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"Quarantined within a quarantine": COVID-19 and GIS Dynamic Scenario Modeling in Tasmania, Australia

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1. Introduction

With a few initial cases in Wuhan, just 4 months before the writing of this chapter, the coronavirus disease 2019 (COVID-19) story unfolded as a health challenge that was believed to be easily contained, but to date, this has escalated into a deadly and devastating global pandemic. Within the past months, it has prompted unprecedented measures like lockdowns [1,2], total suspension of air travels in most countries [3], and reduced activities in different economic sectors such as manufacturing, industries, and transport sectors, all resulting in severe impacts upon supply chains [4–6], among others. It has also overwhelmed the health sector in the majority of economies, especially in most developed economies, with daily confirmed cases, and related deaths, on the incline [7,8]. Socially, it has left families and communities disarrayed; with people isolated in hospitals, care homes, and quarantine facilities. In addition, for those who had traveled outside their country or city, instituted lockdowns, border restrictions, and the halt imposed on ground transportation sectors, it has meant that they would have to wait before they return, thereby rendering them into forced displacement and further fracturing their societal bonds. Politically, the virus has opened new frontiers where countries, especially superpowers, are engaged in a tug of war for acquiring health equipment [9], fueling debates as to the origin of the virus quietly and stealthily moving

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on territorial ambitions [10], and criticizing national and global failures leading to the unprecedented spread [11]. For instance, while the world is still struggling with the impacts of the pandemic, Germany was observed to invoice China £130 billion for “coronavirus damages” [12]. This aligns with remarks by other developed economies like France, the United States, and the United Kingdom targeting China by highlighting that it is through its irresponsibility that the world is suffering and thus it should take responsibility for the same [11].

The impacts of this pandemic have indeed severely affected global supply chains by disconnecting manufacturers, suppliers, and consumers. This is resulting in dramatic impacts on the quality of life of people, especially those in urban areas where scarcity in basic items like food and medical supplies are being observed [12,13]. This is highlighting that it has become paramount to redefine “resilience” to include urban health dimensions, as it is apparent that without quality health, other urban dimensions are insufficient. This has been made clearer by the instances of lockdown where every other aspect of the urban fabric was forced to a standstill, with social interactions, even in areas with robust transport systems, recreation centers, and well-maintained urban open spaces. These have been abandoned and are no longer functioning as long as the lockdown orders remain.

Through these unfolding of events, the role of modern technologies has become apparent and is being appreciated especially in the bid to develop vaccines and cures for this global pandemic. Besides this, technology such as artificial intelligence (AI), machine learning, big data, and Natural Language Processing has been key in the early detection, tracking, and mapping of the outbreak. For instance, even before the official announcement of the virus outbreak to the global population by the World Health Organization (WHO) on January 9, 2020 [14], the technology-based start-up “BlueDot” had already predicted that the world would experience a virus outbreak [16,17,26,27]. The start-up relied on data from different sources like airline ticketing and information from over 10,000 news outlets to make the prediction. Also, Allam [16] highlights that another technology-based start-up, Metabiota, was also able to map and make a prediction of regions that were at high risk of experiencing the outbreak a week before they reported their first confirmed cases. Furthermore, by using different technologies like AI and big data, it is now possible to conduct more effective screening at the points of entries such as airports, ports, and borders to identify cases of possible infection [19], thus allowing for early medical procedures to be initiated on them [18,19].

The success of those has led to tech-inspired formulated policies targeting the reduction of not only human tragedies but also economic impacts, which are already being experienced in different economies [20–24]. This is important, as already, it is true that the world is in limbo, for there is no clear sign as to when the virus will be contained, or a reliable vaccine developed. On the economic front, there are already signs and warning from agencies like the International Monetary Fund (IMF) that global economies should brace themselves for an economic recession, being much severe those experienced in the past few decades [13]. Such news impacts negatively on not only economic spheres but also the environmental realm, where, in the past decade, much effort and resources have been spent to persuade economies to reduce their carbon emissions by adopting sustainable practices [25,62]. After recession, such gains are not guaranteed, as most economies will concentrate on reviving their economies and, in such, may neglect environmental concerns.

Therefore as the emergency response policies settle, it will be necessary to evaluate the effectiveness of those policies so that areas of weakness can be identified. This is critical because these technologic tools could also be used through data management and analysis to visualize "alternative scenarios" of the spread and impacts of COVID-19. To achieve this, this chapter surveys the COVID-19 outbreak in Australia, particularly through the Island of Tasmania, and the role played by the *Ruby Princess*. Through this, an examination of the migration patterns during the time of the outbreak is performed, and by using a geographic information system (GIS) Dynamic Scenario Planning Model (DSPM) that integrates the outputs from Systems Dynamics Modeling of the COVID-19 spread, as well as spatial variables embedded in a Digital Terrain Model (DTM) of the area, including emergency response and recovery optimization through Apparatus Deployment Analysis Module (ADAM), varying scenarios to better evaluate the effectiveness of initial national and state emergency responses, especially regarding COVID-19, will be pursued.

2. Managing pandemics with data science and technology

Throughout the Anthropocene, the world has had to occasionally contend with pandemics. But from a historical perspective, most infectious diseases, although lethal and sometimes with severe casualties, remained mostly local. This is due to small population sizes, with people sparsely distributed with limited connective infrastructures. Since then, the population has continued to grow steadily at a rate of between 1% and 2% every year [28]. Similarly, due to technologic advancement, the world is facing an unprecedented urbanization rate, which has resulted in more complex and intricately connected networks. Technology has also made transportation, whether ground, water, or air, faster and more robust; thus the spread of infectious diseases is an incredible challenge, as is evident with COVID-19 that, at the time of this writing, had already impacted 210 countries globally, representing over 2.2 million positive cases and over 150,000 deaths [7].

The advancement in medical technologies can be put into perspective when compared to the Spanish flu pandemic (1918—20), which is the deadliest till now, killing around 50 million people [124], higher than the total casualties (40 million deaths) of the First World War [29,123]. Advanced medicines and healthcare technologies, coupled with improved living conditions, can be argued to have helped contain numerous succeeding infectious diseases, even if the world suffered from occasional pandemics. For instance, in the late 1970s, the HIV/AIDS pandemic broke, and although its spread was suppressed, it continued to impact communities, especially in African countries (2017).

In 2002–03, the severe acute respiratory syndrome (SARS) spread to approximately 26 countries [29], but was contained only when it had affected 8000 individuals. In 2012, the world was introduced to the Middle East respiratory syndrome (MERS) [30]. Others are noted such as the Ebola outbreak (2014) in West Africa [31,33], the Zika virus (2015) [32], and lethal influenzas like the Swine flu (2009) [33]. All these outbreaks have been responsible for not only the deaths of thousands of people but also billions, if not trillions, of dollars of economic damages and deep social impacts.

The postmanagement analysis of those outbreaks, especially in the past two decades, demonstrates that besides improvement in medicine, novel strategies and approaches need to be adopted to better counter similar outbreaks in the future. On this front, with advanced technologies now available, adoption of data computation and analysis can be utilized in curbing the future pandemics [18,34]. The conviction on this is supported by the fact that data analysis has been instrumental in developing predictions in other fields like climate change that have allowed scientists, governments, and other stakeholders take proactive and preventive measures to counter potential disasters [15,35]. Even in the medical field, and specifically in cases of outbreaks, the examples are noted earlier about how the companies BlueDot and Metabiota were able to use data-driven computation to render predictions on the COVID-19 outbreak and its spread. This demonstrates the need for the application of advanced computing tools not only for outbreak predictions [25,26], but also for postmanagement analysis and evaluation. Supporting this concept does not debase historical approaches, like investigator and hospital records that have been relied upon in the past. But these have been slow to be consulted and predictions derived from them are not as accurate as those made from modern data computation [36].

The potential of data-driven approaches is made even stronger by the availability of diverse data-generating and data-collecting technologies including the use of smart mobile devices like phones or other wearable technologies with the potential to integrate with, and mine data from, different mobile applications (apps), search engines, and social media platforms [37]. A strong precedence is present on this front where the use of mobile phone network data was also evident in 2010 during the Haiti earthquake where a team of health workers from the country collaborated with Digicel (Haiti's largest telecom company) to track people's movement flows, hence rendering more accurate deployment and better resource management [38]. Shortly after, the same strategy was used to track population movement when a nation-wide cholera outbreak overwhelmed the same country, affecting over 91,770 people [39].

Regarding COVID-19, there are numerous mobile app's that have been developed in different countries to help track and map the spread of the disease [40–42]. This is particularly important as today, where multiple disciplines overlap, diverse skill sets are required when tracking outbreaks, especially in early stages, where pandemics are less understood. Tapping across different networks allows for an enriched database from different spheres to address global emergencies, beyond pandemics. In realization of this, companies like BlueDot, which beat the WHO in providing an early warning of

COVID-19, are observed to have a diverse team composed of physicians, veterinarians, ecologists, data scientists, epidemiologists, geographers, designers, meteorologists, and software developers, providing them with the ability to gather information from different backgrounds and later render new and more comprehensive insights [25,26].

The role of data technology is being further accentuated through the COVID-19 pandemic, as seen from the increasing number of computing tools, coupled with medical fields, emerging as a response. For instance, by using advanced technologies, it only took scientists less than a month to decode the coronavirus genome sequence and also via technology deposit the same in a public database (GenBank) where WHO-accredited laboratories could access the information and help in developing the vaccine and cure for the virus [43]. Soon after the upload, the Peter Doherty Institute for Infection and Immunity, an Australian laboratory, was able to clone the virus, increasing the optimism of finding a cure [44]. In China, Chaturvedi [45] reports that the use of predictive tools is also key in guiding different stakeholders, such as security officers and those delivering medical supplies and other essentials, to narrow down areas requiring urgent attention, thus containing the spread and slowing the impacts of the virus in the country. Going forward, after the early stages of the COVID-19 pandemic, predictive tools will become even more important not only for surveying future potential outbreak waves of the virus, but also in re-evaluating our COVID-19 policy responses so as to identify and correct mistakes for better pandemic management responses for the current and future pandemics. This will be key because policy responses are having a severe economic and societal impact on numerous geographies, even if they are island-based like Australia.

3. Australia and COVID-19

This section is broken into five sections that offer an overview of the COVID-19 pandemic transmission patterns in Australia, explain the actions Australia (Fig 19.1) has taken under its *Biosecurity Act 2015* (Cth) [46], explain the nature of Australia's tracing software app, and discuss the background on the *Ruby Princess* cruise ship, before reviewing the Tasmanian context.

Report tracing of COVID-19 goes back as early as November 2019 [47,48], with others stating December 1, 2019 [49]. But it is only on December 31 that the virus received global attention [43]. This is after Chinese officials reported that they were experiencing an outbreak of a new strain of virus, and after concerted efforts with the WHO, it was confirmed 9 days later [14]. By then, the number of confirmed cases remained low (41 cases), but the number increased steadily and by January 23, the situation became dire such that Wuhan, the epicenter, and neighboring cities like Huanggang, Ezhou, Chibi, and others were placed into lockdown [50], cutting off approximately 56 million people from the rest of the world. However, even with the Chinese government's efforts to contain the spread, the virus had already been

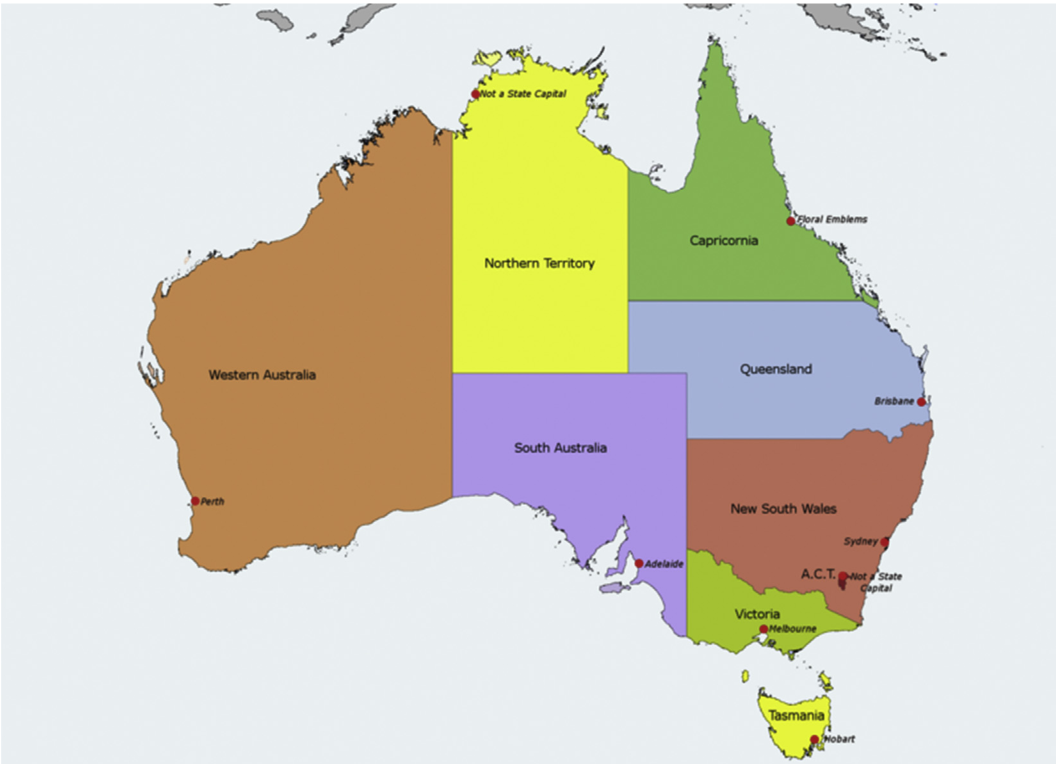

FIGURE 19.1 Australia and its states and territories. *ACT*, Australian Capital Territory. *From: Creative Commons, https://commons.wikimedia.org/wiki/File:Australia_location_map_with_floral.png.*

exported to other neighboring regions, as people, particularly panicked foreigners, had left these cities, especially Wuhan, in fear of being infected. Unknown to them at the time, and to health officials too, the virus could be spread through human-to-human contact, with an incubation period of up to 14 days [51], and could be passed on by asymptomatic cases [52]. Therefore locking down Chinese cities was necessary, but the damage had already been done as the virus was spreading overseas on air flights and on cruise ships, even in island states.

3.1 COVID-19 patterns in Australia

On January 12, 2020, the WHO stated that a novel coronavirus was the cause of a respiratory illness arising from a cluster of people in Wuhan City, Hubei Province, China. A cluster that was first reported to the WHO on December 31, 2019.

Watching this horizon, Australian biosecurity officials from January 23, 2020, began screening arrivals on the three weekly flights to Sydney from Wuhan. Passengers were issued with an information sheet and asked to present themselves to Australian health authorities if they had a fever or suspected that they might have the disease.

The first case of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus strain that causes COVID-19), infection was reported in Australia on January 25, 2020. The first known case pertains to a Chinese citizen who had arrived from Guangzhou on 19th January, and thereupon self-sought medical treatment in Melbourne. On the same day, three other persons tested positive in Sydney after returning by air from Wuhan. A fifth case was reported on 27th January being a 21-year-old person who returned from Wuhan and underwent treatment at Westmead Hospital in Sydney. On 29th January, two more cases were reported: a 60-year-old Victorian (Vic) resident and a 44-year-old Chinese national from Wuhan resident in Queensland (Qld). On 30th January, two more Chinese nationals in Australia tested positive: one in Vic and one in Qld.

Arising from these initial infections in Australia on 31st January, the Australian federal government announced on January 31, 2020, that all foreign nationals returning from China were required to spend a fortnight in a third country before being allowed into Australia. Subsequently, the government imposed travel bans on Iran (1st March), South Korea (5th March), and Italy (11th March). On 13th March, a National Cabinet was formed of federal and state government leaders, chaired by Prime Minister Scott Morrison, to "coordinate and deliver a consistent national response to COVID-19" during the pandemic, following a meeting of the Council of Australian Governments (COAG). This Cabinet is analogous to the successful War Cabinet that Australia established during the Second World War. At its first meeting on 13th March, the National Cabinet announced that gatherings of more than 500 people should be ceased from 15th March with exclusions for schools, universities, workplaces, public transport, and airports. On 15th March, Morrison announced that from midnight, all travelers arriving in or returning to Australia must self-isolate for 14 days, mirroring a New Zealand (NZ) decision [53]. Failure to comply could result in a fine of A$11,000—A$50,000 and a possible prison sentence, depending on the state. Cruise ships were also barred from docking in the country for 30 days.

Historically the total number of new cases initially grew sharply. It then plateaued at about 350 per day around 22nd March and started falling at the beginning of April to about 25 per day by 13th April. As of April 29, 2020, 6746 cases had been reported in Australia, with the highest number of cases being in New South Wales (NSW), i.e., 3016. The Peter Doherty Institute for Infection and Immunity, in Melbourne, estimated that the average national infection rate R_{eff} was about 0.4 on 5th April; an R_{eff} less than 1 means that the virus will eventually die out.

On March 18, 2020, a human biosecurity emergency was declared in Australia owing to the risks to human health posed by the COVID-19 pandemic, under the *Biosecurity Act 2015* (Cth) [46]. Such a declaration thereupon vested in the Australian federal health minister sweeping powers, including imposing restrictions or preventing the movement of people and goods between specified places and evacuations. The *Biosecurity (Human Biosecurity Emergency) (Human Coronavirus with Pandemic Potential) Declaration 2020* [54] and the *Biosecurity (Human Biosecurity Emergency) (Human*

Coronavirus with Pandemic Potential) (Emergency Requirements) Determination 2020 [55] were declared on April 15, 2020, and the latter forbids international cruise ships from entering Australian ports from April 15, 2020.

On 20th March, Australia, in coordination with NZ, closed its borders to all non-residents and non-Australian citizens. On the same day, a social distancing rule of 4 m^2 (43 ft^2) per person in any enclosed space was agreed by the National Cabinet for co-ordinated implementation under state and territory law. These social distancing guidelines, embedded in state and territory declarations, were advertised nationally (see Fig. 19.2) [56,57], with a revised one for Easter (Fig. 19.3) [58].

On 22nd March, Morrison announced closure of places of social gathering, including registered and licensed clubs; licensed premises in hotels and bars; entertainment venues, including but not restricted to cinemas, casinos, and nightclubs; and places of worship. Cafes and restaurants are to remain open but limited to takeaway only. Similarly, enclosed spaces for funerals and similar of that nature will have to follow the strict 4-m^2 rule, effective 23rd March. In these decisions, discretion was given for schools to remain open but parents could keep children at home if they wished to. On the same

FIGURE 19.2 Social distancing restrictions advertisements in Australia. *From: Australia, Advertisement: Coronavirus: You Must Take Action to Save Lives in Your Community, The Australian, March 28–29, 2020, p. 4. From: Australia, Advertisement: Coronavirus: You Must Take Action to Save Lives in Your Community, The Australian, April 15, 2020, p. 8.*

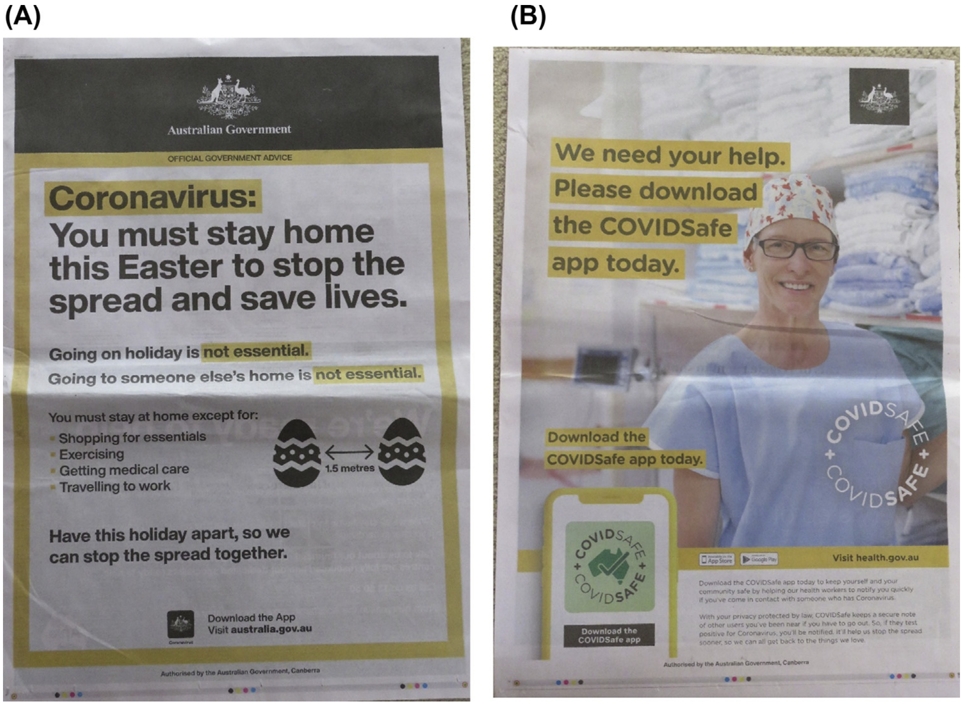

FIGURE 19.3 (A) Easter social distancing restrictions advertisement in Australia. (B) COVIDSafe.App advertisement in Australia. *From: Australia, Advertisement: Coronavirus: You Must Stay Home This Easter to Stop the Spread and Save Lives, The Australian, April 11–12, 2020, p. 9. [67].*

day, the state governments of NSW and Vic imposed a mandatory closure of nonessential services, while the governments of Tasmania (Tas), Western Australia (WA), and South Australia (SA) imposed their own state-border closures.

A second determination under the *Biosecurity Act 2015* (Cth) [46], the *Biosecurity (Human Biosecurity Emergency) (Human Coronavirus with Pandemic Potential) (Overseas Travel Ban Emergency Requirements) Determination 2020* [59], was issued on March 25, 2020, that "forbids Australian citizens and permanent residents from leaving Australian territory by air or sea as a passenger." A third determination under the *Biosecurity (Human Biosecurity Emergency) (Human Coronavirus with Pandemic Potential) (Emergency Requirements—Public Health Contact Information) Determination 2020* [60] was issued on April 25, 2020, "to make contact tracing faster and more effective by encouraging public acceptance and uptake of COVIDSafe," COVIDSafe being the new mobile app created for the purpose [61].

As a reflection, it has been helpful that Australia has had a serious pandemic drill exercise in 2016 and a specific 'hypothetical" outbreak onboard a cruise ship in Sydney Harbour, last May 2019, so that there has been some level of appreciation of the risks of such situations by senior government agencies [63].

Table 19.1 The 2020 COVID-19 pandemic in Australia by state/territory (data dated May 15, 2020).

Australian state/territory[a]	Cases[b]	Deaths	Recovered	Active	Hospital[c]	Tests	Notes
Australia	7019	98	6334	587	50	980,957	
Australian Capital Territory (ACT)	107	3	104	0	0	13,066	[d]
New South Wales (NSW)	3071	45	2605	421	23	345,846	[e]
Northern Territory (NT)	29	0	27	2	2	5940	[f]
Queensland (Qld)	1054	6	1031	17	6	148,60	[g]
South Australia (SA)	439	4	434	1	1	74,293	[h]
Tasmania (Tas)	227	13	188	26	8	20,957	[i]
Victoria (Vic)	1540	18	1407	115	9	309,000	[j]
Western Australia (WA)	552	9	538	5	1	63,248	[k]

[a] Diagnosed in Australia; nationality and location of original infection may vary. Data sourced from the state and federal governments; where there are inconsistencies, the greatest figure is recorded. Under the National Notifiable Diseases Surveillance System reporting requirements, cases are reported based on their Australian jurisdiction of residence rather than where they were detected.
[b] Reported confirmed cases at the time of the update. Actual case numbers may be higher.
[c] Cumulative hospitalizations. There are around 95,000 hospital beds in Australia (3.8 beds/1000 people).
[d] 22 cases from *Ruby Princess*.
[e] 337 passengers and 3 crew members from *Ruby Princess*, 74 from *Ovation of the Seas*, 34 from *Voyager of the Seas*, and 11 from *Celebrity Solstice*; the number of deaths does not include the 2 Queenslanders who had died in NSW.
[f] 2 from *Ruby Princess*.
[g] 70 from *Ruby Princess* and 3 from *Diamond Princess*; the number of deaths includes 2 Queenslanders who died in NSW.
[h] 80 from *Ruby Princess* and 1 from *Diamond Princess*.
[i] 4 from *Ruby Princess* and 1 from *Celebrity Solstice*.
[j] 18 from *Ruby Princess* and 3 from *Diamond Princess*.
[k] 43 from *Ruby Princess* and 2 from *Diamond Princess*.
Abridged From: Australia, Coronavirus (COVID-19) Current Situation and Case Numbers, 2020. https://www.health.gov.au/news/health-alerts/novel-coronavirus-2019-ncov-health-alert/coronavirus.

Table 19.1 summarizes the COVID-19 statistics from across Australia in terms of cases, deaths, recoveries, active patients, and testing, dated May 15, 2020. The data also reflects the highest testing rate per population of a country globally. As evidenced in Table 19.1, the statistics comprising footnotes d–k all originated from cruise ships, with the majority from the *Ruby Princess* and the Tasmanian statistics are in the majority linked the *Ruby Princess*. This pattern is also evident in Table 19.2 that summarizes the COVID-19 "hot spots" in Australia.

In terms of COVID-19 "hot spots" in Australia, COVID-19 hotspots and clusters are of particular importance because of the elevated risk of community transmission (including unknown source of infection). Precautions may include increased testing, surveillance, lockdown measures, and quarantine.

3.2 Biosecurity regimes in Australia

Australia's biosecurity regime is perhaps one of the most rigorous in the world today. This a far cry from the 1800s when respective Australian colonies eagerly enabled the

Table 19.2 The 2020 COVID-19 “hot spots” in Australia.

State	Place	Number of cases	Context
NSW	Bondi	180 cases as at 15th April	Linked to the high concentration of travelers, 34 linked to the “Boogie Wonderland Party”, 14 linked to the Bondi Hardware restaurant, 27 with an unknown source of infection
NSW	Sydney city	155 cases as at 15th April	31 with an unknown source of infection
NSW	Northern Beaches	150 cases as at 15th April	Particularly Dee Why, 15 with an unknown source of infection
NSW	Central Coast	115 cases as at 10th April	8 with an unknown source of infection
NSW	Blacktown	106 cases as at 15th April	6 linked to the Rose of Sharon childcare facility, 14 with an unknown source of infection
NSW	Woollahra	92 cases as at 15th April	
NSW	Canterbury-Bankstown	88 cases as at 15th April	6 linked to the Opal Aged Care Bankstown, 9 with an unknown source of infection
Vic	Stonnington local government area	88 cases as at 11th April	
NSW	Penrith	121 cases as at 12th May	69 cases (32 staff and 37 residents) linked to the Anglicare Newmarch House as at 10th May, 12 with an unknown source of infection
NSW	Ryde	66 cases as at 15th April	21 linked to the Dorothy Henderson Lodge since February 24, 2020, 19 linked to a church meeting since March 8, 2020
Tas	Burnie	127 cases as at 30th April	Linked to the North West Regional Hospital and the North West Private Hospital since 27th March
SA	Barossa Valley	39 cases as at 9th April	Linked to the Lyndoch Hill winery since 14 March
NSW	Wollongong	38 cases as at 10th April	Linked to a Stanwell Tops wedding since March 9, 2020
SA	Adelaide Airport	33 cases as at 9th April	Linked to the baggage handling area since 17th March
WA	Mandurah	27 cases as at 7th April	
Qld	Noosa Heads	17 cases as at 26th March	Linked to the Sails restaurant on 14th March
Vic	Brooklyn	90 cases as at 14th May	Linked to the Cedar Meats meatworks
Vic	Fawkner	8 cases as at 14th May	Linked to McDonald’s Fawkner

NSW, New South Wales; *Qld*, Queensland; *SA*, South Australia; *Tas*, Tasmania; *Vic*, Victoria; *WA*, Western Australia.
Abridged From: Australia, Coronavirus (COVID-19) Current Situation and Case Numbers, 2020. https://www.health.gov.au/news/health-alerts/novel-coronavirus-2019-ncov-health-alert/coronavirus.

transfer of a number of noxious plants, diseases, animals, and bird life to assimilate and establish themselves on the Australian landscape in the colonial belief of transferring the signs, smells, noises, and tastes of their far homelands. As an island nation, Australia is somewhat naturally protected from exotic pests and diseases, but it also has an enormous border coastline to monitor, with the sixth-longest coastline in the world, at 25,780 km.

Biosecurity matters in Australia are governed today under the *Biosecurity Act 2015* (Cth) [46] and related legislation is conjointly managed by the federal Department of Health and the Department of Agriculture, Water and the Environment. The *Biosecurity Act 2015* (Cth) [46] replaced most of the historical and inaugural federation *Quarantine*

Act 1908 (Cth) [64] and involved major reform of the *Quarantine Act 1908* (Cth), strengthening and modernizing the existing framework of regulations governing biosecurity in Australia. The Act holistically seeks to monitor and delimit biosecurity risks to human health, agriculture, native flora and fauna, and the environment.

It also covers Australia's international rights and obligations under the raft of UNESCO and allied international agreements and charters and includes Listed Human Diseases that are deemed contagious and capable of causing severe harm to human health. Included in the list at present are human influenza with pandemic potential, plague, severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), smallpox, viral hemorrhagic fevers, yellow fever, and human coronavirus with pandemic potential. While each Australian state and territory has additional legislation and protocols to cover biosecurity in its jurisdiction; in the first instance, they are legally required to liaise with the federal government in times of national emergency, like the current COVID-19 pandemic.

The Department of Health defines biosecurity as "all the measures taken to minimise the risk of infectious diseases caused by viruses, bacteria or other micro-organisms entering, emerging, establishing or spreading in Australia, potentially harming the Australian population, our food security and economy" [61]. These risks include people as the transmission agency entering Australia from other places (whether on holiday or any other reason), having developed infections through food, water, insect bites, or contact with animals or other people. The practical difficulty is that the infection is unknown because it is not obvious, and the infected person is not aware of it themselves, until they become unwell sometime later. Some of these diseases may be serious, and biosecurity measures are necessary to ensure that the infection does not spread throughout the population.

Under the *Biosecurity Act 2015* (Cth), Australia declared on March 18, 2020, under Section 475 of the Act, that there was "a human biosecurity emergency" owing to the risks to human health posed by the coronavirus (COVID-19) pandemic, following the deliberations of the Australian National Security Committee the previous day. The *Biosecurity Act 2015* (Cth) specifies that the Australian Governor-General may declare an emergency upon the recommendation of the Australian government where they are satisfied that "a listed human disease is posing a severe and immediate threat, or is causing harm, to human health on a nationally significant scale." This declaration immediately gave the federal minister of health sweeping powers, including the ability to impose restrictions or to prevent the movement of people and goods between specified places, and to enable domestic and or international (airlift) evacuations as necessary. The Act only allows for an emergency declaration for a period of 3 months, but it may be extended for a further 3 months if required (Australia 2020b). The *Biosecurity (Human Biosecurity Emergency) (Human Coronavirus with Pandemic Potential) (Emergency Requirements) Determination 2020* [55], made by the Health Minister on the same day, forbids international cruise ships from entering Australian ports before April 15, 2020 [65].

On March 25, 2020, the Health Minister made a second determination, the *Biosecurity (Human Biosecurity Emergency) (Human Coronavirus with Pandemic Potential) (Overseas Travel Ban Emergency Requirements) Determination 2020* [59], that "forbids Australian citizens and permanent residents from leaving Australian territory by air or sea as a passenger" [46,65].

The Australian Prime Minister Scott Morrison announced on March 29, 2020, following a National Cabinet meeting, that public gatherings will be limited to two people, while also urging Australians over the age of 70 years, Australians with chronic illness and over the age of 60 years, and First Nations Australian's (Aboriginal and Torres Strait Islander people) over the age of 50 years to stay home and self-isolate. Morrison stated that there were only four acceptable reasons for Australians to leave their houses: shopping for essentials, for medical or compassionate needs, to exercise in compliance with the public gathering restriction of two people, and for work or education purposes [66].

3.3 COVIDSafe.App

On April 27, 2020, the Australian federal government launched the COVIDSafe.App stating that, as a policy, the government was desirous that up to 40%, or 10 million people, of the Australian phone user community needed to download this app before the government would seriously consider lifting major lockdown restrictions [67]. Despite privacy concerns, within 24 h some 1 million downloads occurred, and by 30th April, some 3 million downloads had occurred, representing 10% of the mobile phone community [68,69,113,117,126]. On May 8, 2020, the source code for the app was released publicly, and on 13th May the Australian Chief Medical Officer stated that the app was now fully functional.

The release of the COVIDSafe.App, available for both iPhone and Android devices, has occurred under a 'determination' under the *Biosecurity Act 2015* (Cth) issued on April 26, 2020, with the intent of seeking to protect people's privacy and restrict access to app information to state or territory health authorities only for the purpose of contact tracing. Thus the contact-tracing app COVIDSafe aims to help track down people who may have been exposed to COVID-19. Legally such a "determination" can be amended or repealed at any time. Interestingly, and to address Australia's privacy concerns, the "determination" also forbids law enforcement or other federal agencies from being able to access the app's information, but some questions still remain about the strength of this prohibition. Australia's Chief Medical Officer has been explicit about this concern stating that "the Federal Government had no access to any of the data. We have locked this down so completely, so thoroughly with the biosecurity bill and legislation that is coming. This app will only ever be used by public health officials [for] the purposes of contact tracing." The legislation pending to be introduced into the Australian parliament in May 2020 will address this concern. The government has also been quick to assert that this app and its downloading is voluntary and not mandatory [69].

But like any smartphone app, it raises privacy and security questions especially because the data the platform collects will be used for potentially sensitive healthcare situations. Although the government has not released the app's source code and new legislation governing its use has yet to be tabled, it has not stopped a hoax email being issued on late 27th April or software experts from exploring both the technical and legal implications of this unprecedented bit of software [70].

The mechanics of this COVIDSafe.App includes its purpose of recording contact between any two people who both have the app on their smartphones when they come within 1.5 m of each other. The app does not collect your location and does not possess a geospatial function. When a user signs up for the app, he/she enters the name (it can be a pseudonym), age range, postcode, and phone number. This data then creates an encrypted code that is then shared over Bluetooth with other COVIDSafe apps you come into close contact with. These IDs are encrypted and stored on the app for 21 days, before being automatically deleted by the app. The app makes a record of the date and time that digital "handshake" occurred, its duration, and the proximity of contacts [69].

Initial research has discovered that the Bluetooth messages are sent unencrypted to other phones and also the phone's make and model are shared. This means that this data could be intercepted raising a level of privacy risk if someone was determined to track you. Singapore's TraceTogether app also collected this data, but unlike in Australia, it explained why in its conditions of service stating "In order to measure distance, information about the phone models and signal strength recorded is also shared, since different phone models transmit at different power" [71].

Medically, if a person is diagnosed with COVID-19, health officials can ask you to upload 21 days' worth of the anonymized IDs stored on your app for contact tracing to a central server. All COVIDSafe.App users who have been in close contact with your app will not be texted the positive person's name, but health officials may phone these close contacts and recommend them to isolate and/or get tested.

Although one can delete the app at any time, it is unclear when the app will be officially switched off. This is despite the federal government statements saying that it will be turned off "at the end of the Australian pandemic" [67]. The data gathered will be stored on a central storage database and will reputedly be also destroyed then, but lawyers are waiting to see whether this will be included in the legislation. This storage is being held in Australia, by the American technology giant Amazon Web Services, and the "determination" under the *Biosecurity Act 2015* (Cth) prohibits the transmission, release, or transferal of any of this data to any country other than Australia.

The COVIDSafe.App designers recognized and have sought to address issues and problems experienced in Singapore with their Bluetooth-based tracing app, TraceTogether, upon which COVIDSafe was partially modeled. iPhone problems have constrained the success of Singapore's app, especially given that the app was required to be in the foreground on an unlocked iPhone to work efficiently. In Singapore, the

TraceTogether app has been downloaded by less than 20% of the country, and its Apple App Store page is full of scathing user reviews complaining of not being able to receive phone calls while enabling the app to properly function.

Digital mapping of citizens in China is well known, and we have witnessed extensive use of it over the past 3–4 months inside China. Such technology, including facial recognition and human tracking, has been applied to control COVID-19 spread but has additionally disseminated into many aspects of daily Chinese life. Signs and advertisements displaying Quick Response (QR) codes are now displayed at the majority of public checkpoints, including bus and train stations, factories, office buildings, shopping centers, and airports. Users are required to scan the QR code with their phones and wait for their devices to display a color-coded signal to determine whether they can proceed. A green code allows the user unrestricted movement, while a yellow or orange code requires 7 days of quarantine. If the code is red the user is determined to have been either a confirmed case of COVID-19 or in close contact with a COVID-19 carrier and must be placed in isolation. As well as documenting and recording people's movement, this app includes contact-tracing mechanisms that enable the notification of users if they come into contact with an infected person.

Like in China, Hong Kong has implemented similar technology to enforce the quarantine of COVID-19-positive carriers, with users required to wear a wristband with a unique QR code that talks with their smartphone. The Hong Kong version, called StayHomeSafe.App, once downloaded enables geofencing technology—a virtual perimeter for a real-world geographic area—to track user movements. At random points throughout the day, a COVID-19-positive carrier and user is required to use their phone to scan their wristband, to ensure the user has not left the house without their phone.

The South Korean government has implemented a suite of digital-tracing tools since March 2020. Using mobile phone location data, along with the country's prolific CCTV and credit card transaction records, South Korean authorities are able to retrospectively track the movements of people who later test positive. This technology uses GPS location data and has necessitated that South Korean phone service providers require all customers to document their real names and national government registration numbers (like a social security number in the United States or a tax file number in Australia), making it near impossible to avoid being tracked if you own a smartphone. Thus the travel route used by a person later confirmed positive can be and is often published online, while a txt alert—similar to a bushfire or flood txt alert commonplace now in Australia—is sent to the phones of people who had recently visited the same locations on the same days. This tracking regime is avoided by the required quarantined person simply leaving their phone at home, so the South Korean authorities are now requiring repeat offenders to wear tracking wristbands similar to incarcerated persons' digital-tracking foot bands used by many law enforcement agencies in Australia, North America, and Europe.

To date, Taiwan is using a contact-tracing app. In contrast, Taiwanese authorities have been using, as an alternate strategy, location-based technology to enforce quarantine whereby the spatial location data of a person required to quarantine at home is e-monitored to ensure compliance. If the monitor device is switched off or inoperable for 15 min or longer, an alert is sent to the Taiwanese authorities. Additionally, users are phoned twice a day to ensure that they are in close proximity to their phone and have not left home without it.

In Europe, German authorities initially advocated the use of a locally produced tracing model that was proposed to store data on a central server in Germany, but authorities retracked on this proposition after extensive criticism from privacy advocates. Germany is now collaborating with Apple and Google toward developing a Bluetooth tracing app that will see data stored on users' phones instead analogous to the Australian COVIDSafe.App [116,126]. Like in Australia, German authorities have been articulating that this app will be voluntary and will alert smartphone users when they have been in close contact with a COVID-19-positive person.

The UK government has now announced the advance of its own contact-tracing app that is being presently tested for prospective availability in mid-May 2020. The proposal for the UK app is to offer users the option of more active interaction with the technology than the COVIDSafe.App, including enabling app users who feel sick the ability to log their symptoms within their app. With this additional information, it is proposed that a yellow warning notification will then be sent to app users who have been in close contact with that person and their app. If that person is thereupon cleared of COVID-19, these close contacts will then be sent a notification saying "You're OK right now" or similar. However, if that person is confirmed to have COVID-19, a red warning notification will be issued telling close contacts "You need to isolate yourself and stay at home."

The Israeli contact-tracing app launched at the end of March 2020 is called The Shield. Reputedly, at the beginning of April 2020, it had been voluntarily downloaded by 1.5 million users, being 17% of Israel's population. The Shield is also analogous to the Australian COVIDSafe.App in storing user data on their smartphones, but smartphone users who are subsequently diagnosed with COVID-19 are availed the option of whether to release their location data to Israeli authorities. Initially, The Shield was activated enabling Israeli authorities access to user phone geospatial location data that could monitor the movements of COVID-19-positive carriers, until this function and practice were halted due to privacy concerns.

In the corporate sector, the Australian mining giant BHP has also advised that it will be issuing an app for upload by its employees internationally, which may "talk" with other country apps [113].

3.4 The *Ruby Princess*

As a precursor to the *Ruby Princess*, a sister ship the *Diamond Princess*—a British-registered cruise ship owned and operated by Princess Cruises—has been historically subject to two outbreaks of infectious diseases: an outbreak of gastroenteritis caused by norovirus in 2016 and an outbreak of the COVID-19 virus in 2020. In the latter incident, the ship was quarantined in the Port of Yokohama, Japan, on February 4, 2020, for nearly a month, with her passengers onboard, and both the passengers and crew were subject to further quarantine after disembarking. As reported, some 712 of the 3711 passengers and crew were infected and 14 died. The infected included at least 138 Indians, 35 Filipinos, 32 Canadians, 24 Australians, 13 Americans, 4 Indonesians, 4 Malaysians, and 2 Britons. The respective home countries arranged to fly-evacuate their citizens and quarantine them further in their own countries [72–74,127].

Knowledge of this incident was commonplace in the Australian media because of the evacuations, as well as within the cruise ship industry, in February 2020.

The *Ruby Princess* was built in 2008 in Trieste, Italy, as a sister ship to the *Crown Princess*, *Diamond Princess*, and *Emerald Princess* and has a capacity to accommodate 3080 passengers and crew. She was turned over to Florida-based Carnival Corporation and Princess Cruises in late October 2008 and operates in Australian waters under Carnival Corporation's Australian subsidiary Carnival Australia.

On the morning of March 8, 2020, the *Ruby Princess* docked at Circular Quay and was boarded by a team of NSW health officials to undertake testing of more than 300 passengers known to be unwell [72].

The *Ruby Princess* sailed from Sydney's Circular Quay on the evening of March 8, 2020, for a 13-night cruise around NZ. Intended ports of call were Fiordland National Park, Port Chalmers at Dunedin, Akaroa near Christchurch, Wellington, Napier, Tauranga, Auckland, and Paihia in the Bay of Islands. Noting the changing biosecurity declaration and COVID-19 situation in Australia the cruise route was cut short on 15th March and the *Ruby Princess* returned directly to Sydney from Napier. Day tour passengers from the *Ruby Princess* to Napier on March 15, 2020, led to a cluster of 16 COVID-19 cases in that city. The *Ruby Princess* disembarked 2700 passengers in Sydney at Circular Quay on March 19, 2020, and many of these passengers immediately sought domestic flights from Sydney to Melbourne, Launceston in Tas, Brisbane, Adelaide, and Perth, as well as international flights to Auckland, London, Fort Worth, and Los Angeles. On March 20, 2020, the NSW state health minister announced that 13 of the passengers on the *Ruby Princess* had been tested for SARS-CoV-2 and 3 passengers had returned positive results. The NSW health authorities thereupon requested that all passengers go into a 14-day self-isolation. On 24th March, it was announced that 1 passenger had died and 133 on the *Ruby Princess* had tested positive for the coronavirus.

By March 30, 2020, some 440 passengers had tested positive for the virus. Of these, 211 were in NSW, 71 in South Australia (SA), 70 in Qld, 43 in Western Australia (WA), 22 in the Australian Capital Territory (ACT), 18 in Vic, 3 in Tas in Burnie, and 2 in the Northern Territory (NT). By 31st March, 5 passengers had died including 1 in the ACT, 2 in Tas in Burnie, 1 in NSW, and 1 in Qld. By 2nd April, cases in NSW had risen to 337 passengers and 3 crew members, and the total passenger cases had risen to at least 576, excluding passengers who left Australia to the United Kingdom, Canada, and the United States without being tested.

On April 1, 2020, the *Ruby Princess* was stationary off Port Botany near Sydney and the Australian trade union, the International Transport Workers' Federation (ITWF), called on the Australian government to allow the crew members to be disembarked so that they could be flown to their countries of residence. On that date, there were some 15,000 crew members in 18 cruise ships sitting idly off the Australian coast including offshore Sydney and Perth. Six passengers from the *Ruby Princess* were medically evacuated on April 2, 2020, the same day that private Aspen Medical was contracted and immediately commenced carrying out medical assessments on the *Ruby Princess*. Aspen Medical is an international provider of health services that, in particular, focuses upon assisting rural and remote communities and responding to emergency and critical situations. Another three passengers from the ship were reported dead in NSW on 5th April and a fourth in Qld. Another died in WA on 6th April followed by one in Tas in Burnie on 7th April resulting in some 13 direct deaths. By 13th April, the number of deaths linked to the ship had reached 18. A 19th death was reported on April 15, 2020. By April 4, 2020, there had been 662 confirmed cases of the virus, including 342 in NSW. Totally 11 cases of secondary transmission from people infected on the *Ruby Princess* had been additionally reported, which had not led to any deaths.

As of April 8, 2020, the ship's crew of about 1000 remained onboard, with 200 exhibiting flulike symptoms; 18 had tested positive for COVID-19. The *Ruby Princess* was moored at Port Kembla, south of Sydney, since April 5, 2020. A news report on April 13, 2020, said that approximately 1700 Australians who had been on the ship of which "18 have died from the virus and hundreds more have been infected" but that unknown was the health of another 900 passengers who were from other countries and flown out from Sydney. On April 15, a woman in Tas dies making her 19th fatality.

The NSW Police on April 5, 2020, commenced a criminal investigation into whether the operator of the ship, Carnival Australia, broke provisions and legal obligations under the *Biosecurity Act 2015* (Cth) and relevant NSW laws by deliberately concealing COVID-19 cases from federal and state agencies. In addition, the NSW government established a "Special Commission of Inquiry into the *Ruby Princess*" under *Special Commissions of Inquiry Act 1983* (NSW) to also review the incident [74]. Across the Tasman Sea, the NZ Prime Minister, Jacinda Ardern, had requested on April 7, 2020, the Crown Law Office (Te Tari Ture o te Karauna) to review whether her country's laws had been broken. As of the evening of April 8, 2020, 30 NSW Police investigators had been assigned to Strike Force Bast, which was investigating the *Ruby Princess* case as to 'the communications, actions, and other circumstances that led to the docking and disembarking of the vessel' without a quarantine. Included in this investigation has been the seizure the *Ruby Princess*' "black box" recorder (similar to an aircraft flight recorder).

3.5 Burnie, Tasmania

Burnie is a port city, established in 1827, on the northwest shores of Tas (Figs. 19.4 and 19.5). In the 2016 census, it hosted some 19,385 residents. Among them, Aboriginal and Torres Strait Islander people (deemed a "high-risk" group under the pandemic) composed 7.2% of the population and some 85.4% of the people were born in Australia.

Medical facilities in Burnie include Tasmania's third largest hospital, the public 160-bed North West Regional Hospital (NWRH), managed by the Tasmanian government's Department of Health & Human Services, provides both in- and outpatient services for general medicine, general surgery, orthopedics, psychiatry, and pediatrics. Adjacent to that is the private North West Private Hospital (NWPH), which is part of Ramsay Health Care, that hosts a 48-bed acute medical, surgical, mental health, and obstetric hospital and is colocated with the North West Medical Centre (NWMC) of the University of Tasmania and the NWRH. The nearby Mersey Community Hospital (MCH), at Latrobe near Devonport, is a campus of the NWRH, the main healthcare facility for the northwestern region of Tas, and it is owned by the Commonwealth and operated by the Tasmanian government.

On March 17, 2020, the government of Tas declared a public health emergency, and on 19th March the government required that all "nonessential" travelers to the island state, including returning residents, be subject to a mandatory 14-day quarantine (Fig. 19.6) [75–77,114].

On April 12, 2020, during the 2020 coronavirus pandemic, the NWRH was temporarily closed by the state government due to an outbreak of COVID-19 at the hospital and local region. All staff, about 1200 people and their families, were required to go into 14 days of

FIGURE 19.4 Burnie. *From: Creative Commons, https://en.wikipedia.org/wiki/Burnie,_Tasmania.*

FIGURE 19.5 Location of Burnie in Tasmania. *From: Creative Commons, https://commons.wikimedia.org/wiki/File:Highway_1_(Tasmania)_map.png.*

FIGURE 19.6 Travel restriction public notice for Tasmania. *From: Tasmania, advertisement: Travel Restrictions Are In Place For Tasmania, The Australian, April 4-5, 2020, p. 6. https://www.rubyprincessinquiry.nsw.gov.au.*

quarantine by self-isolation [78]. Regionally between 4000 and 5000 people in total, included the closure of most retail businesses except for those providing essential services, or those who can provide online services and home delivery were required to quarantine. The NWPH was also closed at the same time. Both hospitals were to be thoroughly cleaned and then reopened by Australian Defence Force and AusMAT (Australian Medical Assistance Teams) medics [79].

One would have expected that will all the above mentioned government interventions and measures meant to benefit those within the perimeters of Australia, Tas, being an island state within this context, would have benefitted from being "quarantined within a quarantine." To its advantage, Tas naturally benefitted from the fact that it was secluded from the mainland, where most spread of the virus was developing rapidly. To ensure that it could maintain its safety, there were calls that it should isolate itself from the mainland [80]. However, with only a few cases (first one reported on 2nd March [78]), the idea was not deemed necessary then. However, the situation for Tas changed on the decision to allow a cruise ship, the *Ruby Princess*, to harbour in Sydney, even though earlier there were directives on the ban of foreign cruise ships in Australian ports. Passengers from the cruise ship docked in Sydney, then traveled to Tas, thus changing the course of confirmed cases in Tas to an incline. From this, as of the time of writing this chapter, the island had already recorded 195 confirmed cases [81], thus showing how some lax on agreed measures and flaws in internal hospital virus management protocols can have far-reaching negative impacts upon a small community in the fight against the pandemic.

The Interim Report investigation of this outbreak has concluded:

> *The outbreak has only recently been brought back under control, due in large part to unprecedented decision making to close the hospital settings that were at the heart of the outbreak, and the hard work and dedication of our healthcare workforce to plan, execute and implement the closure and recommissioning of the hospital sites. Another significant contributor to controlling the outbreak has been our North West staff's determination to positively adhere to a 14-day period of quarantine together with their families and household members for the benefit of the Tasmanian community [82: 3].*

> *As at 21 April, a total of 114 people had acquired COVID-19 in association with the NW outbreak, comprising 73 staff members, 22 patients, and 19 others including household contacts. The original source of infection was most likely to have been one (or both) of two inpatients who were admitted to the NWRH with COVID-19 acquired on a cruise ship, the* Ruby Princess. *Of the initial cases amongst staff at least one was a healthcare worker who had provided care directly to one of these patients. Following these initial infections, multiple potential chains of direct person-to-person transmission were apparent. These were between staff, or between staff and patients (in both directions). These transmission events*

occurred within the different northwest healthcare facilities through either the transfer of infectious patients or through infectious staff working in multiple locations including aged care facilities [82: 9].

4. Data science context

4.1 Geographic information systems

A GIS is a digital software and hardware system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. Roger Tomlinson first used the term "geographic information system" in 1968 and is largely acknowledged as the "father of GIS." Tomlinson assisted McHarg in the use of this digital technology in the 1960s [84]. GIS applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations. GIS sometimes refers to geographic information science, the science underlying geographic concepts, applications, and systems [85]. Since the mid-1980s, GISs have become a valuable tool used to support a variety of city and regional planning functions [86–88].

Ironically, in this era of COVID-19, spatial analysis was first used to assess and map disease spread. One of the first applications of spatial analysis in epidemiology is the 1832 *Rapport sur la marche et les effets du choléra dans Paris et le département de la Seine* [89]. In this report, French geographer Charles Picquet (1771–827) represented the 48 Districts of the City of Paris in half-tone color gradients according to the number of deaths by cholera per 1000 inhabitants. In 1854, John Snow (1813–58), an English physician and a leader in the development of anesthesia and medical hygiene, determined the source of a cholera outbreak in London by marking points on a map depicting where cholera victims lived, connecting the cluster with a nearby water source. This was one of the earliest successful uses of a geographic methodology in epidemiology [86]. While the basic elements of mapping topography existed with cartography, Snow's map used cartographic methods to depict as well as analyze clusters of geographically dependent phenomena. In terms of 2D representations, the first case study is linked to the famous "Red Books" produced by the English landscape designer Humphry Repton (1752–818) to present to his clients to showcase his design proposals. The "Red Books" were small compilations filled with handwritten text and watercolor paintings and bound with the red Morocco leather that gives them their name. In the late 18th and early 19th centuries, the Red Books were an innovation because of their use of "before and after" views and became a key part of Repton's design practice and were very different to the plans and maps that had been produced by landscape designers in the past [125].

While the above information summarizes the first use of one layer of information mapping, and the use of 2D representational imagery to convey a future, the essence of GIS is its use of digital layers of discrete information to model, scenario plan, or represent information [87]. Warren Manning first used the multilayered approach when investigating Billerica in Massachusetts in 1912 [90]. A design competition entry for *Düsseldorf* in Germany in 1912, published in the *Sonder-Katalog für die Gruppe Städtebau* der *Städteausstellung* zu *Düsseldorf,* depicted the use of five historical plans overlaid to assess the morphologic evaluation and future planning of this city [91]. English planners Patrick Abercrombie and Thomas Johnson used a similar approach in their *Doncaster Regional Planning Scheme* report in 1922, and the *Survey of New York and Its Environs of 1929* and the *Plan* of *General Development: Report of the Metropolitan Town Planning Commission 1929* also used this mapping technique for analyzing the metropolitan regions of New York and Melbourne, Australia, respectively, in the same year [87,92].

The early 20th century witnessed the birth of photozincography, a technique that allowed maps to be split into layers, for example, one layer for vegetation and another for water [87,88]. This work was originally drawn on glass plates but later plastic film was appropriated because it was lighter, required less storage, space and was less brittle as a material. When all the layers were finished, they were combined into one image using a large process camera. With the advent of color printing, the layering approach was used in creating separate printing plates for each color. While the use of layers became the hallmark of a contemporary GIS, the photographic process was simply a mapping approach lacking a database for evaluation and/or mapping purposes.

It was through Ian McHarg's use and documented publication *Design with Natur*e [87] that GIS reached an evolutionary legitimacy [93]. McHarg first used the plastic film approach in his studios because appropriating GIS digital technologies to substitute the film, thereby enabling digital modeling and databases to be inserted into the modeling progress. McHarg, reflecting upon his ecologic deterministic theory and use in applied design studios, explained that

> *The method was known but the evidence was not. It was necessary to wait its compilation, make the transparent maps, superimpose them over a light table and scrutinize them for their conclusion. One after another they were laid down, layer after layer of social value, an elaborate representation of the island, like a complex X-ray photograph with dark and light tones. Yet in the increasing opacity there were always light areas and we can see their conclusion (McHarg in [94]: 1)*

The first true operational GIS was developed in Ottawa, Canada, in 1960, called the Canada Geographic Information System (CGIS). Constructed by Tomlinson, it was used to store, analyze, and manipulate data collected for the Canada Land Inventory. The Inventory formed the database upon which to determine landscape capability for rural Canada derived from mapping information about soils, agriculture, recreation, wildlife, waterfowl, forestry, and land use at a map scale of 1:50,000, whereupon a rating classification system enabled ranking, risk assessment, and the identification of new arable land resources.

4.2 CommunityViz

CommunityViz, a dynamic analysis engine, is the name of a group of software extensions to ArcGIS software. CommunityViz is a specialized analytical tool that can be used for, among other applications, urban planning, land use planning, transportation planning, and resource management applications. CommunityViz also allows users to export and view their work in ArcGIS Online, Google Earth, and other KML/KMZ viewers, such as ArcGIS Explorer, and provides options for 3D visualization in the Scenario 3D and Scenario 360 plugins.

In CommunityViz Scenario 360, users can construct their own analyses across multiple scenarios using custom formulas, indicators, and charts that all update dynamically in real time as the user makes changes on a map or to the calculations. Current 3D capabilities include automatically exporting to Google Earth and creating scenes using SketchUp models; creating highly realistic, interactive 3D scenes using Scenario 3D with 3D models in common CAD and SketchUp formats (.KMZ, .3DS, and COLLADA interchange (.DAE)); and working as an extension to ArcGIS ArcScene [95,96,128].

Being an extension to ArcGIS, users can readily import GIS data and use CommunityViz while additionally accessing ArcGIS Desktop and ArcGIS Online functions. CommunityViz provides a playable modeling framework and tool enabling over 90 analysis functions ranging from simple arithmetic to complex geospatial calculations, with easy assembly into compound formulas that can talk to one and another to create a complete dynamic 2D/3D model. Model calculations typically operate in real time, enabling real-time edits to a map resulting in changes to modeling inputs (called assumptions), scenarios, or alternate data inputs, with the modeling results appearing immediately in a variety of visual representations including color-changing maps; dynamically changing charts, tables, and reports; and potentially 3D visualizations [96].

CommunityViz is used primarily for land-use planning and natural resource management. Because it allows its users to create custom purpose analyses, it can be applied to almost any geographic decision-making process. The largest user groups of CommunityViz to date include urban planners and universities, with most users being already familiar with GIS capabilities.

4.3 Launceston City Deal project

Before discussing the Burnie project, it is important to understand the Launceston City Deal project [97–99]. This is because the technologies devised for the latter have been quickly brought to bear in the Burnie project.

The Launceston City Deal project originated from a federal government initiative in Australia toward supporting the implementation of Smart City Initiatives. The government, in 2018——20, invested some A$50 million through its Smart Cities and Suburbs Program to scaffold the delivery of innovative smart city projects that sought to improve the livability, productivity, and sustainability of Australia’s cities. The augural City Deal approved was the Launceston City Deal [97,100]. Launceston is approximately 146 km east of Burnie, within a 2-h drive, on the north coast of Tas. With a population of 87,328 in 2018, Launceston is the second most populous city in Tas after the state capital, Hobart, and the 12th-largest noncapital city in Australia.

The Launceston City Deal is a 10-year plan to elevate Launceston to become one of Australia's most livable and innovative regional cities, while growing incomes and seeking to reduce disadvantage [100]. For this City Deal, the Australian and Tasmanian governments and the City of Launceston agreed to cooperate to deliver integrated investment and practical actions that build upon Launceston's strengths and to tackle its key challenges. The plan focuses on the following objectives: jobs and skills growth; business, industry, and population growth; a vibrant, livable city; innovation and industry engagement; and a healthy Tamar Estuary.

Included in this overall City Deal package was the Greater Launceston Transformation Project (GLTP) (see <u>Fig. 19.7</u>) that involved the construction of a digital twin of the city (including 2D and 3D models) with accompanying smart technologies to support the future industries in this region. These models involve a merging of GIS and CommunityViz software, enveloping some 6567 km^2 and incorporating live 3D scenario modeling. The GLTP is a collaboration with the local governments of Launceston, West Tamar, Meander Valley, and George Town, along with the University of Tasmania and Telstra, to explore smart city approaches to improve service delivery and innovation across the Greater Launceston area. Led by Telstra, in partnership with Sensing Value, it involved expertise from the University of Tasmania and Deakin University [98,99].

The GLTP created the foundations for a smarter region and more engaged citizenry through the following projects: "using smart analytics to build better educational outcomes; providing new 3D virtual city modeling tools to transform city planning processes; providing a community co-designed innovation framework and hub; developing a roadmap to build an intelligent city of the future; and, planning the deployment of smart technology in industries of the future, such as aged care and smart emergency response systems" [99: 30]. The GLTP, under its Creating Our Digital Future aim, has three components: Smart Movement Launceston, Internet of Things (IoT) in Schools, and Digitising Cultural Experience programs. Smart Movement Launceston seeks to install a traffic management system (TMS) at up to 53 sites across the city that synchronizes traffic signals to optimize traffic flows and manage congestion. The real-time data collected via the TMS will be complemented with additional sensors, CCTV, and mobility data patterns (from the digital models) to build a Multimodal Model. The IoT in Schools program seeks to build entrepreneurship and innovation and help prepare students for careers and future studies in science, technology, engineering and mathematics (STEM) and design. In includes the delivery of 600 IoT kits to grades 4–5 in public, independent, and catholic schools across the greater Launceston area. The Digitising Cultural Experience project seeks to enable data collections to be digitally scanned and then discoverable, searchable, and accessible online by developing an interoperable digital platform.

(A)

(B)

FIGURE 19.7 (A—D) Cover images from the Greater Launceston Transformation Project. *From: Herron, M., 2020, Greater Launceston Transformation Project, unpublished report.*

5. Tasmania COVID-19 spread: systems dynamic modeling

5.1 COVID-19: a complex system of factors

The spread of COVID-19 is affected by a complex system of several influencing factors. Some of the most significant inflecting factors include government intervention policies, contact rate, seasonal effect, asymptomatic period, disease period, infectivity rate, and international air travels. Modeling and simulation tools are best suited to take

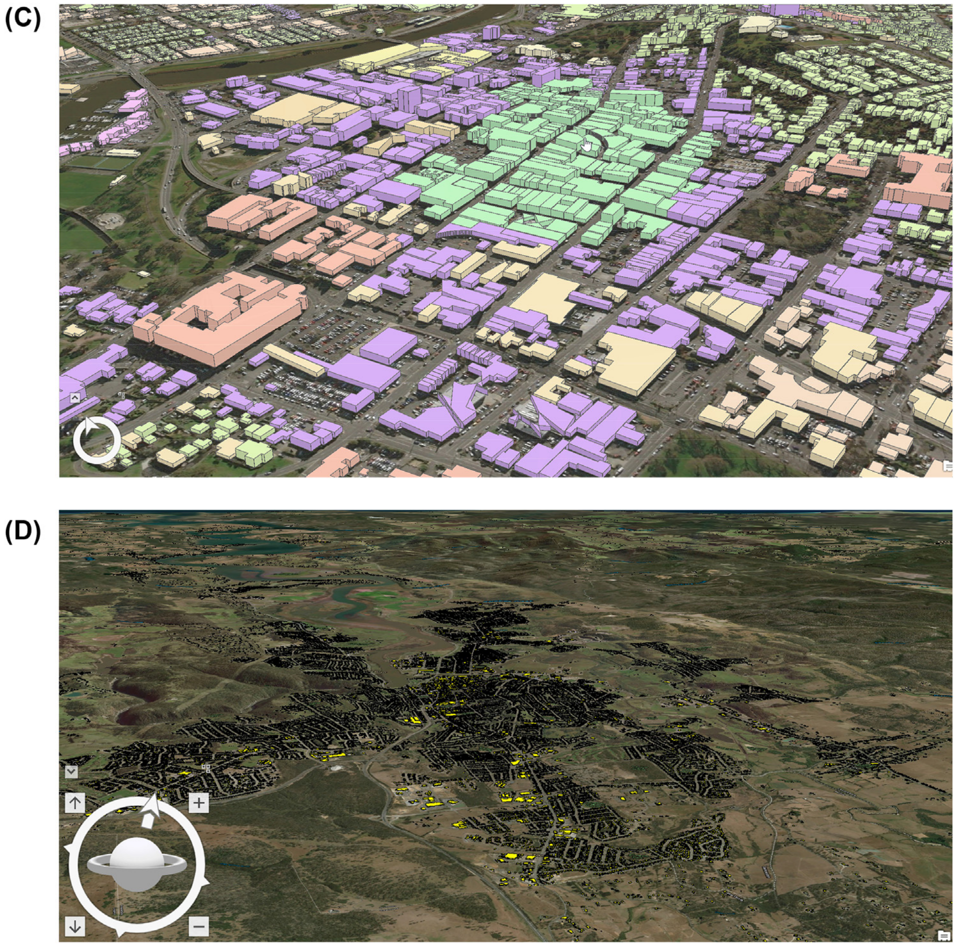

FIGURE 19.7 Cont'd

into account the complex interrelated structure of these influencing factors and understand the state of the disease in Tas. The simulation tools will aid to predict the trend of the disease and assess the impact of different control policies.

In the following, system dynamics (SD) is introduced as the most widely used simulation approach. Then applications of SD in health and medicine are reviewed. Finally, a dynamic modeling framework is proposed using the SD approach to predict and control the spread of COVID-19 pandemic in Tas.

5.2 Systems dynamics approach

SD is an object-oriented simulation methodology that provides a simplified abstraction of reality [101]. SD helps us to understand the complexity surrounding a system, predict trends in data over time, and design better control policies. Much of the art of SD is to determine the dynamic behavior of the system through revealing governing casual feedback loops showing the relationships among different system components, stock and flow structures, time delays, and nonlinear effects [102]. The system behavior is then captured by running a computer software such as Vensim [103].

5.3 Application of system dynamics in health and medicine

Although SD was initially used for modeling and simulation of industrial systems [104,105], it has been successfully applied to different fields of studies, including health and medicine. SD has recently had several applications in medicine to gain a better understanding of complex health issues. It has been used to model the prevalence of major infectious or noninfectious diseases over time and plan to reduce their impacts [106−108]. SD is best suited to model infection rates and population movements within infected and susceptible states. It provides valuable insights to better understand the infection dynamics [109] and presents an efficient and powerful tool to support national and global policymakers in healthcare systems.

5.4 Dynamic modeling of COVID-19 pandemic in Tasmania, Australia

The complex system of the spread of infectious diseases such as COVID-19 can be understood by adopting SD. Using this dynamic modeling approach, the effect of alternative control measures can also be assessed [110]. In this section, the application of SD to understand the complex system of the COVID-19 pandemic in Tas, Australia, is discussed and a basic model for predicting the trends is presented.

SD has been previously used to model different types of infectious diseases including polio, HIV, tuberculosis, chlamydia, and flu and the structure of the dynamic model presented in this section is adopted from these studies.

In our developed dynamic model of COVID-19, the population flow is captured through different stages of a disease. The standard infection rate model is used to depict infectious dynamics using the governing feedback loops, as shown in Fig. 19.8. There are four stock (state) variables including "susceptible population," "infected individuals," "recovered individuals," and "death," which represent the cumulative values of these four parameters over time. The state variables are shown using boxes with flows between them representing the rate of increase or decrease in the state variables. The initial value of "susceptible population" is equal to the state population.

As shown in Fig. 19.9, there are two important feedback loops (R1 and R2) that affect the prediction trends and determine the behavior of system. The first feedback loop (R1) shows how infection rate as the most important driver of the COVID-19 system is intensified through the loop of "susceptible population" → "total contacts of susceptible" → "contacts between infected and susceptible" → "infection rate." The second feedback loop (R2) models the impact of infected cases on the infection rate in the next time step through the loop of "infected individuals" → "probability of contact with infectious" → "contacts between infected and susceptible" → "infection rate."

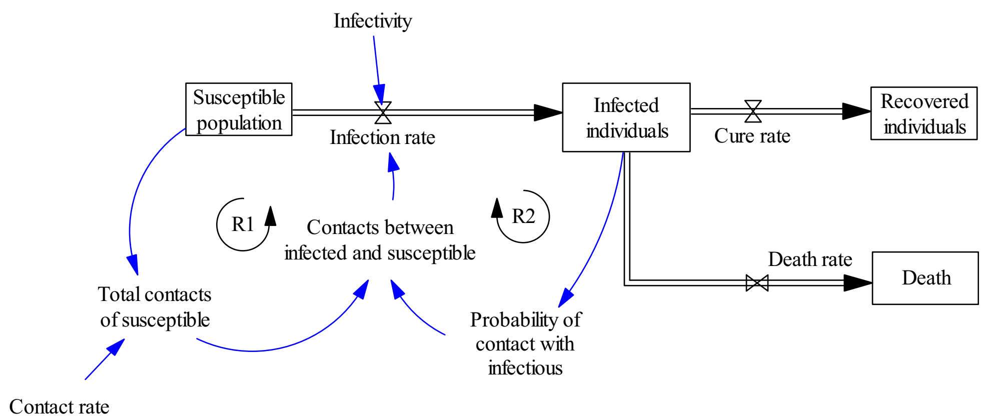

FIGURE 19.8 Dynamic modeling of COVID-19 based on three states of the disease (susceptible-infected-recovered). *From: F. Nasirzadeh.*

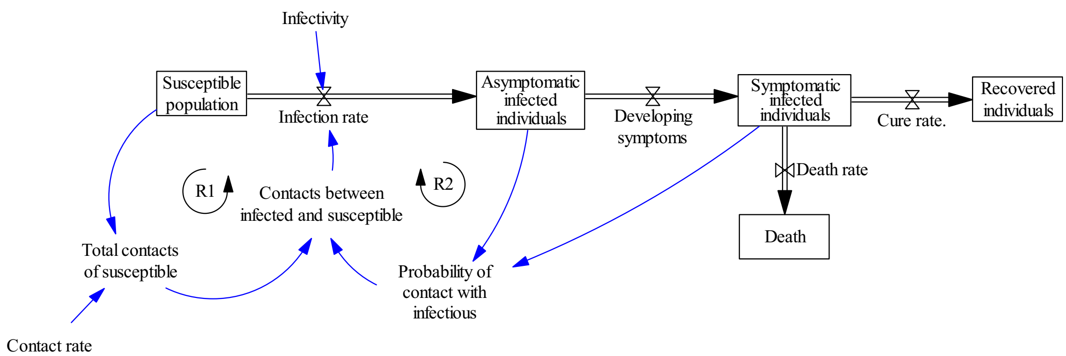

FIGURE 19.9 Dynamic modeling of COVID-19 based on four states of the disease (susceptible-asymptomatic infected-symptomatic infected-recovered). *From: F. Nasirzadeh.*

It should be stated that the state variable of "infected individuals" can be disaggregated to "symptomatic infected" and "asymptomatic infected" to capture the impact of infected individuals without symptoms. Some reports have indicated that people with no symptoms can transmit the virus. It is not yet known how often it happens. But some studies suggest that some individuals can test positive for COVID-19 from 1 to 3 days before they develop symptoms. Thus there is a possibility of transmitting the virus before significant symptoms are developed in the infected individual. Based on another study conducted in Australia, the probability of transmission for asymptomatic/presymptomatic individuals was set as 0.3 of that of symptomatic individuals [111].

Having constructed the dynamic model of COVID's standard infection rate, the other required details are added to consider the complex interrelated structure of various factors affecting the COVID epidemic such as contact rate, seasonal effect, asymptomatic period, and disease period to analyze the spread of the disease in the state. Context-specific mechanisms are added to the basic model to represent different phenomena or policy decisions.

In order to model COVID-19 spread in Tas, the first cases of infection are given as input to the model and the dynamics of infection are then analyzed through the four disease states shown in Fig. 19.9 to see how the number of asymptomatic infected, symptomatic infected, recovered, and deaths is changed over the time. The first cases of infection are related to the international passengers arrived in Tas from early January until the travel restrictions were adopted. These international arrivals started the epidemic in Australia. While aligning with early efforts to restrict foreign arrivals, the decision of allowing a cruise ship, the *Ruby Princess*, to harbour in Sydney was perhaps one of the most contested decisions, which then saw an incline of resulting cases. Passengers docking in Sydney then traveled to Tas, introducing the outbreak there. Fig. 19.10 shows how international arrivals as the first cases of infections triggered the spread of COVID-19 in Tas. It should be stated that the proposed model assumes perfect mixing for the whole population of Tas and includes no disaggregation of population into different groups to avoid proliferation of parameters and aid in rapid development of the simulation model.

After adding the details and completing the COVID-19 model, the spread of COVID-19 is predicted and the trends of asymptomatic infected, symptomatic infected, and recovered individuals in Tas are determined. The efficiency of different intervention policies can then be assessed using the developed dynamic model. These intervention strategies include restrictions on international air travel, isolation, and social distancing with varying levels of compliance.

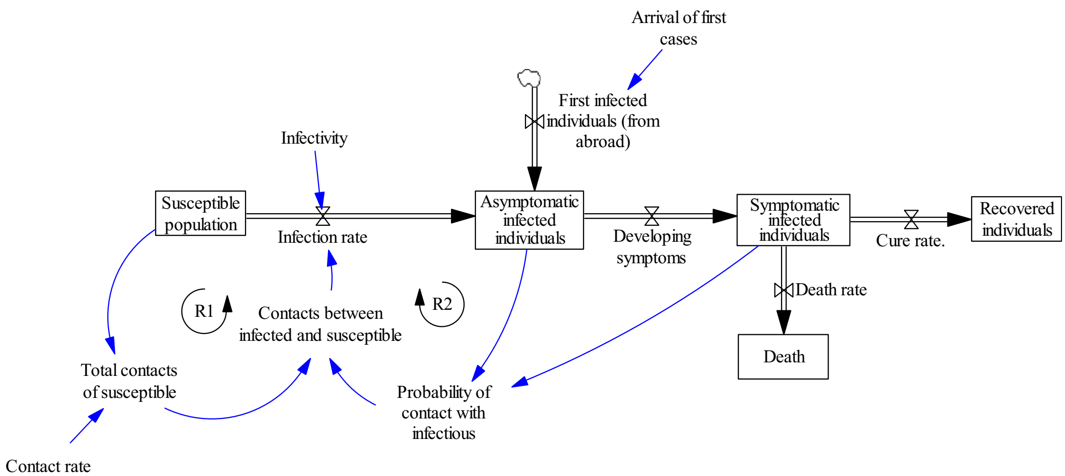

FIGURE 19.10 Arrival of first cases and its impact on the spread of COVID-19 in Tasmania. *From: F. Nasirzadeh.*

Based on Figs. 19.8–19.10, it is observed that by adopting these intervention policies, the contact rate is decreased. As a result, contacts between infectious and susceptible and consequently the infection rate are decreased. By decreasing the infection rate, the cumulative number of asymptomatic infected and symptomatic infected will be decreased and this will slow COVID-19 spread by flattening the curve. This will aid to select the optimal measures to spread the number of people infected by the COVID-19 out over time so that the state's health system is not overwhelmed.

Based on our findings, policymakers can rely on SD to determine the best interventions to control the spread of COVID-19 in Tas, with a particular emphasis on flattening the growth rate of the disease, which will consequently reduce the pressure on the state healthcare system. Modeling of the complex system of various interrelated factors affecting the spread of COVID-19 using SD provides an opportunity for the governments to assess the efficiency of different interventions in a virtual environment rather than experimenting on the real population.

6. North West Tasmania emergency response and recovery dynamic scenario modeling

6.1 Dynamic scenario modeling

Considering the complexities of a pandemic situation, and the impacts that this will have on the community, as well as the pressures on emergency response and recovery, the need arises to be able to predict "what-if" scenarios to be able to plan for an efficient response and recovery in future pandemic situations. The previous sections in this chapter clearly indicate that the COVID-19 pandemic is indeed a complex and dynamic situation to be dealt with. This requires the ability of dealing with current situations, as well as with future planning scenarios. To be able to provide assistance in decision-making, we propose the use of a DSPM, developed by the Live+Smart Research Laboratory, Deakin University, that is a custom-built dynamic scenario planning tool. This tool provides scenario-modeling capabilities (i.e., scenario testing) to better understand how the physical, landscape characteristics, social, cultural, built form, and land use attributes of the North West Tas region will change under different impacts from population growth, climate events [115], development, and disaster impacts such as the COVID-19 pandemic scenario.

The fundamental method of the DSPM is based on the use of "indicators" (key metrics), while over a 100 standard indicators potentially can be used and custom indicators need to be developed for the North West Tas region. The identification of the top-priority custom indicators for the scenarios of COVID-19 pandemic and the implementation of the DSPM will aim to address the issues currently experienced. Furthermore, the DSPM will use the outputs from the Systems Dynamics Modeling for COVID-19 as inputs to develop the custom indicators to be able a dynamic scenario model exercise with the considerations of various "what-if" contexts.

6.2 Digital Terrain Model

The DSPM is embedded in a GIS DTM. The base platform 2D/3D GIS DTM of the North West Tas area will use satellite data on built form, vegetation, topography, and a DTM inclusive of land use, environmental factors and classifications, climate, open source data, and geodemographic classification data developed from the 2016 Australian Bureau of Statistics Census, as well as other sources identified. The DTM is embedded in ArcGIS Pro, combined with the CommunityViz tool and other Web-based visualization tools, to enable the functionality of scenario modeling capabilities.

6.3 Emergency response and recovery modeling

Based on the simulation results of the Systems Dynamics Modeling of the COVID-19 spread, and the modeling of various "what-if" scenarios in the DSPM, this will inform the emergency response and recovery scenario modeling. To be able to identify scenarios of impact to emergency response and recovery, advanced modeling tools will be utilized, such as the ADAM, which is a predictive modeling tool that uses historical CAD data, GIS map data, and a rigorous projection algorithm to calculate the impact of deployment changes on response times and availability [112]. ADAM provides a limitless number of deployment scenarios that can be evaluated to maximize efficiency in emergency response and recovery operations. In the context of COVID-19 in North West Tas, ADAM will be used to analyze the effect on deployment changes and projects the impacts on response times due to the factors of

- peak-time units per station,
- station closures,
- staffing reductions,
- apparatus relocation,
- annexation,
- call volume increase,
- road closures,
- hospital closures.

6.4 Hypothetical scenario context

The following description is a typical hypothetical scenario that can be modeled within the DSPM. During a pandemic like COVID-19, maintaining the health of medical and emergency medical services personnel is critical to ensure that the needs of the community continue to be addressed. During a pandemic, emergency services personnel could fall victim to the virus that is spreading quickly. Additionally, emergency centers such as hospitals and related medical facilities could be shut down as a result of infection. In such situations, and due to the increased illness of staff, emergency services may need to be reduced or consolidated. To identify risks of impact due to closure of hospitals and ambulance stations and to maintain the current emergency services levels of functioning, through the likelihood for maintaining a healthy workforce, this scenario would analyze which stations and additional hospitals could be temporarily closed and in what order if they anticipate the need to close multiple ambulance stations. The goal of the hypothetical scenario would be to close the station(s) and the hospitals that would have the least adverse impact on emergency services provisions and response times. To be able to identify the outcomes and impacts of this "what-if" scenario, the ADAM tool [112] will be used in combination with the DSPM, and the following steps/stages in the research study need to be followed:

1. build base GIS DTM;
2. identify and confirm current spread, and model the potential spread of COVID-19 Systems Dynamic Modeling (short term) and/or Agent-Based Modeling (longer term);
3. collect data including information for vulnerable communities and locations;
4. resource identification—identify the Northern Tasmania Ambulance and Hospitals resources, station locations, equipment, and vehicles, including past 2 years of historic emergency response data;
5. build/adapt the custom DSPM for the Northern and North Western Region of Tasmania to accommodate scenario testing;
6. impact analysis using ADAM—conduct response time analysis and provide recommendations on which stations could be temporarily closed and provide the resultant projected response times due to the station closure, considering various scenarios of COVID-19 spread;
7. record the findings.

7. Conclusions and future work

It is evident that dealing with such a complex topic, the use of various modeling tools in combination, such as the Systems Dynamic Model, the DSPM, and the emergency response modeling tool ADAM, may have the capability to provide foresight to assist in decision-making before and during a pandemic.

Furthermore, the potential application and benefits of these modeling tools spreads far beyond the case study of Tas. Beyond Tas, the DSPM GIS modeling tool described in this chapter may be key in better understanding how COVID-19 can impact communities in different regions and how vulnerable these communities are. In particular, the model can be helpful to test different scenario management protocols, especially in situations where available policies and management solutions need to be recalibrated to ensure that they would be applicable in the case of the present pandemic or future pandemics.

Second, in a different dimension, the described model may benefit from a wide range of frontiers, especially noting that similar models have occasionally be employed in the case of earthquakes and other disasters [118,119]. Regarding COVID-19, the model is bound to gain from the economic dimension especially following the development in the sector, particularly relating to the ongoing trends by different countries to seek economic compensation from the Chinese government for the damages incurred as a result of spread of the coronavirus in their country [12]. On this context, the argument by different countries such as the United States, Germany, Spain, Sweden, and Australia is that China's action, or inaction, of delaying information sharing and/or lack of transparency, especially in regard to the origin and spread of the virus in the country, has brought much pain globally. Following this, those countries have been unsatisfied with the information given by the WHO and the Chinese government concerning the origin of the virus and have thus turned to forming independent fact-finding committees to establish both the truth and the various subsequent consequences [120]. Following those, the United States has already withdrawn its funding to the WHO and other countries are expected to follow [121]. With increasing global pressures, including economic compensation sought and the evaluation of policy mechanisms, there will be an increasing attention aimed at better evaluating which response scenario policy measures were more effective. The present DSPM GIS model would gain from an economic frontier to better compute "what-if" scenarios on a wider lens.

Third, the application of the model in different contexts to test its validity and to better understand the spread outcome and the effectiveness of policy responses would aid local governments and policymakers. Such contexts could include urban areas, suburban areas, towns, developed and developing countries, and others. This also includes built facilities like jails and such institutions where outbreaks have been observed, rendering governments, like in the Republic of Iran, ineffective and forcing the release of prisoners to reduce congestion and ultimately reduce the risk of contamination and spread [122]. Testing these different places and contexts that have been observed to warrant different policies, depending on issues such as population capacity and others, would help establish the strength of this model and lead to better implementation.

Finally, there are numerous uncertainties as to the biology of the virus and the factors of contamination and its long-term impacts on human health. It is premature at this stage to ascertain with confidence that one particular model may stand as a one-size-fits-all solution in mapping the outbreak and responses in relation to the pandemic. As more knowledge is gained on the virus, models need to be revised and retested accordingly.

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