

Management of the COVID-19 Pandemic in Singapore from 2020 to 2021: A Revisit

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Abstract: The first coronavirus disease 2019 (COVID-19) case was detected in Singapore on 23 January 2020. Over the two years, Singapore witnessed tightening and easing of policies in response to and in anticipation of new variants, stress on the healthcare sector, and new waves of infection. Upon confirming the reliability of the data using Benford's analysis, the collated COVID-19 data and trends were analyzed alongside the policies between 2020 and 2021 in Singapore. Due to the proactive nature of these policies, Singapore was largely successful in reducing the imported cases that would spill over and result in community waves of infection and death. The government has taken necessary steps to support the citizens and reduce the impact of the pandemic on the economy of the country. Furthermore, there were policies that were more responsive and there are lessons to be learned from neighboring countries on their management of the pandemic. Given the endemic approach the government has adopted, the efficacy of these policies comes down to its sustainability. Since the pandemic requires frequent revisiting of these policies, Singapore's long-term management of the pandemic (or endemic) and its impact comes down to the ability of the government to introduce sustainable policies and update these according to new developments in treatments, variants, and vaccines, bearing in mind the socioeconomic condition of the country.

Keywords: SARS-CoV-2; COVID-19; Benford's Law; Singapore; pandemic management



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1. Introduction

In December 2019, a novel coronavirus named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causing serious pneumonia was first reported in Wuhan, China. Coronavirus disease 2019 (COVID-19) was a novel disease with major respiratory symptoms with no effective treatment schemes then. Singapore reported its first COVID-19 case on 23 January 2020 [1]. The Singapore government swiftly implemented various policies to combat COVID-19 while maintaining the economic competitiveness of Singapore. One such example is the Disease Outbreak Response System Condition (DORSCON) framework which serves as a simple way to communicate the level of severity of the current disease situation [2]. The efficient and immediate updates ensured credibility and timeliness of information, which supports the country in recovering from the pandemic crisis. In addition, the COVID-19 multi-ministry taskforce of Singapore also reacted swiftly to the situation and commenced tracking of the global situation from 2 January 2020.

The following months witnessed a rise and fall of cases that were imported, prevalent in the community and within the migrant worker dormitories. This resulted in an all-time peak of cases in May 2020 leading to circuit breaker measures being implemented on 7th April and extended until early June 2020 [3]. This period of increasing cases was met with stricter restrictions imposed by the government. These measures included travel

restrictions, compulsory mask mandate, and digital contact tracing systems like Trace Together. Travel restrictions were imposed in February 2020 and became stricter as the cases increased. With increasing community cases, compulsory mask mandate was established in April 2020. To facilitate better contact tracing and early detection of cases, Trace Together was also implemented first in March 2020 [4].

As the number of cases stabilized and the economic repercussions of tighter restrictions were considered, safe and progressive reopening was carried out gradually in three phases. Phase I—Safe Re-opening was implemented on 2 June 2020, and Phase II—Safe Transition was initiated on 19 June 2020. Phase III—Safe Nation started from 28 December 2020 onwards [5]. This approach was designed considering the impact of COVID-19 on the national economy while also being cautious of community spread.

However, following these phases, Singapore witnessed an oscillation between restricting and easing of policies, either in response to or in anticipation of latest developments regarding the pandemic. These developments were often in the form of new variants or sub-variants, new clusters, rise in imported cases or scientific developments such as vaccinations. The situation stabilized by the second half of 2021 as the government adopted an endemic approach when dealing with the pandemic. Recognizing that COVID-19 will continue to exist in the society, the focus was on stabilizing the cases with minimum restrictions using vaccination differentiated measures (VDM) [6].

Throughout the circuit breaker period and the subsequent phases, the cases have displayed interesting patterns that were influenced by policies and reveal how three components of the total cases—imported, community, and dormitory cases—changed over time. This paper revisits the COVID-19 policies over the course of 2020 and 2021 and discusses the consequences of these policies in Singapore.

2. Materials and Methods

2.1. Data Collation

For this study, data were collected from a combination of the situation reports from Ministry of Health (MOH) News Highlights and the Interactive Situation Report with the epidemic split curve. The situation reports with data from the most recent 14 days was utilized for collating the linked and unlinked cases. However, since the published reports cannot be updated in the same table, the interactive situation report was used. This situation report, updated daily, allowed collection of updated data for imported, community, and dormitory cases as well as the cases that were isolated before detection and detected through surveillance. Additionally, this facilitated cross-checking of the situation report data which may have been later altered due to contact tracing developments (www.moh.gov.sg/covid-19, accessed on 10 July 2022) [6].

2.2. Benford's Law Analysis

To determine the accuracy and reliability of our COVID-19 data collated from MOH, we need to show if the dataset obeys Benford's Law, and if there is anomaly in our readings. Benford's Law, also known as the Newcomb-Benford Law or the First-digit Law, was first observed by Newcomb and popularized by Benford. After extensive research about this distribution phenomenon, Benford's law remains an interesting methodology for finding anomalies in data. The law is considered an empirical gem of statistical folklore used for fraud detection in many naturally occurring datasets such as financial reports, election data, macroeconomics data, and scientific data [7]. The same technique has also been deployed in the modeling of behavioral features for social network users. Research conducted by Anran Wei et al. in September 2020 studied the application of Benford's Law to COVID-19 datasets where they targeted data readings of total confirmed cases, total deaths, and daily confirmed cases. They obtained numbers from nineteen countries and the general results showed that COVID-19 data readings follow Benford's Law [8]. The idea behind Benford's Law is that the leading digits 1, 2, . . . , 9 of any naturally occurring data follow a certain probability distribution where the probability of digit 1 occurring is approximately 30% of

the time and decreases monotonically to less than 5% for digit 9. More precisely, the exact law is given by:

$$P(d) = \log_{10}(d + 1) - \log_{10}(d) = \log_{10}(1 + 1/d), \text{ for all } (d = 1, \dots, 9)$$

Here, d denotes the first significant of the decimal digit, e.g.,

$$P(d = 1) = \log_{10}(2/1) = 0.3010, P(d = 2) = \log_{10}(3/2) = 0.1760, \dots,$$

$$P(d = 9) = \log_{10}(10/9) = 0.04575$$

2.3. Policy Evaluation

The policies were collected from the MOH website (www.moh.gov.sg/covid-19, accessed on 10 July 2022), where daily updates are posted since 2 January 2020 [6]. The updates include the daily new cases, grants given out by the government, trade agreements with other countries other updates on the COVID-19 situation in Singapore. There are multiple updates per day, hence, multiple hyperlinks will be shown under the same date. A table was created to facilitate referencing of the policies updated. These policies were analyzed alongside the COVID-19 data to understand the impact of the pandemic on these policies and vice versa.

3. Results

3.1. Benford’s Law Analysis

In our study, we superimpose our readings onto the Benford’s Law curve and determine whether it will yield a good fit. If the datasets match closely to the Benford’s Law curve, then the COVID-19 dataset can be considered reliable for our subsequent analysis. The graph of the first digit of daily cases from 2020–2021 plotted against frequency (in %) seems to follow Benford’s distribution closely. The frequency of the first digits obeys the law, more accurately among the higher digits than the lower digits. The shape of the graph matches the expected shape of Benford’s distribution. Given that no anomaly was detected (Figure 1), the variation of empirical measurements from the expected values may not be statistically significant.

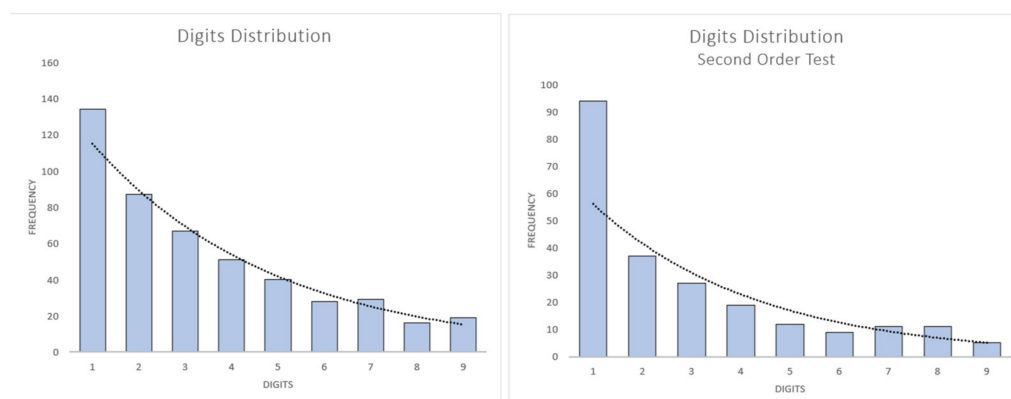


Figure 1. First digit distribution and second order test for COVID-19 data from 2020–2021 in Singapore (Benford’s test).

Slight deviations in data are acceptable since the Benford’s distribution is an ideal case scenario and the real-world examples deviate slightly from the ideal model [3]. Given that Benford’s law has been used widely to detect fraudulent reporting and the data largely follow the distribution, it can thus be concluded that the data for COVID-19 cases in Singapore are largely accurate and reliable for further analysis [9].

The digit distribution second order test in Figure 1, related to Benford’s Law, could also be used to detect if there are any inconsistencies in the internal pattern of our COVID-19

data. A formal definition of the second order Benford test is as follows: Let x_1, \dots, x_N be a data set comprising observations drawn from a continuous distribution, and let y_1, \dots, y_N be the x_i 's in increasing order. Then, for many natural data sets, for large N , the digits of the differences between adjacent observations ($y_{i+1} - y_i$) are close to Benford's Law. Therefore, this test helps to detect the relationship and anomaly in our data based on the digits of the difference between the largest number of cases and the smallest number of cases after sorting. As observed in Figure 1, these digit patterns also seem to be closely approximated by the digit frequencies of Benford's Law using the second-order digit distribution test [10].

3.2. COVID-19 Trends in Singapore

Singapore reported its first imported case of COVID-19 on 23 January 2020 and continued to report imported cases until March. Imported cases peaked by end March when there was a significant increase in cases. However, this decreased toward the second half of March and April. Ever since travel restrictions were eased by mid-June, imported cases resurfaced and gradually increased until the end of December 2020. Furthermore, the first community case was detected in Singapore during February and steadily increased until April, peaking during the second week of April. With two periods of circuit breaker measures, community cases gradually decreased by June 2020. However, Singapore witnessed what was possibly a second wave of much weaker intensity in July. This could be attributed to the easing of circuit breaker measures in June, which increased community transmission. However, most of the dormitories were only cleared in August, while the second wave is seemed to have started as early as July. Another possible explanation is from an immunological standpoint. In his paper on the second wave of COVID-19, O Hossein argues that the second wave of the pandemic in several countries is likely a cause of pathogen–host interaction pattern rather than relaxed social distancing measures [11]. Healthy individuals infected with the virus possibly cleared the viral load before adaptive immune response could be initiated. Thus, making them more susceptible to a second round of infection due to a lack of memory cells. Eventually the community cases tapered out and was negligible by November of 2020 (Figure 2).

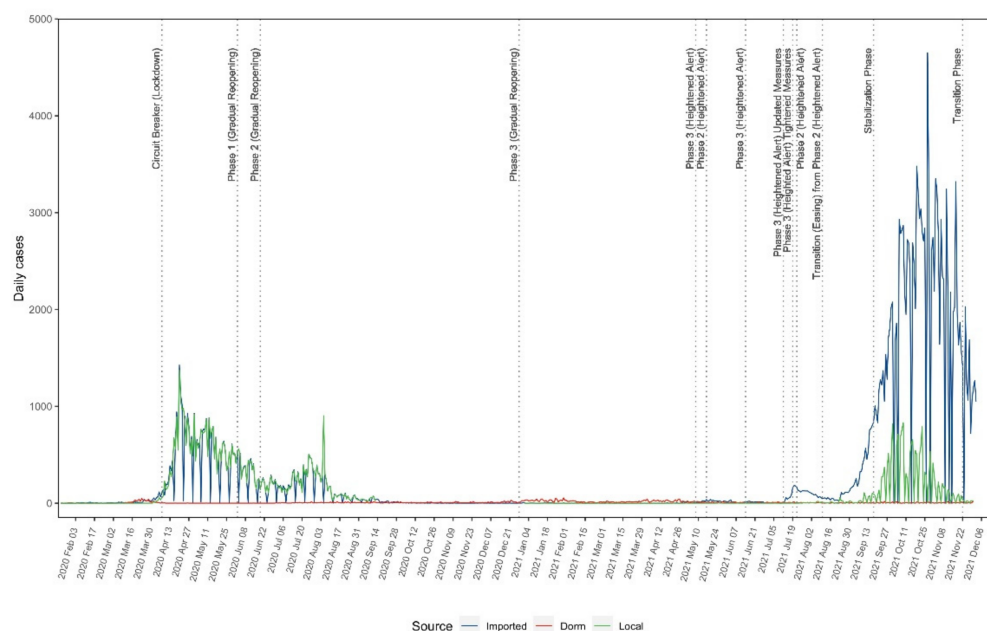


Figure 2. COVID-19 cases and phases in Singapore (2020–2021).

Meanwhile, the dormitory cases, first detected in March 2020, experienced a dramatic rise in cases, peaking in April 2020. This could be attributed to two reasons. First, the significant number of community cases that were prevalent at the time and infected dormitory

workers. Second and possibly of greater importance is the high density of dorm workers living within small spaces under poor living conditions that favored rapid transmission within the dormitories [12]. With frequent testing and isolation, the number of dorm cases decreased subsequently. However, there was still a significant number of cases resurfacing in September owing to a second peak that emerged in August. When the dorms were intended to be cleared on 7 August, the number of cases leading to this day reached a three-month high [13]. Eventually, all dormitories were cleared and there were practically no dorm cases reported by December 2020.

Taken together, the data for imported, community, and dormitory cases together make it evident that a spike in imported cases was followed by community cases within two weeks during the first half of the year. The first wave of community cases seemed to follow Farr's Law, tapering off owing to circuit breaker measures [10]. The second wave of community cases is about a month after phase 1 was initiated and was possibly due to a lax in restrictions. Once travel restrictions and quarantine were imposed, while the imported cases started increasing, community cases remained low. This is because most of the imported cases became isolated before detection, decreasing the chances of it spilling into the community, thereby decreasing the percentage of imported cases that turned into community cases. However, this did not prevent community cases from spilling into dorm once again in July/August 2020—a week after the community peak of the second wave since most dorms were open by then. By the end of December 2020, both community and dormitory cases were close to zero and only newly imported cases were prevalent.

However, in 2021, Singapore witnessed several new challenges in management of the pandemic. More COVID-19 cases started to resurface, and Singapore reverted to a heightened alert in Phase 3 during May. This was followed by several rounds of tightening and subsequent easing of measures. In July 2021, the government announced several measures tightening the restrictions within Phase 3 (heightened alert). Following this announcement, Singapore witnessed the largest wave it had seen since the beginning of the pandemic.

To understand the evolution of pandemic management from 2020 to 2021, these policies enforced during this period are sufficient. The government clearly adopted an endemic approach to managing the pandemic—accepting that COVID-19 will remain in the society and measures must focus on gradual reopening without placing a burden on the healthcare system rather than complete restrictions on activities. Recognizing the impact that COVID-19 has had on the economy of Singapore, it was crucial to strike a balance between the cost of the infections, its impact on the healthcare system, and the economic consequences of a zero-COVID strategy.

As Singapore's largest COVID-19 wave placed an immense burden on healthcare workers, the stabilization phase was announced on 27 September 2021 when Singapore reported 1641 daily cases. The aim of this phase was to stabilize the cases and ease the burden on the healthcare system. Hence, this period was further extended until November 2021. In November 2021, when cases were still high, Singapore exited the stabilization phase and entered the transition phase. This period was characterized by lifting of several restrictions that were imposed for stabilization. A significant difference between this wave and the COVID-19 wave in 2020 was the nature of the cases. Most of these reported cases were imported cases and unlike 2020, the government managed to contain these cases without spilling over into the community. Hence, community transmission was less severe compared to 2020 and is further a testament to the success of pandemic management in Singapore.

4. Discussion

4.1. What Has Singapore Done Well?

4.1.1. Information Transparency

As a role model to some countries, the Singapore government tackled the pandemic effectively, be it reducing the economic impacts as much as possible or slowing down

community spread. Singapore's success in effectively managing the pandemic can be largely attributed to the public willingness to cooperate and adherence to the policies that were enforced. This can be attributed to the transparency from the government regarding the COVID-19 situation in Singapore as well as the rationale behind all of the policies enforced [14]. The Singapore government communicated daily developments and situation updates through press releases and situation reports. The Gov.sg WhatsApp channel was a medium to disseminate important announcements to the public in an accessible manner daily [15]. This was done to disseminate information, reduce panic, and debunk misinformation that was spreading throughout the Internet [16]. This level of transparency has been crucial in solidifying the public trust in the government, contributing to their role in pandemic management.

4.1.2. Efficient Screening

To curb the spread of cases, liberal testing was conducted on the population, with Singapore being one of the countries with one of the greatest numbers of swab tests done [17]. On top of the testing done, contact tracing and the SafeEntry were implemented to break the chain of transmission, with the contact tracing being widely commended for its efficiency [18]. The Public Health Preparedness Clinic (PHPC) was also activated. The PHPCs are clinics across the country that are activated during public health emergencies which dispense medications, administer vaccinations, and provide subsidized treatments. The PHPCs are adequately prepared since they have been receiving constant training before the pandemic [19]. By serving as the intermediary between the community and hospitals, these PHPCs help to increase the efficiency and reduce the stress on hospitals by supplementing manpower to screen for patients and categorize them into low-risk and high-risk groups [20].

4.1.3. Vaccination

One of the most important factors that shaped Singapore's response to the pandemic in 2021 has been its vaccination campaign. With an aggressive campaign, the Singapore government aimed to ease restrictions largely allowing vaccinated individuals to return to almost pre-COVID-19 levels of activity while protecting the unvaccinated population. Singapore initiated the vaccination rollout on 30 December 2020, prioritizing health care workers who are most at risk. The subsequent phases of the campaign targeted senior citizens and the vulnerable before reaching the young adult population and children. As of 29 December 2021, 87% of the population had been fully vaccinated. To attain this, the government mobilized several clinics as centers where walking vaccinations were encouraged. As a result, vaccination-differentiated measures were introduced in 2021 wherein vaccinated individuals could carry out activities to greater level of freedom in comparison to non-vaccinated individuals allowing easing of restrictions while protecting the unvaccinated [21].

This campaign is frequently updated based on latest scientific developments and expert advice on the types of vaccines and doses required as the pandemic progresses and variants like Delta are identified. Booster vaccine doses were encouraged and were determined as necessary to be considered fully vaccinated. The Singapore government has been largely transparent regarding the vaccination situation in Singapore and even prepared the public for a possibility of taking booster shots periodically to maintain their fully vaccinated status according to the vaccinated differentiated measures [22]. Vaccination has been crucial in the stabilization that was achieved in 2021 while avoiding a strain on the health care system as well as protecting the vulnerable senior citizens in Singapore.

4.1.4. Providing Grants

To protect the economy from the consequences of the COVID-19 pandemic, different grants and packages were distributed. For instance, the Unity Budget, Resilience and Solidarity Budget, and the Fortitude Budget were approved to help offset the costs and

protect the livelihood of many [23]. These budgets were targeted toward employment-related issues, sectors that were affected by COVID-19, and stimulating the economy. For example, the SGUnited Jobs and Skills package aids jobseekers in looking for a job and grants such as the self-employed person income relief scheme (SIRS) help to ease the costs for the self-employed. Industries such as the Arts & Culture sector and the tourism sector received \$55 million and \$90 million respectively as they were hit hard by the impact of COVID-19 [24]. Besides the different subsidies for businesses and industries, the government also provided subsidies to offset the costs of healthcare. This is important, especially in times when healthcare is most needed by the people. Through the one-off COVID-19 subsidy and additional support to the lower and middle income, as well as the elderly of the Merdeka and Pioneer generation, Singaporeans can now receive healthcare without worrying about the costs [25]. As a country that is heavily reliant on imported products, Singapore has been constantly stockpiling its supplies and is well-prepared for a disruption in the supply chain. Even though production and exports were reduced by many countries during the pandemic, the Singapore government had months' worth of essential items and food for the country. These stockpiles allowed more time for the government to source for alternative productions [26].

4.2. What Could Have Been Done Better?

4.2.1. Electronic Tracking

To date, there are different ways of tracking the places a person has visited in Singapore. This includes the SafeEntry, Trace together application, and the Trace Together token. The SafeEntry was implemented on 12 May 2020, the Trace together application was launched on 20 March 2020, and the Trace together token was distributed from 14 September 2020 onwards [27–29]. Prior to the implementation of electronic tracking, contact tracing was done manually and involved greater time and manpower. This process included monitoring the movement of the patient for the past 14 days, investigation and identification of close contacts, and notifying the close contacts [30]. Interviewing the patient was also the most crucial process in identifying potential clusters and hence, a patient's memory and integrity are vital to identifying close contacts. While the contact tracing methods in Singapore has been commended for its high accuracy and persistence in tracking, some lapse in contact tracing is inevitable as patients could lie about their history or suffer from recall biases especially when these patients are already unwell [18,19,31]. Therefore, the use of electronic tracking in the earlier phase could have been implemented to a greater extent to prevent such lapses.

While SafeEntry is compulsory, downloading of the Trace together application is voluntary. The Trace together application acts like the Trace together token where it tracks whether a person had been in close proximity to an infected individual. Short-distance Bluetooth signals that are exchanged between the application or the token mean that these individuals are near each other [32]. Therefore, the Trace together application is much more accurate in determining whether a person is in close contact with the patient compared to SafeEntry, which only tracks whether a person has entered a certain premise. Furthermore, SafeEntry could be less accessible to elderly who are not proficient in technology since it requires the use of smartphones [4]. Even though the National Registration Identity Card (NRIC) could replace our smart phones for SafeEntry, not all places are equipped with the NRIC scanner. Thus, the Trace Together token, which tracks the location more accurately and is simpler in terms of usage, would be more convenient and appropriate for contact tracing. However, owing to the lack of time, the tokens could not be manufactured in time. Thus, earlier implementation of the SafeEntry could have made the contact tracing process more efficient.

4.2.2. Mask Mandate

Policies regarding mask wearing are a crucial element of the pandemic, which if managed more closely, could have prevented the outbreak from spreading within the

community in Singapore. Singapore confirmed the first case of COVID-19 on 23 January 2020. At that time, only sick persons (with obvious symptoms) were required to wear masks and the public was specifically instructed by the government to not wear masks unless they were sick. This was to prevent any shortage of mask supply due to excessive use. Until 5 June, the World Health Organization (WHO) did not encourage the public to wear masks at all times. However, as of now, WHO announced that mask wearing may become a part of normal life. [33]

The Singapore Government only enforced compulsory mask wearing from 15 April 2020 onwards. According to the policies, individuals who did not wear a mask could be fined \$300 the first time and \$1000 the second time. Based on medical recommendation, children below two years of age and adults doing strenuous exercise were exempted from mask wearing [34]. For evidence that the decrease in community spread was due to compulsory mask enforcements, Singapore has to look no further than Vietnam. The first case of COVID-19 was detected in Vietnam on 17 January 2020. The government made wearing masks on public transport and all public places compulsory on 21 February and 16 March respectively [35]. Vietnam's limited community spread and well-controlled second wave is likely due to these policies [36].

Furthermore, Taiwan's success in managing COVID-19 has been attributed to its compulsory mask wearing policies and medical care [37]. M. T Leffler et al. found that the per capacity mortality of countries where mask wearing was practiced diligently was significantly lower than other countries that did not strictly enforce mask wearing [38]. Scientifically, this is attributed to masks acting a barrier, preventing almost all droplets from an infected person being suspended in the atmosphere [39]. Epidemiologically, the impact of mask wearing of daily COVID-19 cases has been established. A Health Affairs study on the COVID-19 spread in 15 U.S. states has found that there was a significant decline in the growth of daily COVID-19 cases in states with strict mask mandates [40]. These evidence illustrate that an early intervention to make masks compulsory while securing mask supplies could have significantly decreased community cases in Singapore.

4.2.3. Travel Restrictions

Since the outbreak of COVID-19 in Wuhan, Singapore has consistently been monitoring its epidemiological spread and imposing travel advisories and restrictions to Wuhan. All inbound flights from Wuhan, China were ceased when the first COVID-19 case in Singapore was confirmed [41]. By February 2020, all travel to Hubei province in mainland China, and non-essential travel to the rest of mainland China, Iran, Japan, and the Republic of Korea were issued travel advisories. Thereafter, Singapore continued to impose travel restrictions and advisories on countries with very high numbers of cases such as Italy, France, Spain and Germany [42]. On 23 March 2020, all short-term visitors were not allowed entry or transit through Singapore [43].

In the early stages of a pandemic outbreak, mobility plays a significant role in the spread of a disease [44]. This was demonstrated in a recent study on the outbreak of COVID-19 which showed that mobility is indeed a strong contributor to the global spread of the virus [44]. As a country that is highly connected to the rest of the world, there would naturally be visitors from many countries. Inevitably, there were imported cases which led to a few clusters. Two clusters were linked to tourists from China while another was the Grand Hyatt cluster which involved several overseas cases [45]. Although the clusters were closed, there were other unlinked cases which emerged. These could be linked to undetected imported cases since air travel was still active in March, when Singapore received the greatest number of visitors from Indonesia, UK and Australia [46]. In these three countries, COVID-19 cases started increasing since the start of March [47–49]. Since some travelers could be asymptomatic or pre-symptomatic, those that were in Singapore before 23 March 2020 might have already been infected with the virus. Furthermore, there were cases in Indonesia that went unreported due to low testing rate [50,51]. Hence, cases in Indonesia could be higher than recorded. Moreover, European countries and the USA

had high number of cases as well [52]. Even though Singapore received fewer visitors from these countries, there could be higher chance of having an infected visitor from these countries. This was especially so in Europe, where cases in Italy multiplied more than nine times in ten days within the period when Singapore was still receiving travelers from Europe [46]. Cases also escalated in USA and was as high as that in China in mid-March [52]. Hence, the Singapore government could have prevented the sudden spike in the number of cases if stricter travel restrictions were implemented earlier.

5. Conclusions

In summary, Singapore has tackled the pandemic effectively, balancing restrictions with economic impact. The government has constantly updated the public on the COVID-19 situations through different platforms. To curb the spread of cases, extensive testing was conducted. To protect the economy from the consequences of the COVID-19 pandemic, different grants and packages were distributed as well. However, there were several policies and measures that could have been more effectively established. For instance, the late establishment of a compulsory mask mandate due to limited mask supply may have contributed to the spread during the early months of the pandemic. Furthermore, restricting travelers earlier could have decreased the imported cases that enter the community. However, with emerging nature of the pandemic, the success of these policies eventually comes down to the government's ability to be flexible and responsive to latest developments, whether regarding new variants or vaccines.

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