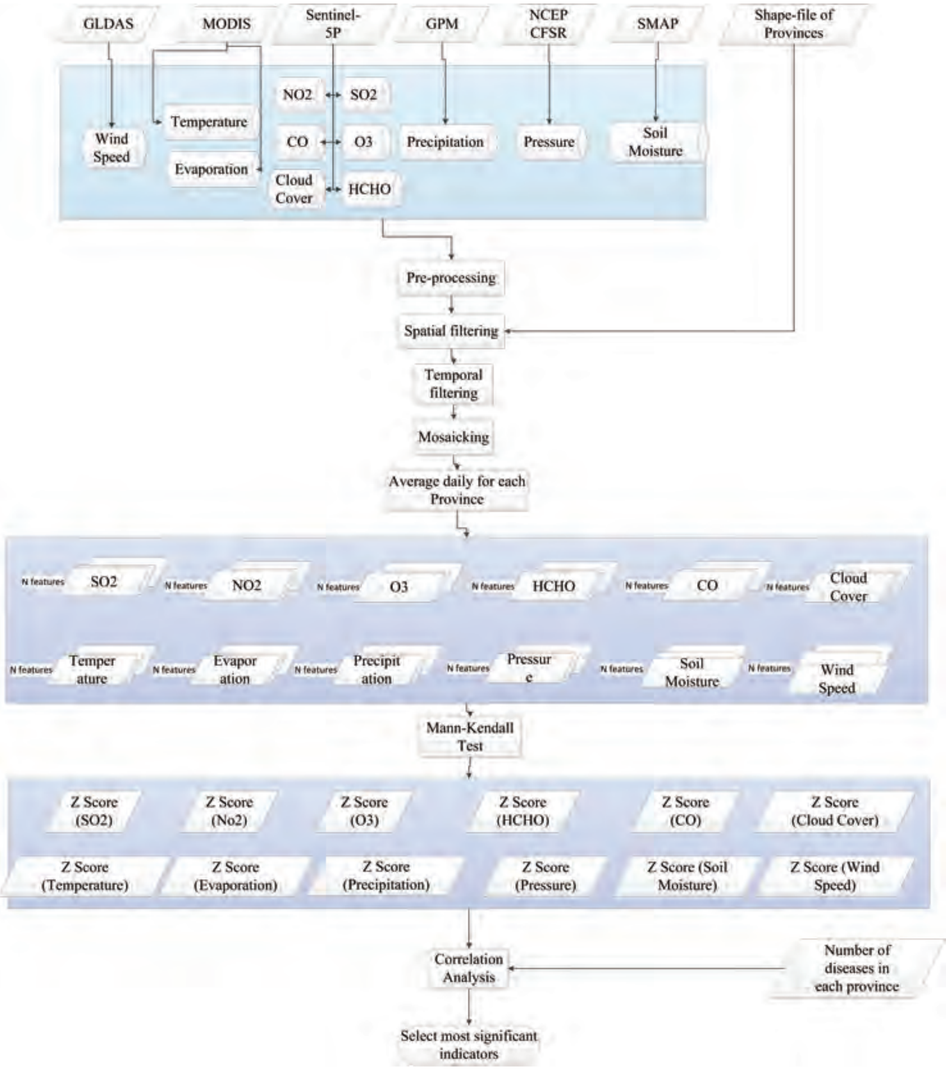

FIGURE 22.2
Workflow of the proposed method to identify effective time-series RS indicators on COVID-19

at 95% confidence level.

$$ZScore = \begin{cases} \frac{(S-1)}{\sqrt{Var(S)}} & if S > 0 \\ 0 & if S = 0 \\ \frac{(S+1)}{\sqrt{Var(S)}} & if S < 0 \end{cases} \tag{22.4}$$

22.2.4.2 Correlation Analysis for Validation

The relation between COVID-19 and spatial indicators was investigated using correlation analysis. Correlation analysis was examined between Z score of each indicator and the number of COVID-19 cases. Three correlation coefficients including Pearson, Spearman, and Kendall were utilized, which were frequently used in previous studies [52]. If at least two correlation methods confirm high correlation values, it can be concluded the spatial indicator may be related to the COVID-19.

Pearson is a linear approach to measure correlation among two variables, which was frequently used in previous researches. The range of values in Pearson is changing between -1 and 1. Values approaching -1 and 1 show high correlation between variables [53]. Spearman is another correlation estimation method which assesses monotonic relationships between variables [54]. The Kendall rank correlation coefficient is another way to measure correlation of two variables [55]. To assess the significance level of the three correlation approaches, P-values were also computed.

22.3 Results and Discussion

Figure 22.3 shows the map of average time-series of each indicator across Iran. According to cloud cover map, maximum cloud was observed in North and West regions of Iran. Maximum values of CO were seen in regions near Caspian Sea, Persian Gulf and Oman Sea. While, minimum values were observed in central areas. Precipitation of the wettest regions in Iran was higher than other regions. While, precipitation of central and east regions were lower than other regions. Maximum precipitation was occurred in south regions of Iran, where some flood events were also reported during 2020. HCHO over Tehran, Gilan, Mazandaran, Khuzestan, and Bushehr provinces was more than others during the study period. Temperature of north and west regions of Iran was lower than south and east, which is true based on climate of those areas. Wind speed of east regions was more than north and west ones during the study period.

Maximum value of NO_2 was observed in Gilan, Mazandaran, Albourz, Tehran, Qom, Markazi, Isfahan, and Khuzestan. High density population in the mentioned areas may be a possible explanation for this finding. Moreover, a high number of COVID-19 cases were registered in the mentioned provinces. Time-series analysis of O_3 showed a higher density in higher longitude compared to lower altitudes.

According to time-series analysis, the larger amount of SO_2 values were observed in Gilan, Mazandaran, Tehran, Khuzestan, Bushehr, East Azarbaijan, and Kerman provinces. Surface pressure of south, west and central regions of Iran was more than other areas. In addition, SM of north and west regions of Iran was more than other areas, while central regions had the lowest values compare with the other regions.

The Z scores of each indicator obtained from Mann-Kendall test were presented in Table 22.3. Cloud cover time-series analysis shows that the percentage of cloud cover in south and north regions including Alborz, Isfahan, Fars, Hormozgan, Semnan, Sistan and Baluchestan, and Yazd have been significantly increased during study period (Z score < 1.96). While, a significant decrease with Z Score lower than -1.96 in cloud cover was observed over Kordestan and West Azarbaijan (Wazar). Among the mentioned provinces, Alborz, Isfahan, Semnan and Yazd have a high number of COVID-19 cases. In general, according to Z score results, it seems that the cloud cover is not an effective indicator to find provinces with low and high numbers of COVID-19 cases were not detected.

Although the amount of evaporations over all provinces has been increased during the study period, it is not significant ($0 <$ Z score < 1.96). Therefore, it seems that ET is not a related indicator to COVID-19.

According to satellite observations and Mann-Kendall test, precipitation was significantly increased over Bushehr, Isfahan, Fars, Hormozgan, Kerman, Kohgiluyeh and Buyer Ahmad, North Khorasan (Nkhorsan), Razavi Khorasan (Rkhorasan), Semnan, Sistan and Bluchestan, and South Khorasan (Skhorasan). During the study period, the number of COVID-19 diseases in the mentioned provinces was lower than others. It seems that Z score of precipitation is negatively correlated with the number of COVID-19 cases.

Z score of temperature over all provinces was positive and greater than 1.96, which shows an increase in temperature in all provinces. Since the research period was between winter and spring, the results seem to be correct. There was no significant association between the number of COVID-19 cases and surface pressure and the association has not changed over majority of provinces. Based on SMAP observations, SM of central and east regions of Iran i.e., Fras, Kerman, Razavi Khorasan, South Khorasan, and Yazd were increased. Moreover, the Z scores of west regions

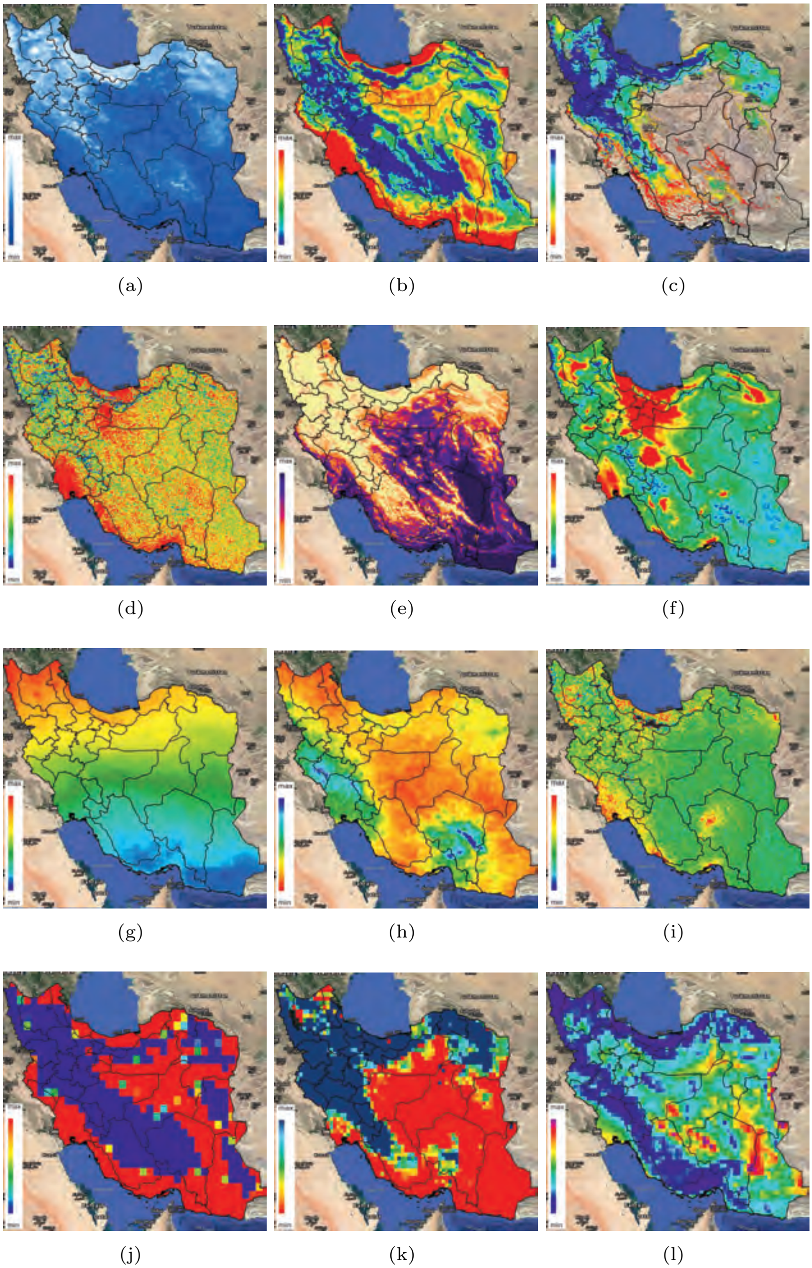

FIGURE 22.3
Average maps of indicators obtained from Iran in time of study(a) Cloud cover (b) CO (c) ET (d) HCHO (e) LST (f) NO2 (g) O3 (h) Precipitation (i) SO2 (j) Surface pressure (k) SM (l) Wind speed

of Iran i.e., Ilam, Kermanshah, Khuzestan, Kordestan, Lorestan, Mazandaran, and Zanjan were decreased. According to the results, a strong relation among SM and the number of COVID-19 cases is not observed.

The values of CO, O3 and HCHO indicators in all provinces were increasing, decreasing and increasing, respectively. NO2 was decreased in some provinces, especially in regions that the number of patients was higher than others. Moreover, based on the Z score, SO2 was decreased over all provinces. Due to several limitations of government on industries, universities, schools, and transportation, it appears that the results of NO2 and SO2 were reasonable. Since results of these indicators are complex, we use correlation analysis to find relation among these two indicators and COVID-19.

All the correlation coefficients (i.e., Pearson, Kendall, and Spearman) between spatial parameters and the number of COVID-19 cases, were calculated and presented in Table 22.3. A significant correlation is not observed between number of COVID-19 diseases and spatial indicators including evaporation, cloud cover, SP, SM, temperature, wind, CO, formaldehyde, and O3 (P value > 0.05). Their correlation values were closer to zero with large P values.

Unlike the study of Yongjian [3] that showed a positive correlation among CO, O3, and the number of COVID-19 cases, the correlation values of Pearson, Kendall, and Spearman for CO and O3 were (0.04, 0.06, 0.09) and (0.24, 0.02, 0.04), respectively. This suggests that there is no correlation among the mentioned indicators and the number of COVID-19 cases in Iran.

Based on outcomes of [4], a high correlation among humidity, temperature, and number of death due to COVID-19 is observed. In this study, Kendall and Spearman correlation values for ET are 0.19 and 0.24, respectively, which shows a correlation among them, but it is not significant enough. Also, a low correlation value (<0.1) is obtained between temperature and number of COVID-19 cases in this study.

According to our findings, precipitation, NO2, and SO2 are the most effective indicators that were highly correlated with the number of COVID-19 cases. Correlation values of Pearson, Kendall, and Spearman for precipitation were -0.35, -0.28, -0.39, respectively. Based on low P-values of each correlation value (P-P value=0.08, K-P value=0.05, S-P value=0.05), it can be deduced that these associations are not due to the chance alone. Moreover, the P values of two correlation analysis methods confirmed that the correlation between precipitation and COVID-19 cases with confidence level of 95% is meaningful. Moreover, NO2 with the correlation values of -0.25, -0.24, -0.33 for Pearson, Kendall, and Spearman is another important indicator. Likewise, SO2 seems to be associated with the number of COVID-19 cases. P-values of NO2 and SO2 are higher than precipitation. Based on P-values of Kendall and Spearman, results with a confidence level of 85% are acceptable. This suggests that Kendall and Spearman correlation analysis methods confirm a significant correlation among NO2, SO2, and number of COVID-19 cases. Results of [3] are in agreement with our findings about NO2 and SO2.

Although this is a new study about the effect of RS indicators on COVID-19 in Iran, there are some limitations that should be considered. As the spatial and temporal resolutions of the used indicators are inconsistent, the integration of those indicators in data level would be a great limitation. Moreover, there are some no-data pixels in products of some days that should be corrected by interpolation methods. Another limitation is that the used products such as SO2 and NO2 should be calibrated based on ground observations for Iran to achieve more reliable outcomes. Finally, we employed the number of registered COVID-19 cases for two months. Since satellite observations can be provided on a daily basis, the use of daily statistics regarding COVID-19 cases can help us to perform a more robust validation on environmental indicators. The most important limitation is related to lack of detailed understanding of the nature of COVID individual cases & deaths, or correcting for epidemiological & personal health issues.

TABLE 22.2
The Z scores of spatial indicators over all provinces

Province / Indicators	Cloud cover	Evaporation	Precipitation	Surface pressure	Soil moisture	Temperature	Wind speed	CO	HCHO	NO2	O_3	SO2	NCD
Alborz	2.00	1.22	0.36	-0.37	0.53	4.53	-1.22	0.01	-2.35	-4.37	4.37	-1.83	N/A
Ardebil	0.84	0.73	0.19	0.09	0	1.82	1.08	2.60	-1.67	2.48	5.31	-3.61	0.018
Bushehr	0.97	-0.24	3.01	-4.42	0.07	4.24	0.37	0.92	0.01	-2.25	4.60	-1.31	0.006
Ch-Mahal & Bakh*	1.48	1.22	0.76	-0.25	-1.28	2.81	0.47	4.30	-1.88	1.95	5.12	-0.31	0.008
East Azarbaijan	-0.53	1.22	-0.38	-0.79	1.51	5.16	2.07	3.52	-2.21	0.01	4.53	-3.56	0.111
Fars	3.61	1.22	2.74	-0.96	2.34	2.16	0.27	2.22	-1.78	-1.36	4.52	-1.56	0.077
Gilan	-0.11	1.22	-0.56	0.12	-0.30	2.18	1.35	2.88	-0.56	-1.24	5.42	-0.95	0.134
Golsetan	1.71	1.71	0.22	0.08	-1.11	1.62	0.03	2.31	-1.16	-0.20	4.40	-2.80	N/A
Hamedan	-1.17	1.22	-0.14	-0.83	-0.68	3.79	1.05	4.85	-1.19	-0.95	4.70	-2.10	0.023
Hormozgan	2.06	0.73	4.12	-3.03	0.75	2.87	0.67	0.77	-0.67	-1.20	2.44	-1.25	0.024
Ilam	0.24	1.22	0.02	-1.99	-3.78	5.71	-0.17	3.38	-0.38	0.56	4.68	-0.60	0.011
Isfahan	2.60	1.22	2.21	-0.77	0.62	2.72	0.06	3.71	-2.86	-2.81	5.232	-2.55	N/A
Kerman	3.97	1.22	5.39	-1.35	2.27	2.30	0	2.78	-1.23	0.50	3.12	-0.80	0.017
Kermanshah	-0.55	1.22	0.33	-1.04	-2.12	3.61	0.04	3.92	-0.62	-0.81	4.99	-1.37	0.035
Khuzestan	-0.44	0.24	0.95	-4.09	-2.49	4.32	0.61	3.24	0.51	-0.88	4.91	-0.81	0.086
Kohg & B-Ahmad**	0.80	0.73	1.99	-1.47	0.90	3.94	0.54	2.01	-1.26	0.10	4.96	-1.02	0.010
Kordestan	-1.93	1.71	-0.68	-0.85	-2.58	4.49	2.78	4.88	-3.0	0.22	4.60	-1.81	0.034
Lorestan	0.01	1.71	0.12	-0.75	-2.27	3.58	0.24	5.04	-1.35	0.40	4.62	-0.51	0.044
Markazi	0.72	0.73	1.11	-0.68	-0.07	2.95	0.44	4.37	-1.71	-1.28	4.74	-1.21	0.033
Mazandaran	0.91	1.71	-0.68	0.17	-2.04	3.27	-1.80	2.63	-0.46	-1.55	4.34	-3.75	0.072
North Khorasan	1.46	1.71	2.54	0	1.25	2.87	0.01	3.28	-0.93	0.57	4.27	-3.56	0.023
Qazvin	0.28	0.73	0.29	-0.25	-0.30	2.12	1.01	2.11	-1.59	-2.74	4.97	-2.91	0.038
Qom	0.58	0.73	1.64	-0.75	0.15	3.05	-0.03	4.45	-3.10	-3.09	4.82	-3.07	N/A
Razavi Khorasan	1.70	1.22	3.86	0.02	2.80	1.76	-0.03	3.44	-1.81	1.17	3.81	-2.18	N/A
Semnan	2.07	0.73	2.77	-0.28	1.21	3.70	-0.40	3.62	-3.45	-3.15	4.64	-2.89	N/A
Sistan & Baluch***	2.27	0.73	4.07	-2.02	1.13	3.94	0.84	1.87	-0.68	1.89	2.05	0.94	0.015
South Khorasan	2.30	0.73	4.85	-0.25	2.87	0.98	0.03	4.05	-0.61	5.39	2.79	0.50	0.011
Tehran	1.49	0.73	0.85	-0.16	-0.22	4.85	-1.29	0.08	-3.22	-3.82	4.36	-2.94	N/A
West Khorasan	-1.81	1.71	0.16	-1.04	0.07	6.27	2.41	3.68	-0.99	1.26	3.98	-2.47	0.061
Yazd	2.59	0.24	3.16	-1.08	3.21	3.83	-0.23	3.24	-1.86	2.58	3.87	-0.92	0.077
Zanjan	-1.43	1.22	-0.23	-0.69	-2.04	3.79	1.39	3.67	-0.89	0.089	4.86	-2.71	0.020

* Chaharmahal and Bakhtiari
** Kohgiluyeh and Boyer-Ahmad
*** Sistan and Baluchestan

TABLE 22.3
Correlation and P value obtained from Pearson, Kendall, and Spearman, Pearson P-Value: P-P value; Kendall P-value: K-P value; Spearman P-value: S-P value.

Indicators	Pearson	P-P value	Kendall	K-P value	Spearman	S-P value
Cloud Cover	-0.16	0.43	-0.18	0.20	-0.29	0.15
ET	0.13	0.53	0.19	0.24	0.24	0.25
P	-0.35	0.08	-0.28	0.05	-0.39	0.05
SP	0.14	0.49	0.11	0.44	0.19	0.36
SM	0.06	0.74	-0.05	0.70	-0.06	0.77
T	0.10	0.62	0.03	0.80	0.06	0.77
Wind	0.15	0.47	0.12	0.41	0.16	0.43
CO	0.04	0.82	0.06	0.69	0.09	0.65
HCHO	-0.03	0.88	-0.10	0.50	-0.12	0.54
NO2	-0.25	0.22	-0.24	0.09	-0.33	0.10
O3	0.24	0.24	0.02	0.86	0.04	0.84
SO2	-0.22	0.27	-0.19	0.19	-0.31	0.13

22.4 Conclusion

In this study, we examined the association between 12 spatial indicators obtained from satellite observations and COVID-19 cases in Iran using time-series analysis. Our findings indicated that changes of SO2, NO2, and precipitation were highly correlated with the number of COVID-19 cases. At least two correlation analysis methods including Pearson, Kendall, and Spearman and their P-values confirm that there was a relation between the three mentioned indicators and the number of COVID-19 cases. Changes of the effective indicators can be measured in other periods, so results may be useful for public health decision makers to mitigate the disease effects. As a future work, it is recommended to apply the methodology based on the number of COVID-19 deaths. Moreover, spatial modeling disease using these indicators is recommended as another topic for future studies.

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23

Creating a Set of High-Resolution Vulnerability Indicators to Support the Disaster Management Response to the COVID-19 Pandemic in South Africa

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This chapter presents the "COVID-19 Vulnerability Dashboard" for South Africa, developed by the CSIR for the National Disaster Management Centre (NDMC). It maps vulnerability to COVID-19 for the whole of South Africa, down to the level of the 103 576 enumerator areas (EAs). The COVID-19 Vulnerability Dashboard aims at helping the NDMC, local authorities and other stakeholders with disaster risk reduction (DRR) and evidence based decision making. Several national government departments have used the Dashboard for planning support. South Africa has large populations around the country vulnerable to COVID-19 because of the triple challenges of poverty, inequality and employment, and the high levels of HIV/AIDS and tuberculosis; high potential for rapid spread because of many dense informal settlements; and limited health resources. The COVID-19 Vulnerability Dashboard draws on our expertise in spatial analysis and disaster risk reduction of human settlements, and our tools, data and expertise — including the Green Book*, also developed in partnership with the NDMC, to deal with the likely impacts of climate change. Using a multi-criteria analysis approach, we created a set of vulnerability indicators based on domain knowledge, which was peer-reviewed by expert groups. These are disseminated by dynamic spatial mapping through an interactive, online dashboard.*

23.1 Background

Released in 2019, the *Green Book* is an online planning support tool providing quantitative scientific evidence on the likely impacts climate change will have on South Africa at the local authority level. It was co-funded by the CSIR and the Canadian International Development Research Centre (IDRC), and developed by the CSIR in partnership with the National Disaster Management Centre (NDMC) and others [1, 2]. For more, see Section 23.3.

The CSIR has been helping the NDMC deal with the COVID-19 pandemic in several ways, including disseminating the *COVID-19 Vulnerability Dashboard*, built rapidly using the technologies and expertise (strong spatial analysis and deep understanding of risk and vulnerability analysis of human settlements) used for the Green Book. This dashboard provides indicators at a high resolution for all of South Africa, to help role players understand better the risks COVID-19 poses to communities and the health system, and the associated vulnerabilities. The focus is on the location and vulnerabilities of communities, and the required response mechanisms (coping capacities) [3].

Note that these COVID-19 vulnerability indicators are not based on epidemiological modelling, but were intended to support the early prevention, mitigation and preparedness phase of the disaster management cycle. As more data become available, updated versions of the COVID-19 vulnerability indicators will be released and shared to improve their usability and accuracy. Unsurprisingly, several organisations have been conducting research on SARS-CoV-2 and COVID-19 in South Africa and these initiatives collaborate with one another, such as through the *COVID-19 Modelling Webinar Series* [4].

This chapter then reports on this COVID-19 Vulnerability Dashboard developed following disaster management principals for the NDMC and used by several national government departments (particularly the Department of Health) for planning support. It has three main components: the *COVID-19 Vulnerability Index*, the *COVID-19 Transmission Potential Indicator* and the *COVID-19 Health Susceptibility Indicator*. See Section 23.5 for details.

Significantly, this link between the Green Book and addressing the COVID-19 pandemic demonstrates that modelling climate change risk (a potential disaster) and pandemics (as a disaster emanating from a biological hazard), and their impacts, are closely related. Hence, adaption and mitigation for both could be intertwined [5, 6].

This section has provided the background to the COVID-19 Vulnerability Dashboard. The next section provides some background on South Africa and the context for developing the COVID-19 Vulnerability Dashboard. This is followed by sections on the situation regarding SARS-CoV-2 and COVID-19 in South Africa, the Dashboard itself and the challenges encountered. This chapter ends with some conclusions and a look at the way forward.

23.2 Government Structures in South Africa

Since 1994, South Africa has had a constitutional, multiparty democracy with three spheres of government: national, provincial and local. South Africa has nine provinces and 8 metropolitan (metro), 44 district and 205 local municipalities. Within these, there are 4392 wards and 103 576 census enumerator areas (EAs) [7, 8]. The metros and districts are contiguous, each consisting of a mix of urban, peri-urban and hinterland or rural areas (even in the metros). Within each district, the local municipalities are contiguous. Unfortunately, too many municipalities are dysfunctional, due to corruption, incompetence, limited resources and limited capacity [9].

This obviously complicates dealing with the COVID-19 pandemic effectively, efficiently and fairly, such as accessing data and resources. Our COVID-19 Vulnerability Dashboard helps by providing a mechanism to obtain data and map the very vulnerable spaces, etc. The Auditor-General of South Africa (AGSA) has found "*clear signs of overpricing, unfair processes, potential fraud . . . delays in the delivery of personal protective equipment and quality concerns*" and many problems with relief payments [9]. Subsequently, the AGSA has been conducting *real-time auditing*[1] of the key COVID-19 [10].

To deal with the pervasive poor municipal management, the South African Government initiated the *Khawuleza*[2] *District Coordination Service Delivery Model* on 18 October 2019. It aims to break the pattern of municipalities operating in silos and the "*lack of coherence in planning and implementation* [that] has made monitoring and oversight of government's programme difficult", to improve service delivery and beat the triple challenges of poverty, inequality and employment [11]. There will then be a single, integrated plan for each district and the national and provincial budgets and programmes will be referenced spatially to districts. Implementation began with the 2020/21 Budget cycle (from 1 April 2020), though this has probably been disrupted by the COVID-19 pandemic.

The mid-year estimate for 2020 for the population of was 59.62 million, with about 51,1% being female, about 28,6% being aged younger than 15 years and about 9,1% being 60 years or older. Life

[1] As opposed to conventional annual audits in the months after a financial year-end.

[2] *Khawuleza* means "hurry up" in Zulu.

expectancy at birth was estimated at 62,5 years for males and 68,5 years for females, with infant mortality at about 23,6 per 1000 live births. Internal migration is high, estimated to average over 550 000 per year between provinces during 2016-2021 [7, 12]. Many South Africans, even amongst the poorest, have two family homes, one in a traditional rural area and one close to the job market, so there is also much travel between the provinces — adding to the COVID-19 risks.

23.3 The Green Book

In 2008, the South African Department of Science and Technology (DST)[3] published a ten-year Innovation Plan to meet five grand challenges, including "global-change science with a focus on climate change" [13]. DST then published its draft *Global Change Grand Challenge National Research Plan, South Africa* [14] and its ten-year *Global Change Research Plan* [15].

A *flagship science-into-policy initiative* of this Challenge is the *South African Risk and Vulnerability Atlas* (SARVA). The first edition of SARVA was published in 2010 [16]. SARVA targets local government specifically, but is also aimed at academia and was in South Africa's submissions to the COP17 meetings on climate change [17]. The second edition of SARVA was peer-reviewed and published in 2017 [18].

Building on our experience with SARVA, the concept of the *Green Book* was initiated by the CSIR and released in 2019. It is an online planning support tool providing quantitative scientific evidence on the likely impacts climate change will have on South Africa at the local authority level. The Green Book also presents various adaptation actions that can be implemented by local government to support climate resilient development. The Green Book was co-funded by the CSIR and the IDRC and developed by the CSIR in partnership with the NDMC and others [1, 2].

The key problem is the rapid urbanisation in South Africa (largely into informal settlements), but with poor economic performance and growth (now exacerbated by the COVID-19 lockdown) and the constrained capacity of many municipalities to cope. Further, many people are very vulnerable to any shocks, be they social, economic or environmental — or a pandemic. The Green Book has been developed to help municipalities across the country understand their threats and plan suitable adaptation and mitigation [2].

The Green Book integrates the *grounding in science* of climate change adaption (CCA) with the *practical planning and operations* of disaster risk reduction (DRR). This *interplay* or *overlapping-world* for understanding risk better, particularly disaster risk, makes the work multidimensional and opens-up future possibilities — as has now happened with dealing with the COVID-19 pandemic.

The Green Book has been flexible enough to be adapted for other types of disasters, such as the COVID-19 pandemic.

23.4 SARS-CoV-2 and COVID-19 in South Africa

On 15 March 2020, a national state of disaster was declared [19]. A severe lockdown for 21 days was then declared and subsequently extended [20]. The lockdown caused a short-term decline in the rate of new COVID-19 cases [21] ("flattening the curve") and initially, the South African Government received praise for the rapid and drastic response, still before the first death from COVID-19. However, by 22 May 2020, arrests for allegedly contravening the lockdown regulations were made in almost 230 000 cases [22] and as at 29 June 2020, the Independent Police Investigative Directorate (IPID) was examining 588 complaints, including 11 deaths allegedly due to police action [23].

A risk-adjusted strategy of five Alert Levels was created on 23 April 2020 [24], ranging from

[3] Now the Department of Science and Innovation (DSI).

level 1, being almost normal (but with a curfew), to level 5, with drastic measures such as confining everyone to their home (except for essential services and goods), closing most businesses and complete bans on the sales of alcohol and tobacco products [25–27]. The then existing *hard lockdown* effectively morphed immediately into Alert Level 5 on 23 April 2020. Some of the Regulations were found to be distressing, arbitrary and irrational [28]. South Africa moved to Alert Level 1 on 21 September 2020 [29].

Unfortunately, COVID-19 cases increased rapidly in South Africa with 364 328 confirmed cases by 19 July 2020, behind only the USA, Brazil, India and Russia in total cases. From 28 August 2020, the rate of new infections in South Africa slowed to the extent that Peru (621 997 cases) overtook South Africa (620 132 cases), followed by other countries. However, the death rate in South Africa has been relatively lower. As at 30 September 2020, South Africa had the tenth highest number of cases, at 674 339, but the thirteenth highest number of deaths, at 16 734 [30–33]. A sentinel surveillance study in July/August 2020 in Cape Town of women attending public-sector antenatal clinics and public-sector patients living with HIV, found that 40% had SARS-CoV-2 antibodies, but only 4% of those with the antibodies had COVID-19. Such herd immunity "is likely the main contributor to the observed decline in the epidemic curve in the Cape Town Metro" [34].

There has been some contention over the modelling of infections and their consequences, with forecasts of deaths from COVID-19 in South Africa ranging from as high as 351 000 (made in March 2020) [35] to as low as less than 10 000 [36]. Excessively high forecasts of deaths have been made in other countries, as well [37] and there are several reasons for why such forecasting has failed [38]. On the other hand, some consider the actual deaths from COVID-19 to be much higher. The South African Medical Research Council (SAMRC), for example, estimate that the excess deaths (including from COVID-19) between 6 May 2020 and 15 September 2020 were 44 481 [39].

23.5 The COVID-19 Vulnerability Dashboard

23.5.1 Background

With the looming threat of the SARS-CoV-2 and COVID-19 pandemic, the NDMC approached the CSIR in March 2020 to assist with supporting under-capacitated municipalities in responding to the COVID-19 disaster and mitigating all possible risks. The focus was to provide conceptual and guiding input to the NDMC's approach to the national crisis. A key part of this response is the *COVID-19 Vulnerability Dashboard*, developed using the CSIR's tools, data and expertise, including the Green Book [3].

For modelling the COVID-19 risks, we provided conceptual input and supported the NMDC's spatial mapping of the vulnerabilities of communities to COVID-19, packaged into a spatial dashboard with vulnerability indices (using a web-based geographical information system(GIS)) to show how and where the NDMC should focus its efforts. We report here only on this *COVID-19 Vulnerability Dashboard*, which is underpinned by strong spatial analysis and deep understanding of risk vulnerability analysis of human settlements,as gained through the Green Book project [40].

The COVID-19 vulnerability indicators for all of South Africa are calculated at the level of the 103 576 EAs, but are displayed and reported in the Dashboard at the level of the 4 392 wards, as that is the relevant granularity for making interventions (each ward is represented by a municipal councillor). These indicators were developed with conceptual input from the Albert Luthuli Centre for Responsible Leadership (University of Pretoria), and help role players understand better the risks COVID-19 poses to communities and the health system, and the associated vulnerabilities. The questions most often asked by these role players are:

- Where are the communities that will struggle to apply the principles of social distancing?
- Are there areas that will struggle to maintain the principles of good basic hygiene due to a lack of basic water and sanitation services?
- Where are the elderly and other vulnerable communities located?

- Can the potential hospitalization demand be met with an adequate supply of beds, equipment, health workers and emergency personnel [3]?

These questions fall into two groups: the location and vulnerabilities of communities, and the required response mechanisms (coping capacities). One needs to understand these vulnerabilities to anticipate the risks and identify the high-risk intervention areas. The following are the main indicators that have been developed:

- Risk = Exposure to hazard × (Vulnerability / Coping capacity)
- COVID-19 vulnerability index = Transmission potential + Health susceptibility
- Transmission potential = Informality + Lack of access to basic services + High population density
- Health susceptibility = Weighted age factor + (Amplification correction factor × Weighted age factor)
- Amplification correction factor = Disease burden + Poverty rate

The COVID-19 Vulnerability Dashboard was created on 3 April 2020, made fully public on 6 May 2020 and as of 22 July 2020 had received 2601 views. It has been used by the NDMC, the National Department of Health, other departments, municipalities and others for planning support.

23.5.2 The Dashboard Platform

Esri's ArcGIS Dashboard [41] was used as the technology platform for rapidly disseminating the analytical results and for them to be openly accessible by national, provincial and local government officials and decision-makers in South Africa. The ArcGIS Dashboarding environment was chosen because of the wide user reach, reliability and immediate availability of the data assured by an openly accessible web-based platform. The use of dashboarding technology also allowed users of the COVID-19 Vulnerability Dashboard to explore interactively the COVID-19 vulnerability analysis data by dynamically filtering data for the spatial extent of their choice (national, provincial, district municipal level, local municipality or ward level), making the COVID-19 Vulnerability Dashboard an invaluable decision support tool at all levels of South African government. Lastly, the COVID-19 Vulnerability Dashboard, as the single source for accessing the COVID-19 Vulnerability Index data, ensured decision makers the trusted reliability of accessing the data and metadata for decision making directly from the CSIR as the COVID-19 Vulnerability Index data custodian.

A valuable outcome has been the development and provision of data-sharing facilities, such as the COVID-19 Vulnerability Dashboard, to help with the effective planning and management of the response to the pandemic. Using dashboards for health evolved as web-based GIS platforms became more capable at providing ready access and real-time sharing of spatially-referenced operational data, a vital component for evidence-based decision-making in disaster situations. Dashboarding technology has played an important role in the spatial analysis and rapid data-sharing related to the COVID-19 pandemic around the world (such as [31, 32, 42, 43]), where accurate and timely information is required to support decision-makers so that epidemic prevention, control and management can be efficiently carried out.

23.5.3 Overview of the COVID-19 Vulnerability Dashboard

The following are some details of how the *COVID-19 Vulnerability Dashboard* has been assembled and how it functions.

- **Version control and updates**: The COVID-19 vulnerability indicators were designed and developed based on currently available data and knowledge. Given the unfolding and evolving nature of the COVID-19 pandemic, both locally and internationally, the assumptions that informed the creation of these indicators, the input data and critical weights used in calculating the indicators should be updated, corrected and refined as new information and understandings emerge. As more data becomes available, the aim is to release updated versions of the COVID-19 vulnerability indicators and to share these to improve their usability and accuracy.

- **Limitations and considerations in use**: The COVID-19 vulnerability indicators are not based on epidemiological modelling. The development of the indicators was intended to support the early prevention, mitigation and preparedness phase of the disaster management cycle, and their use should, therefore, be restricted to supporting and informing disaster management decision making. Care has been applied in testing the assumptions on which the indicators are based with a small expert user group, but we recommend that those who use these indicators should familiarise themselves with the input data and assumptions made, acknowledging that the resultant indicators might not reflect the reality on the ground.

- **Background of the disaster management cycle**: Four important phases (mitigation/ prevention, preparedness, response, and recovery) are applicable in any disaster management cycle. Disaster management is the process of focusing on reducing and/or avoiding the potential or expected losses from any hazard (e.g. loss of life or livelihoods, economic loss); ensuring that timely assistance is provided to affected, or potentially affected, communities; and facilitating the rapid and effective recovery from a disaster event through "building-back" better. When a disaster strikes (e.g. the spread of an infectious disease such as COVID-19), government departments and sectors, businesses, NGOs, industries and civil society will engage and respond differently with the disaster management cycle according to their mandates, responsibilities and contingency plans. Although the phases can overlap, differ concerning their purpose and objective and last varying lengths of time it is assumed that the phases would strive to:

    1. **Mitigation/prevention phase**: Minimising the devastating impacts of the disaster. The focus here is on preventing or reducing the exposure to the disaster and mitigating vulnerability;
    2. **Preparedness phase**: Planning the response strategy and capacitating emergency managers to provide the best response possible. The focus here is on strengthening various coping capacities;
    3. **Response phase**: Implementing efforts to minimise the consequences of the disaster and reduce associated mortality and morbidity. In this phase, humanitarian action and aid are often applicable. The focus here is on coordinating of various efforts to preserve life and livelihoods, and to provide essential services and/or subsistence to those affected by the disaster; and
    4. **Recovery phase**: Returning the community and affected groups to a new state of normal. The focus here is on striving to "building-back" better.

- **Purpose of the indicators**: In the early phase of the disaster management cycle (mitigation/prevention and preparedness), data and information are vital to the success of the subsequent phases (response and recovery). With the COVID-19 pandemic in South Africa, many sector departments faced similar questions at the start of the outbreak. Departments were concerned with understanding better the risks posed by COVID-19 to communities and the health system, and the associated vulnerabilities.

- **Role of the indicators**: The questions outlined above can be divided into two groups, those relating to the vulnerabilities of communities and their location, and those relating to the response mechanisms (coping capacities) to be put in place to offset these vulnerabilities. To anticipate the risks and identify high-risk intervention areas, it is vital to understand the vulnerabilities of communities. The subset of indicators presented in the following sections is thus concerned with looking at the vulnerabilities present in communities and identifying areas in need of targeted coordinated interventions and early response.

23.5.4 COVID-19 Vulnerability Index

The *COVID-19 Vulnerability Index* attempts to indicate the vulnerability of communities to the potential impact of COVID-19, based firstly on how effectively the spread of COVID-19 can be contained (the transmission potential), and secondly on the population's susceptibility to severe disease associated with contracting COVID-19 (the health susceptibility). For this, the following formula is used:

$$Vulnerability\ index = Transmission\ potential + Health\ susceptibility \tag{23.1}$$

We used an indicator-based assessment method to construct the composite COVID-19 vulnerability indicator. This indicator was computed using multi-criteria analysis (MCA), a spatial analysis technique that combines similar descriptive variables into indicators, and indicators into a final descriptive composite index. The different variables contributing to the indicators were standardized using the min-max normalisation process, which allowed the different variables to be added together to form the indicators. Min-max normalisation linearly scales data to fall within a specified range and we used 1–100 for this standardization process. In this method, each Enumeration Area (EA) in South Africa was compared and related to all the other EAs in the country, thus ensuring the COVID-19 Vulnerability Index could facilitate a coordinated national response. The following formula is used to normalise the data:

$$MinMax = \frac{X_i - X_{min}}{X_{max} - X_{min}} \times (End\ of\ range - Start\ of\ range) + Start\ of\ range \tag{23.2}$$

After the standardization process, an equal-weighted multi-criteria analysis was performed in order to add the different indicators (*transmission potential* and *health susceptibility*) together to form the vulnerability indicator. A weighted average was calculated to provide the final score for each feature (variable/indicator), thus producing a score between 1 and 100 for each EA, where 1 is least vulnerable and 100 is most vulnerable.

Figure 23.1 is a screen shot of the COVID-19 Vulnerability Dashboard, showing high vulnerabilities in the rural areas in the eastern areas. However, the extremely vulnerable areas (red dots) are actually scattered across the country, particularly in high density but small EAs in urban areas, though they are unsurprisingly not so obvious in such a small-scale map.

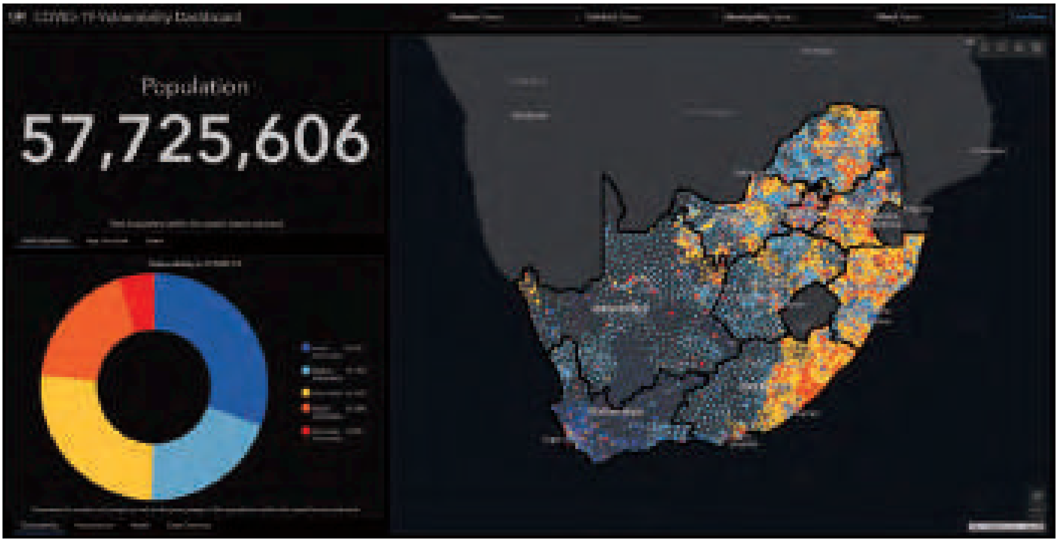

FIGURE 23.1
COVID-19 Vulnerability Dashboard, showing vulnerability [44].

23.5.5 COVID-19 Transmission Potential Indicator

The *COVID-19 Transmission Potential Indicator* identifies areas where existing living conditions could make it difficult to maintain social distancing and practice good basic hygiene in order to contain the spread of COVID-19. The following formula is used:

$$Transmission\ potential = Informality + Basic\ services + Population\ density \tag{23.3}$$

This indicator classifies EAs throughout South Africa according to transmission risk, producing a score between 1 and 100 (where 1 refers to least risk and 100 to extreme risk), indicating areas where the virus might spread more rapidly than other areas in the country. Three main variables were used as inputs into this indicator (the higher the value for each, the worse the risk):

- **Informality**: Number of informal dwellings per EA (informal dwellings and informal backyard structures).
- **Basic services**: The *lack of access* to basic services, being the number of households without basic access to running water and sanitation.
- **Population density**: Number of people per hectare.

Transmission potential has a similar pattern to that of vulnerability, see Figure 23.1.

23.5.6 COVID-19 Health Susceptibility Indicator

The *COVID-19 Health Susceptibility Indicator* provides an indication of areas where larger numbers of people are potentially more susceptible to being adversely affected by COVID-19 (suffering more severe disease). Given that current observations indicate that mortality rates associated with COVID-19 tend to be higher in elderly populations and those individuals with underlying health conditions (one or more co-morbidities), these two factors were included in the health susceptibility (sometimes referred to as epidemiological vulnerability) indicator. Since information on the epidemiological vulnerability of population groups is limited, it is suggested that this indicator be complemented and refined based on local assessments and observations. The health susceptibility indicator was derived by assigning specific weights to various age categories and assigning a higher susceptibility to groups of people with known co-morbidities. The following formula is used:

$$\begin{aligned} &Health\ susceptibility = Weighted\ age\ factor + \\ &(Amplification\ correction\ factor \times Weighted\ age\ factor) \end{aligned} \tag{23.4}$$

Weighted age factor: Weights were assigned according to observed death rates. The known death rates reported for Asian and European countries were used to weight the various age groups in each EA to estimate how many people might be more susceptible to severe disease (the 0–4 age category was elevated in certain provinces/local municipalities based on high infant/child mortality rates in South Africa). The following formula is used:

$$\begin{aligned} Weighted\ age\ factor = {} & Total[total0\_4(age0\_4 \times CMRF) \\ & + total5\_39(age5\_9 + \cdots + age35\_39) \times 0.002) \\ & + (total40\_49(age40\_44 + age45\_49) \times 0.004) \\ & + (total50\_59(total50\_54 + total55\_59) \times 0.013) \\ & + (total60\_69(total60\_64 + total65\_69) \times 0.036) \\ & + total70\_79(total70\_74 + total75\_79) \times 0.008) \\ & + total80over(age80over \times 0.21)] \end{aligned} \tag{23.5}$$

Where,

- **Child mortality rate factor (CMRF)** = Value between 0.002 (low infant/child mortality rates) to 0.004 (high infant/child mortality rates), based on observed child mortality rates in local municipalities.

- **Amplification correction factor**: This factor was derived from taking both disease burden and known poverty rate into account. Current observations show that people with a history of one or more co-morbidities (disease burden) are at higher risk of more severe disease from COVID-19. There has been much speculation as to the severity of the impact of the COVID-19 virus and whether it will affect low and middle-to-low income countries more severely due to factors such as access to medical facilities, malnutrition, poverty and/or lifestyle. The following formula is used:

$$Amplification\ correction\ factor = Disease\ burden + Poverty\ rate \tag{23.6}$$

- **Disease burden**: Prevalence of HIV infections as well as life expectancy (as a proxy for underlying health conditions).

- **Poverty rate**: Household income below R76 400 *per annum* (as a proxy for malnutrition, healthy food choices, lifestyle choices and access to medicine and health support).

Figure 23.2 is a screen shot of the COVID-19 Health Susceptibility Dashboard. This shows a different pattern from those for vulnerability (Figure 23.1) and transmission potential, with lower risks in the Transkei (eastern part of the Eastern Cape) but higher risks in KwaZulu Natal and the south-western parts of the Western Cape, for example.

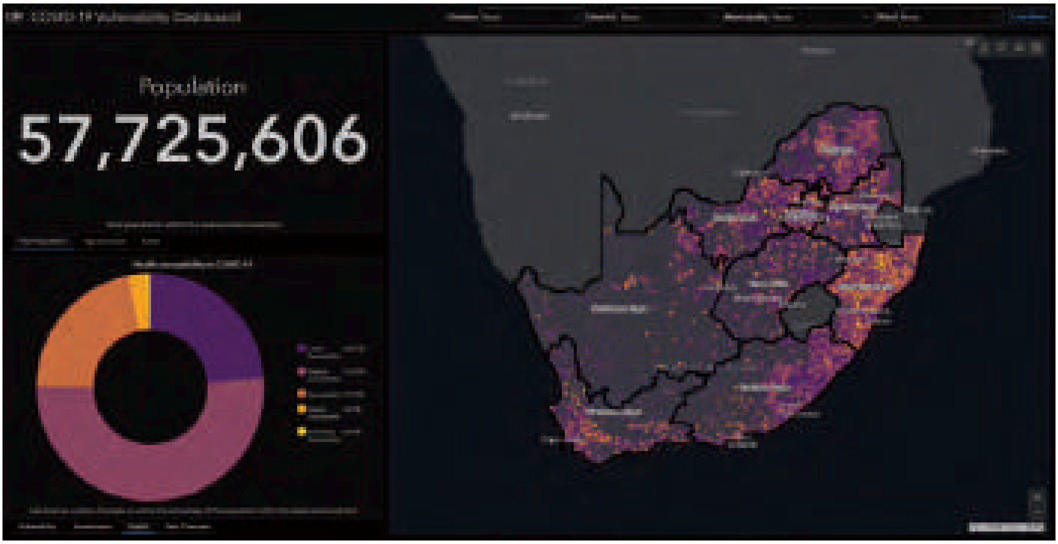

FIGURE 23.2
COVID-19 Vulnerability Dashboard, showing health susceptibility [44].

23.6 Challenges

23.6.1 Data Sources

Concerns have been raised at the general lack of access to data about SARS-CoV2 and COVID-19, which could be constraining unified action against the pandemic [45]. In particular, case data at a high (fine) spatial resolution are critical for complete and full risk assessments for successful disaster response and planning. Many feel that open data should be the default [46], with even the Organisation for Economic Cooperation and Development (OECD) declaring that open science is critical to combatting COVID-19 [47].

Fortunately, we were able to draw on our extensive data holdings, for which we have done quality assurance, cleaning and integration over the years for various products and services. For the COVID-19 Vulnerability Dashboard, the key data sources used to compile the indicators at the EA level are:

- Population demographics 2018, from GeoTerra Image.
- Building Based Land Use 2018, from GeoTerra Image.
- Mid-year population estimates at the district council level for 2002-2018, from Statistics South Africa (StatsSA).
- 2011 Population census and its EA demarcation, from StatsSA.
- Health Data for 2016, from Quantec.

23.6.2 Quality

There are several problems with the quality of the data on COVID-19 cases, recoveries and deaths. The first is identifying the relevant cases and documenting and reporting them correctly. This has been an issue in South Africa, as some clinicians and pathology laboratories did not complete the documentation properly for all the patients who presented for tests, even though it is a notifiable disease. This increased the administrative burden on the NICD, as its staff had to search for the missing patient information of the confirmed cases, so that the patients could be contacted to see if they actually needed treatment and to trace everyone with whom they had been in direct contact, so that they could be warned, etc [48].

This obstacle is systematic, unfortunately: Table 23.1 shows *Number and percentage distribution of deaths by method used to ascertain the cause of death, 2017*, from the report, *Mortality and causes of death in South Africa: Findings from death notification, 2017* [49]. The data for this report are "completed by medical practitioners and other certifying officials", yet in one third of the cases (33.3%), these professionals did not know how they ascertained the cause of death!

TABLE 23.1
Method of ascertaining the cause of death [49]

Method of ascertaining the cause of death	Number	Percent
Autopsy	44 848	10,0
Post mortem examination	116 246	26,0
Opinion of attending medical practitioner	64 663	14,5
Opinion of attending medical practitioner on duty	7 777	1,7
Opinion of registered professional nurse	52 810	11,8
Interview of family member	5 238	1,2
Other	6 033	1,4
Unknown	344	0,1
Unspecified	148 585	33,3
Total	**446 544**	**100,00**

Then comes tracking each case to its conclusion: recovery (which requires the case file to be closed and reported properly) or death. A key issue with the latter is the structuring of the death certificate and whether COVID-19 gets recorded as the immediate cause, an underlying cause, a significant condition contributing to death, or not at all [50].

It is also necessary to get accurate data on the locations of cases, for tracing potential contacts and other interventions. While South Africa has a suite of standards for addresses [51], it is not yet widely used and the forms for COVID-19 do not cater for it. The result is that municipalities, provinces and national departments are having to manually and laboriously geocode the addresses [52]. A consequence is over-counting, such as when an infected person is tested several times but each test gets recorded as a separate case of COVID-19: this could result in the total number of cases fluctuating as the duplicates get identified and removed later.

Finally, of course, there needs to be metadata, that is, documentation of the data.

23.7 Conclusions and the Way Forward

This chapter has presented the *COVID-19 Vulnerability Dashboard* for South Africa, developed by the CSIR originally for the NDMC. The Dashboard provides the *COVID-19 Vulnerability Index*, *COVID-19 Transmission Potential Indicator* and *COVID-19 Health Susceptibility Indicator* at ward level. It provided critical information for sector departments and under-capacitated municipalities early in the disaster management cycle. The purpose was to highlight the high-risk intervention areas so that decision makers could intervene with the appropriate adaptation measures where needed. The COVID-19 Vulnerability Index, COVID-19 Transmission Potential Indicator and COVID-19 Health Susceptibility Indicator were made available for free and were peer-reviewed by various stakeholders.

The ESRI dashboard environment was used as this supported an interactive, dynamic and accessible approach in which to convey these critical datasets in an open-access manner. Open access to data is critical in the disaster management cycle if anyone is to respond effectively and timeously. The open access nature of the dashboard proved highly affective as more than 2600 entries to the dashboard where recorded between May 2020 and July 2020. Since the dashboard was created, published and hosted by the CSIR infrastructure, it provided the opportunity to correct, alter or add any information deemed necessary with little additional effort.

When the open dashboard was released, many of the users of the dashboard requested additional supportive information to be added and loaded. The most requested included the location and capacity of hospitals, hospital admission rates and the location of quarantine facilities. Including these datasets into the COVID-19 Vulnerability Dashboard proved a much harder task as the team ran into data custodian restrictions, data censorship, fragmented data capturing techniques and a general lack of critical information being made open and accessible to decision makers. The lack of cooperation and sharing of critical datasets resulted in these datasets being excluded in the dashboard.

An additional request made by users was to gain access to the spatial information in the back-end. Many of the decision makers and researchers with in-house GIS and analytical capability requested copies of the information for their own decision-making purposes. Since the dashboard did not support the functionality to download the spatial information, a file hosting service was set-up in the cloud to share the information with these decision makers. This resulted in many copies of the various vulnerability indicators being used even more effectively and widely for various processes.

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24

Rapid Development of Location-based Apps: Saving Lives during a Pandemic – the South Korean Experience

Bola Michelle Ju, Lesley Arnold and Kathrine Kelm

The first confirmed case of COVID-19 in South Korea was recorded in January 2020. The government took swift wide-ranging measures to protect the health and wellbeing of citizens using geospatial data and information communications technology, which included immediate upgrades to the Emergency Broadcast System. Several location-based applications were developed during the height of the evolving pandemic. The speed with which these applications were developed and subsequently used by the community was a remarkable feat, and one that has set a benchmark for other countries aiming to flatten the curve of infections. These Apps have delivered benefits contributing to the prevention of community transmissions, particularly from the influx of overseas travellers. The Smart City Data Hub system enhanced resiliency during the second wave in Daegu where mass infections eventuated at a large religious gathering. The system enabled the analysis of pathway tracings of people who attended the event using big data analytics and data provided by credit card, transport and mobile companies. This chapter describes seven major location-based applications. It discusses the mechanisms behind each system, the technological and data foundations that enabled their development and operation, and how they are contributing to strengthening resiliency efforts during the COVID-19 crisis. The chapter also describes how the South Korea Government has previously made use of geospatial information and data processing systems to respond to past pandemics, and how the lessons learned from these earlier developments has contributed to the success of COVID-19 response efforts today. The major technology, data, policy and institutional arrangements that enabled the COVID-19 applications to be developed in such a short space of time are discussed, including broad direction for future research and development opportunities to manage future pandemics.

24.1 Introduction

Global pandemics have occurred with devastating impact over the past centuries. The well-known Black Death outbreak in the 14th century killed around 50 million lives [1], and the Spanish flu is typically estimated to have caused between 17 and 50 million deaths worldwide from 1918 to 1920 [2] [3]. In the 21st century, major pandemics include SARS (Severe Acute Respiratory Syndrome) in 2002, Swine flu in 2009, MERS (Middle East Respiratory Syndrome) in 2015, and the most recent COVID-19 from late 2019.

The first confirmed COVID-19 case in South Korea was recorded on 19 January 2020 – a Wuhan resident visiting South Korea [4]. The number of cases increased rapidly over the following months with over 13,550 confirmed cases, recorded as of 15 July 2020 [5]. The spread of the disease was exponential. In January, there were only 11 confirmed cases. By February, the number grew to 3150 and in March 9786. With government interventions and the deployment of location-based applications to enable social distancing, the curve began to flatten, with the number of cases increasing to 10,765 in April and then 11,468 in May[1] [6].

The COVID-19 outbreak globally, is proving inherently difficult to manage because transmission can occur when people are pre-symptomatic or asymptomatic and not just when they have symptoms. This has meant that people may be unaware that they have the virus and are inadvertently spreading the disease [7]. The range of channels through which people can become infected has also made the spread of COVID-19 difficult to manage, with 'contact-based' transmissions caused by respiratory droplets, direct contact with contaminated objects and surfaces, and so forth [7].

To limit the spread of the disease and prevent community infections, the South Korean government launched a location-based service that uses mobile phone GPS technology to send notifications, via the Emergency Broadcasting Service, to people living in the vicinity of reported COVID-19 case/s. This service communicates the routes taken by COVID-19 patients and the places they visited. This official information is being released so that people will be able to go for COVID-19 screening in case they find overlapping pathways [8], and to permit people to avoid visiting affected areas if they are still being disinfected [6].

Private companies have also leveraged location-based health-related data to create more sophisticated visualisation applications using geospatial data so that people can see the contaminated areas and pathways of confirmed cases throughout the country. By taking prompt action with location-based applications and services, the government and private sector have jointly enabled South Korea to successfully flatten the curve - saving many lives and increasing community resiliency against COVID-19 in the longer term.

Between 30 January to 18 March 2020, several location-based applications were developed; each application playing a vital (but different) role in managing COVID-19 transmissions and needs – from tracking and tracing COVID-19 cases to locating pharmacies with available mask stocks, and so on. This chapter describes seven applications that have played a substantial role in communicating essential services to citizens during the pandemic, and controlling and preventing community-spread infections. The applications are:

- **Emergency Broadcasting Service** (CBS, cellular broadcasting service): Emergency text messaging transmission service that alerts people in the near vicinity of pathways taken by the COVID-19 infected people.
- **Coronavirus Map**: A website showing the location of all confirmed cases.
- **Corona Now**: A map-based information service providing information on national and international confirmed cases and mortalities, as well as real-time news broadcasts and the location of nearby COVID-19 screening centres, quarantined areas, and testing locations.
- **Now and Here**: Developed by ITL (Innovative Technology Lab), the 'Here and Now' App calculates a mix of risk factors and the percentage of risk associated with commuting routes based on identified COVID-19 cases.
- **CoBaek Plus**: Launched by a private developer Tina3D, CoBaek Plus App sends an alarm to a user when they are within 100 meters of a place that has had a confirmed case.
- **Masks Stock App**: An information system developed to resolve 'mask stock' shortages by showing the availability of face masks at various locations and recording purchases - where, when and by whom - to manage supply equitably.

[1] KCDC Statistics are accessible at https://github.com/jooeungen/coronaboard_kr/blob/master/kr_daily.csv

- **Self-Quarantine App**: A self-monitoring and self-diagnosis service for citizens that is also used by government to monitor self-quarantined individuals when they are outside of designated quarantine areas.

There are numerous factors that contributed to the rapid development of COVID-19-related Apps, but the overreaching factors can be categorized into two major components:

1. Systems
2. Policy/legal and institutional arrangements

In terms of systems, the South Korean Government has a robust National Spatial Data Infrastructure (NSDI) in place. The NSDI provided the underpinning development environment for COVID-19 location-based applications. The NSDI consists of modern technologies, governance and policy frameworks, and wide-ranging fundamental and specialist data themes. The success of the NSDI is a result of a comprehensive and continuously updated NSDI Development Strategy that had guided enhancements to the NSDI over the past 20 years. The NSDI elements and policy/legal and institutional factors that have contributed to the success of the COVID-19-related applications and systems are described further in Section 24.4.

24.2 Location-based Apps

Location-based services are defined as 'services that integrate a mobile device's location (or position) with other information to provide added value to a user' [9]. Location-based applications (Apps) or websites, such as the Self-quarantine App, are created using these location-based services (Figure 24.1). Location data is used to pinpoint, visualise and integrate data, making it easier for people to understand the complex relationships between people, the economy and the environment.

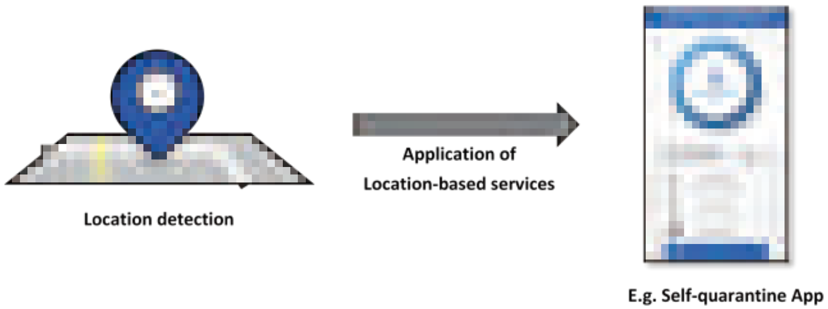

FIGURE 24.1
Location-based services (LBS) and example of LBS App: Self-quarantine App

According to Seoul economy statistics, between February and April 2020, South Korea was ranked as having the highest growth rate (135%) in monthly downloads of medical Apps during the COVID-19 pandemic. This contrasts with 65% growth rates, globally [10].

As COVID-19 spreads by personal contact, private companies and individuals quickly faced the challenge of developing location-based applications to show the locations of people with infections, enable social distancing, self-monitoring and self-diagnosis, and provide updates about new local cases, and the mitigation of face mask stockpiling. These applications, developed between January and March 2020, have played a significant role in saving lives and flattening the rate of infections.

The rapid development of COVID-19 applications was facilitated by several overarching factors including a high-level of science and technology education in both the developer- and user-community; a robust NSDI built on modern technologies, a solid data foundation and an open data policy; ubiquitous internet access and a high-number of mobile users able to access free smartphone Apps; and public trust in authorities and a 'collective' community culture.

The seven major Apps and websites' services, represented in Figure 24.2, are described below including their features, data sources and the location-based services used to control and prevent the spread of COVID-19 during the height of the pandemic.

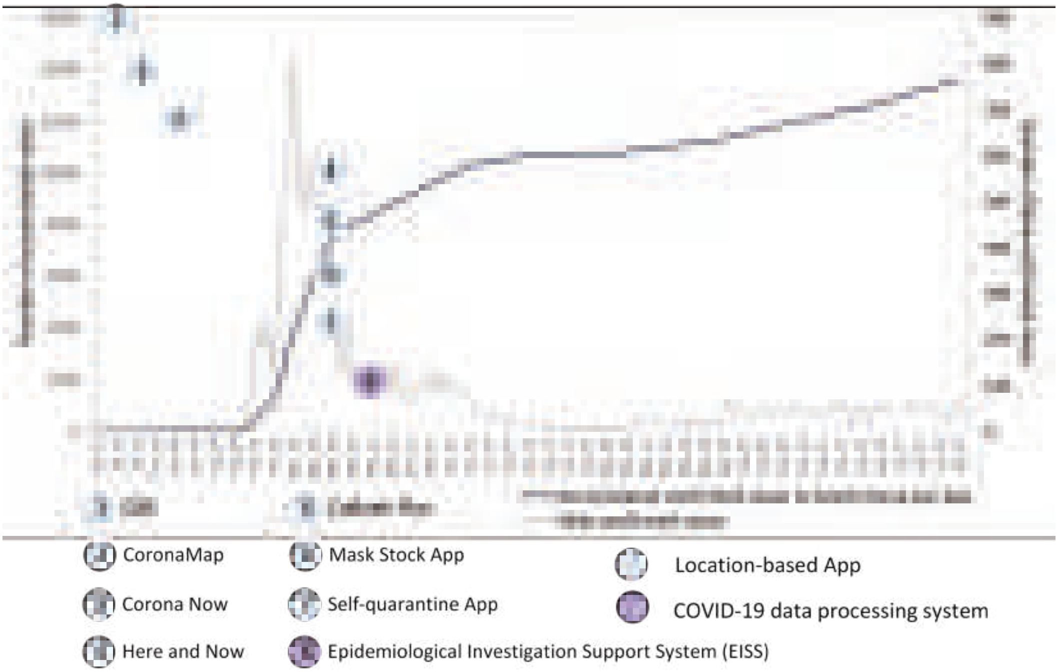

FIGURE 24.2
COVID-19-related location-based Apps in different timelines, and number of COVID-19 cases in South Korea; Statistics source: [5]

24.2.1 Emergency Broadcasting Service

The Emergency Broadcasting Service or CBS (Cellular Broadcasting Service) was first implemented for 2G cellular phones in 2005 by the Ministry of Interior & Safety (MOIS). The service was developed to alert citizens to impending natural and manmade disasters in their local area so they could prepare early for potential eventualities [11], and to enable authorities to quickly respond to those natural disasters and avoid missing the 'golden time' [12], which occurs within the first hour following the onset of an emergency or disaster.

While the Ministry of Interior and Safety (MOIS) oversees the central CBS system and its operation, metropolitan and local governments can also send CBS messages to local residents and visitors in the vicinity of an emergency. The CBS service is an 'opt-in' subscriber service. Subscribers consent to having their mobile phone GPS location identified so that they can receive alerts. There is also an option to receive translated messages in English and Chinese.

In an endeavour to curb the contagion, municipalities throughout South Korea have been using Code 3 alerts to notify subscribers in the vicinity of COVID-19 infectious people.

The CBS uses COVID-19 confirmed patient 'pathway' data made available by the Korea Centers for Disease Control & Prevention (KCDC). More specific information on COVID-19 patients' pathways is provided by local government. In South Korea, the data about COVID-19 patients is considered public data (i.e. the data collected from confirmed patients).

In addition to sending CBS alert messages to people living in the nearby vicinity of a patient, pathway tracing data is also uploaded to the MOIS CBS official website. In this way, all citizens can access the pathway data and, in turn, make informed decisions about social distancing and personal safety while commuting.

South Korean Laws on managing and openly sharing information on patients with infectious disease were enforced after the MERS outbreak in 2015 [8]. At the time of the MERS outbreak, South Korea ranked second for MERS confirmed cases, and the country was criticized for not having released patient location data publicly. This led the government to bring in new laws to enforce the sharing of information on the location of patients with infectious diseases.

However, while CBS has brought about far-reaching beneficial outcomes in the prevention of secondary infections, there have been criticism over privacy issues. Even though patients are not identified outright (i.e. by their name and address, which is protected data), citizens still dread stigma, fear losing their jobs or experiencing other potential hardship [13].

24.2.2 CoronaMap

The CoronaMap website enables people to make a visual inspection of where confirmed COVID-19 cases are using a map interface. This was an important design feature; while health officials release locations of COVID-19 patients, the official information is not very visual. CoronaMap not only pinpoints patient locations, it also connects the places they have visited with lines to show their pathways.

The data for CoronaMap is derived from the KCDC official website and managed by the CoronaMap database management team. An open API map from the Naver[2] cloud platform provides the base map detail. CoronaMap includes a function that can determine a user's location using their mobile phone GPS. This enables them to compare their location with COVID-19 cases on the map and make an informed decision to go for COVID-19 screening because they have overlapping pathways (Figure 24.3).

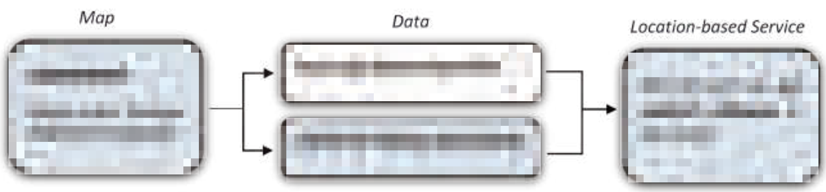

FIGURE 24.3
CoronaMap data components and service provided to end users

A link to CoronaMap was communicated through social media channels, such as Kakaotalk (a free mobile instant messaging application for smartphones) and Facebook. News of the application spread quickly, and the website had over 2.4 million viewers on the day it was launched [14]. According to in an article published by Hankyoreh Press,[3] Dong-Hoon Lee expressed on his Facebook page 'The coding and the UI (User Interface) is still messed up. But I hope the website provides a useful service to the local community'. The public responded with messages of thanks and comments of gratitude for freely providing the CoronaMap website.

[2]NAVER Co., Ltd. is South Korea's largest web search engine, as well as a global ICT brand that provides services including LINE messenger, currently with over 200 million users from around the world, the SNOW video app, and the digital comics platform NAVER WEBTOON. Retrieved from: https://www.navercorp.com/en/naver/company

[3]Hankyoreh Press is accessible at https://www.w3newspapers.com/south-korea/

24.2.3 Corona Now

Corona Now was initially developed to provide COVID-19 national and international statistics dashboard and to fill an information delivery gap [15]. At the time, KCDC statistics on confirmed patients' pathways were only available via CBS messaging and there was a lack of information delivery on national and international dashboard in which people could see confirmed cases, number of discharged patients, or number of deaths at a glance. National statistics were only available at the country-level, and people wanted to have more accurate data at the district, province and neighbourhood levels, and be able to compare statistics at a global level. In addition to the statistics dashboard, Corona Now has added a location-based information service including the 'find the closest screening centre' feature.

Since its development, the community have used Corona Now extensively. Like CoronaMap, the Corona Now website link was communicated via social media. The Website was visited over 30,000 times in the first few days it was released. By 25 February, the total number of web visitors reached 2 million and was ranked first in the 'Naver Search' [16].

A key success of Corona Now stems from the fact that it draws information from reliable sources. Having access to authoritative data from the Korea Centres for Disease Control & Prevention (KCDC), Johns Hopkins University Centre for Systems Science and Engineering (CSSE), and the China Medical information website[4] [17] has meant that developers could analyse and process the data with confidence (Figure 24.4). This, in turn, has led to a high-level of community trust in location-based services.

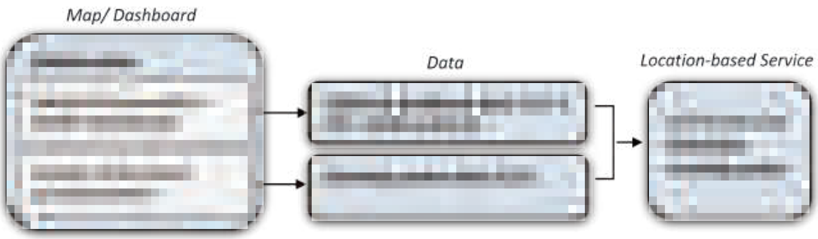

FIGURE 24.4
Corona Now data source, features and location-based service

24.2.4 Now and Here

The 'Now and Here' App is a community-based information sharing platform developed by private company Innovative Technology Lab (ITL). On 3 March 2020, ITL launched a new COVID-19 preventive service on the 'Here and Now' platform. The new feature calculates a mix of risk factors by detecting users' location and nearby infected areas. It also shows the percentage of 'risk' associated with commuting routes based on identified COVID-19 cases [18].

The Now and Here App not only shows the relative locations of the users to recent patient pathways in the vicinity, but also shows the closet COVID-19 screening centres, nearby ShinCheonJi churches, and recent news posts on COVID-19 (Figure 24.5). In March 2020, the mass outbreak of COVID-19 confirmed cases surged from a large gathering at the ShinCheonJi church in Daegu and spread the virus throughout the country. ShinCheonJi believers returned to their local ShinCheonJi churches and continued to spread the virus to the local community. Each local government hence decided to collect all ShinCheonJi Church locations, which were officially disclosed via the local government's official website (i.e. Seoul Metropolitan website, or Incheon city website), from which people could locate the church locations in their vicinity and avoid those areas [19]. The confirmed patients' data is sourced from KCDC, while news information is collected from reliable websites.

[4] China Medical information website is accessible at www.dxy.cn

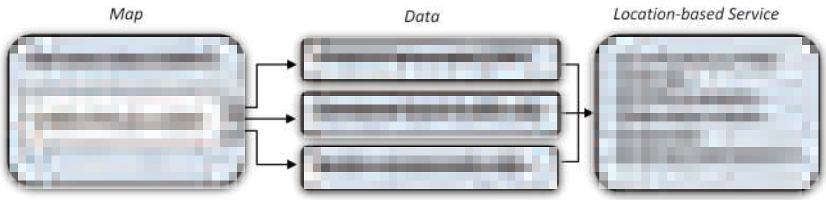

FIGURE 24.5
Here and Now data source and website services

The value of the new feature in the Now and Here App is that information is updated and refined as more information becomes available. For example, if a user posts a question in the App (e.g. where can I purchase face masks?); other users respond by uploading answers, relating to the user's region of interest within a radius of 0.5 km, 1 km, 2 km, 5 km, 10 km from the user's current location [20].

The Now and Here App has become one of the most essential Apps to have during the COVID-19 pandemic, particularly for commuters. In March 2020, the Now and Here App was ranked as one of the most downloaded Apps in Korea [21], because it provides diverse 'community-driven' location-based services that support both social-distancing measures and community well-being though knowing where essential services can be located [18].

24.2.5 CoBaek Plus

The 'Corona 100m' App was launched February 2020 and rereleased as 'CoBaek Plus' App on 18 March 2020 by private company Tina3D.[5] Corona 100m was first created to provide a visualisation of COVID-19 patient pathways, including the ability to send alarm messages to users, when they approach within a 100m radius of a confirmed patients' recent pathways. In March 2020, the company updated 'Corona 100m' as 'CoBaek Plus' by adding new features such as Mask stock availability, and COVID-19 pathway tracing and withdrew the Corona 100m App.

'CoBaek Plus' has proven to be an ideal App for commuters and travellers who do not receive CBS messages nor regularly check COVID-19 pathway information. It is one of the most downloaded Apps in Korea. CoBaek Plus has achieved over 112,515 downloads and the earlier version Corona 100m over 3,400,000 downloads as of February 26 [22]. One of the key success factors, is that the App is intuitive and easily downloaded by users. The developer, Tina3D, has not only received attention from the South Korean community but also from international communities and organizations. Mr. Bae, a board member of the company, said in an interview: 'We are currently in discussions with the Inter-American Development Bank (IDB) and the World Bank, Mexico and Spain' [22].

CoBaek Plus uses COVID-19 Pathway data released publicly by KCDC, and Mask Stock data is sourced from the government's open data platform.[6] A map API (Naver) is used as the base map for the App and other location-based data, such as mask stock and pathway tracing data, are sourced from the Mask API (Figure 24.6) and pathway tracing API (from reliable sources such as Kaggle), respectively. National and International COVID-19 statistics data are sourced from KCDC for the national data, from WHO for international statistics and from BIDU for COVID-19 Statistics in China [22].

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[5] TINA3D is accessible at http://www.tina3d.com/

[6] South Korea Open Data Platform is accessible at www.data.go.kr

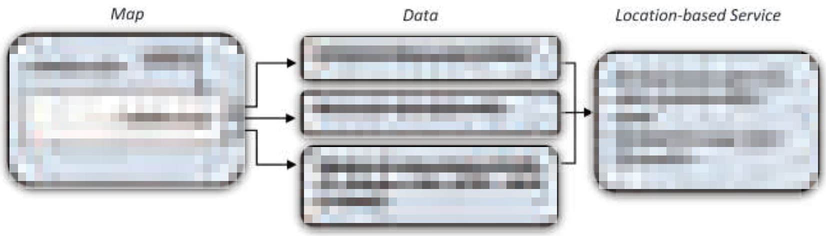

FIGURE 24.6
CoBaek Plus App data source and location-based services

24.2.6 Masks Stock App

Due to the scarcity of masks, the government launched the 'Five-day Rotation Face Masks' policy and distribution system on 9 March 2020. Under this policy, the general public can only purchase 2-3 face masks per week, and only on designated days. For instance, people with an ID number ending with 1 or 6 can only buy public masks on Monday, ID number ending with 2 or 7 on Tuesday, ID numbers ending with 3 or 8 on Thursday, and so on. Since people have only one day to buy public masks, checking on the mask stocks before heading to the nearby pharmacy was essential.

Masks are distributed to government-designated pharmacies, post offices and Nonghyup Hanaro Mart[7] stores. The sales of face masks are recorded by the government designated retailers, and then uploaded to the Health Insurance Review and Assessment Service (HIRA).

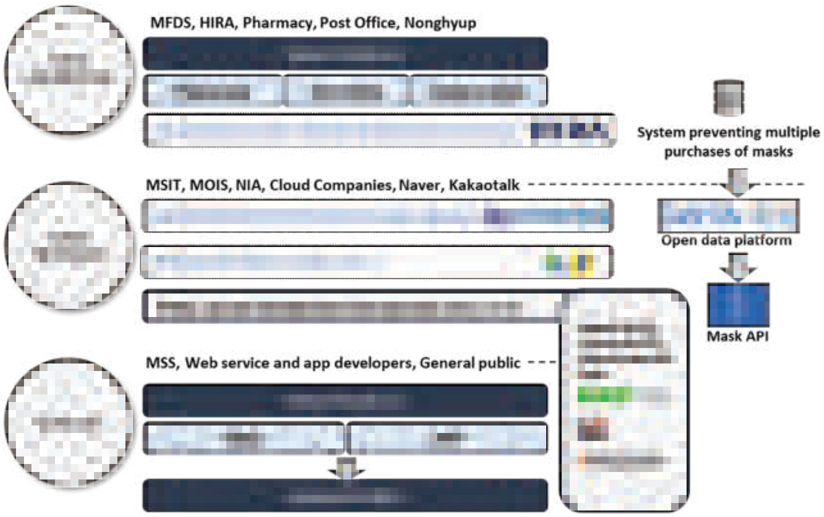

FIGURE 24.7
Publicly Distributed Face Mask Information Service

However, in order to manage the 'mask stock' shortage and direct the public to available stock, the government had to rapidly develop an information system showing the status of face mask stocks across the nation. To achieve this objective, the government took a Public-Private Partnership approach to development. In this partnership, the government released the data on face masks sold

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[7] Name of a supermarket.

at public designated-retailers through the public data centre of the National Information Society Agency (NIA). The NIA processed and published the HIRA data so it was accessible to the general public (as Open Data). Private companies could then develop cloud and other mapping services and Apps, through an Open API cloud service, provided free by the private sector (Figure 24.7).

The Public-Private Partnership approach was hugely successful. The face mask data was released by the government on 10 March 2020, and an App service was launched the very next day. The availability of Open Data through a sophisticated data infrastructure meant that it only took 13 hours to develop and deploy the first App service. Since then, more than 150 Apps have been developed to assist the public to purchase face masks.[8] The number of data calls, related to mask distribution, through the API cloud reached 570 million (around 9.64 million per hour) from 11-31 March 2020 [12].

24.2.7 Self-Quarantine

The South Korean government developed the 'Self-quarantine Safety Application' to effectively support the monitoring of those under self-quarantine. The Android version was launched on 7 March and the iOS version on 14 March 2020. The Self-quarantine Safety Application supports three languages Korean, English and Chinese [12]. It comprises 3 main functions:

1. Self-diagnosis instructions for the users to conduct and submit results to an assigned government officer;
2. GPS-based location tracking to identify those outside their designated area; and
3. the provision of necessary health information including self-quarantine guidelines.

The App allows users to self-monitor their condition by uploading body temperature and answer survey questions relating to four symptoms: fever, cough, sore throat and respiratory difficulties (Figure 24.8). These survey results are automatically shared with their assigned officer. An alarm is triggered when a self-quarantine user does not submit their result. In addition, a monitoring officer gets an alarm when a person under self-quarantine violates self-quarantine restrictions (e.g. moving outside of the quarantine area). This information is retrieved from a person's mobile phone and submitted to designated officials.

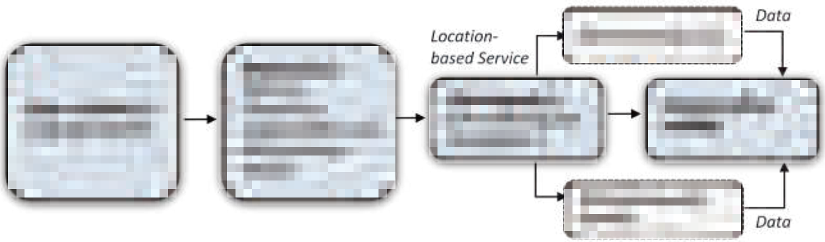

FIGURE 24.8
Process of Self-quarantine App use, and data generated

24.3 Real-time Data Processing Systems

Since 1954, the South Korean Government has been obligated to report all kinds of diseases, but omissions and delays were still apt to occur. As a consequence, the government decided to

[8] Apps for mark stock locations are accessible at `http://mask.paas-ta.org`

take measures by introducing the ‘Integrated Information Support System for Infectious Disease Control’ in 2013 [23] to aggregate different disease-related reporting and management systems [24]. In 2015, the system was integrated with the ‘Automatic Infectious Disease Report Support System’, in which diagnosis results could be directly reported in real-time [24]. The integrated system has played a substantial role in controlling previous pandemics, MERS and SARS.

In 2015, the *Infectious Disease Prevention and Control Act*, originally enacted in 2009, was revised to enforce the disclosure of infectious disease patients and the collection and use of the data. This Act established a legal basis for the reporting, handling, securement, and disclosure of information required for epidemic investigations. Based on the Act, the Epidemic Investigation Support System (EISS) was developed as an application platform on the Smart City data platform [22].

24.3.1 Integrated Information Support System for Infectious Disease Control

The project to develop the ‘Integrated Information Support System for Infectious Disease Control’ was developed over a number of years and consisted of several development phases:

The Government was able to control the growth of infections for previous pandemics, MERS and SARS, solely by making use of these systems, mainly because the total confirmed cases and the rate of infections were fewer and with slower transmission rates than the recent COVID-19 pandemic. However, the Integrated Information Support System for Infectious Disease Control alone was not enough to manage and contain the spread of the virus, as COVID-19 is infected by contact, requiring more accurate location data.

24.3.2 Smart City Data Hub

The ‘Smart City Data Hub’ is a real-time platform that automatically collects city data using IoT devices (sensors and automatic reporting systems), which permit the analysis and visualisation of Big data without manual input, using technologies such as AI and machine learning. Data is collected across a wide range of sectors such as energy, transportation and city administration. The South Korean government launched the ‘Smart City Innovation and Growth Project’ at the national level in 2018. The project consists of three different focus areas:

1. Smart City Modelling;
2. Daegu Smart City Development Project; and
3. Si-Heung Smart City Development Project [25].

When the ShinCheonJi church-related COVID-19 outbreak occurred in March with hundreds of confirmed cases per day, the Ministry of Science and ICT, the Ministry of Land Infrastructure and Transport (MOLIT), KCDC, Police Department, Financial Service Committee, the Board of Audit and Inspection decided to launch the Epidemic Investigation Support System (EISS) into the ‘City Data Hub’ [26]. The EISS was therefore developed as an application built on the Smart City Data Hub [27] (Figure 24.9), that has been legally supported by the ‘Infectious Disease Prevention and Control Act’. EISS contributed greatly to reducing time spent on analysing real-time analysis of large scale outbreak areas, including the visualisation of patients’ pathways and hot spot locations. EISS also enabled App developers to use real-time data for other services.

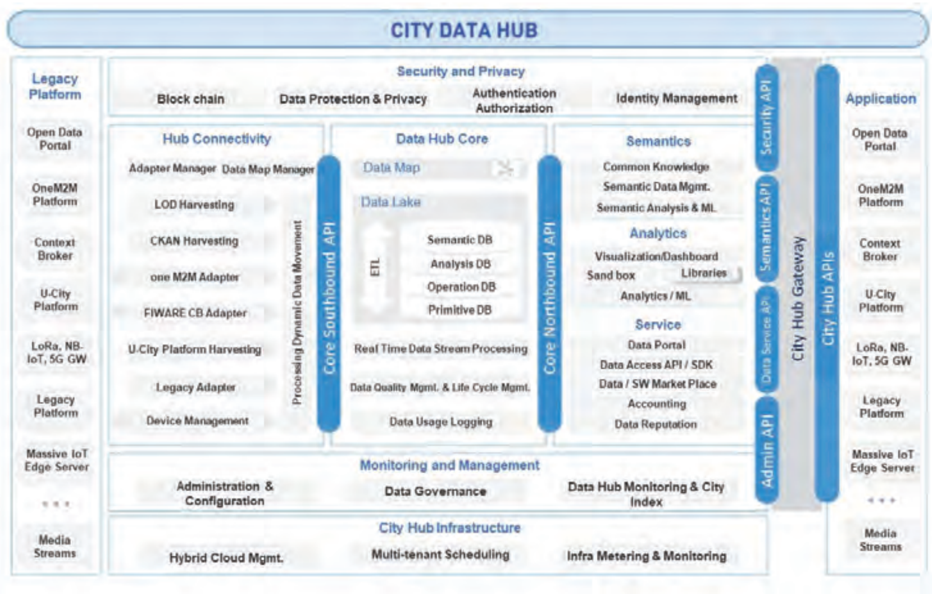

FIGURE 24.9
Structure of City Data Hub [27]

24.3.3 Epidemiological Investigation Support System (EISS)

According to the *Infectious Disease Prevention and Control Act*[9] and its enforcement Decree,[10] COVID-19-patient data are collected by the KCDC, under the Ministry of Health and Welfare (MOHW). The Act grants authority to the Police Department to ask for location information on infectious disease patient data that are normally retained by private mobile network companies. The Act also allows other responsible (designated) departments to collect additional data such as details of credit card usage (that has to be approved by the credit card association), visits to medical institutions, transport card use, entry and departure from the country, and closed-circuit television video footage.

In addition, the *Infectious Disease Prevention Act* has a provision to rapidly disclose the tracking information of infectious disease patients, depending on the outbreak situation [27]. The provision for the use of personal information amended in the *Infectious Disease Prevention Act*, including the disclosure of information for tracking purposes, was enforced during the MERS outbreak on 8 July 2015. To prevent the introduction and spread of dangerous infectious diseases, the Act was amended to enable the use of specific measures to rapidly control infectious diseases in the early stage of inflow [27].

According to the Infectious Disease Prevention Act, EISS has two different approval processes:

1. Location data: the Police Department has the authority to directly ask telecommunication companies (3 main national telecoms companies) to provide the requested data; and

2. Credit card-related data: the approval must be granted by the credit card association (22 credit card companies).

Following the EISS pilot operations conducted 16 March 2020, the system was officially launched on 26 March 2020 by the Ministry of Land, Infrastructure, and Transport (MOLIT), together with

[9] Infectious Disease Prevention and Control Act is accessible at http://elaw.klri.re.kr/eng_mobile/viewer.do?hseq=53530&type=part&key=36

[10] The Decree is accessible at http://elaw.klri.re.kr/eng_mobile/viewer.do?hseq=43547&type=part&key=36

the Ministry of ICT and Korea Centres for Disease Control and Prevention (KCDC) [26]. The EISS is operated in collaboration with private companies that provide location and card use data.

24.4 COVID-19 Response Success Factors

There are a number of factors that have contributed to South Korea's success in managing the COVID-19 pandemic. These factors include having a robust National Spatial Data Infrastructure (NSDI) that has provided the foundation for:

1. integrated geospatial data management and technological innovation;
2. an Open Data Policy that has stimulated the development of COVID-19-related systems and applications by government, private sector and individuals in the community;
3. institutional arrangements that have fostered a strong culture of data sharing;
4. high-quality fundamental and specific datasets; and
5. application development.

24.4.1 National Spatial Data Infrastructure

South Korea is recognized as one of the most influential digital economies powered by a well-coordinated NSDI [28], supportive policies and leadership. The NSDI success is founded on well-established and integrated geospatial datasets, interlinked Ministry and regional systems, a central database system, accessible information portals and cloud-based services that support application development.

It is the development of geospatial information-related technologies that has played a key role in enabling COVID-19 location-based products and services to be developed rapidly. In line with Industry 4.0, the geospatial information sector has experienced rapid innovation in parallel with major national agendas, such as Smart Cities and Ubiquitous Cities [29].

South Korea has continually developed and revised its overarching NSDI Basic Plan since 1995, and several major NSDI projects have been completed. The current 6th NSDI Basic Plan (2018-2022) aims to:

1. encourage the use of geospatial information in a way that creates social and economic value;
2. implement geospatial platforms to share information innovatively;
3. advance the geospatial information industry to stimulate job creation, and
4. augment geospatial information management through a public-participatory environment to enhance data quality and usability.

The presence of a well-established NSDI framework, including the legal system, and standards has provided the groundwork for base maps as an Open API format, which is essential for the development of COVID-19 location-based applications.

24.4.2 Open Data Policy

The rapid development of fit-for-purpose COVID-19 location-based Apps has provided far-reaching benefits for local communities faced with social distancing and precautionary travel. However, debate has sparked on the disclosure of private data: The Open Data Policy and other Acts, such as the Infectious Disease Prevention Act, have made it possible to legally disclose COVID-19 confirmed patient data. While the Government took precautionary measures when sending CBS messages during the onset of the pandemic, the number of confirmed cases was so low to start with, that people could identify patients from news and media reporting.

As a consequence, people were more concerned about being stigmatized through news reports than benefitting from the released data [13]. As the severity of COVID-19 grew and there was increased fear in the virus, people came to trust the government in the management of their personal data.

24.4.3 Institutional Arrangements

A robust NSDI governance model, underpinned by a central coordinating body (NSDI Committee) and supportive institutional networks, has been an influencing factor in the development of COVID-19 applications and services, which rely on effective collaboration and data sharing. In addition, South Korea has embraced public-private partnerships (PPP). In 2011-12, an NSDI project introduced a new collaboration and data sharing model between local governments, central government and the private sector. This collaboration has since become entrenched in the fabric of government.

In order to better promote geospatial information-related industries, the government established the Spatial Information Industry Promotion Institute (SPACE N), to support geospatial information-related industries, support the operation of 3D geospatial maps (vWorld), promote research and development, and provide consultation for start-ups and other private sector businesses [30]. SPACE N has encouraged the development of new and innovative technologies, datasets and platforms, which have since become vitalizing components of the geospatial data market in South Korea and enablers for COVID-19 applications.

24.4.4 Fundamental and Specific Dataset

Fundamental datasets are provided through the 'NSDI Portal' and 'V-World Portal'[11] (comprising 3D geospatial data), launched and operated by MOLIT. The list of fundamental datasets is based on the South Korean 'National Framework Data', which is progressively being translated to the set of Fundamental Data Themes endorsed by Member States at the Seventh Session of United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM).

Fundamental datasets are distributed via data portals and made available in various formats so that companies and individuals have greater options when developing new application and services. Formats include shapefiles, GPS (Global Positioning Systems) data and LBS (Location Based Services), Real-time data and open APIs. It is this breadth and variety of available high-quality integrated data that has made it possible to develop COVID-19 applications and services so quickly.

24.5 Conclusion

Several factors have contributed to the rapid development of these COVID-19 applications and services. The Spatial Information Industry Promotion Institute (SPACE N), established under MOLIT in 2012, has been promoting business start-ups and capacity building through education programs since 2012. The Open data policy adopted in 2013 played a substantial role in releasing base map data needed for the development of location-based Apps, supported by the robust NSDI that contributed in integrating geospatial data into one coordinate system (including for Smart City Data Hub) and aggregate the data into real-time geospatial platform.

These factors are categorized as:

1. **Factor 1: Systems**, which consist of technical components such as automation supported

[11] http://map.vworld.kr/map/maps.do

by real-time systems that have contributed to processing COVID-19 mass data efficiently (discussed in Section 24.3); while

2. **Factor 2: Policy/legal and institutional arrangements**, including capacity development from national institutions such as SPACE N, which contributed to building highly skilled professionals in geospatial information and supported businesses and start-ups with enabling technologies and policy, which in turn had far- reaching impacts in procuring, releasing and sharing the base maps, which were essential to creating the location-based applications.

South Korea has been lauded for rapidly controlling and flattening the COVID-19 curve, but the location-based services and release of personal data has raised concerns with the public as they are used to trace and track people's movements, and are thus an invasion of privacy. These concerns remain unanswered, and the balance between public good and privacy is still debated.

In summary, hundreds of COVID-19 Apps were developed between the first outbreak up until to today (September 2020). However, privacy issues remain a key concern. Some Apps demand access to users' location and to other mobile device features, such as camera, to enable the collection of individuals private data. Legal enforcement, bridging the gap between public good and privacy, needs to be thoroughly addressed. In addition, with so many Apps available, there is need for a platform with a regularly updated list of COVID-19 Apps to enable the avoidance of similar services. This platform is expected to increase the efficiency and effectiveness of App development, enabling private developers to rapidly bridge communities' need in times of a pandemic.

What is clear from the Korean experience is that location-based Apps, in the hand of citizens, have delivered huge benefits in reducing the spread of COVID-19 because people have been able to make informed decisions about social distancing, their welfare and the welfare of others.

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