Catalysing innovation and digital transformation in combating the Covid-19 pandemic: whole-of government collaborations in ICT, R&D, and business digitization in Singapore

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Catalysing Innovation and Digital Transformation in Combating COVID-19 through WOG

Collaborations in Singapore

Celia Lee[1,*]· Jong Min Lee[2] · Yipeng Liu[2,3]

Abstract

Combating the COVID-19 global health crisis necessitates rapid response and agile action in the design and implementation of appropriate policy measures and management practices. Collaborative partnerships between public and private sectors play a critical role in developing and deploying innovative practices to overcome the crisis. However, the extant literature has not paid adequate attention to the determinants for managing collaborative partnerships in the emergency context. By juxtaposing the literature on readiness for change and strategic agility, this paper addresses this gap by articulating readiness and agility as the two salient enabling conditions for collaborative partnerships in the COVID-19 context. We conceptualise that readiness consists of three dimensions (national infrastructure, government ability to integrate resources, and citizens' willingness to cooperate) and that agility has two manifestations (speed and scale). By using the case of digital transformation and ICT deployment in Singapore, this paper illustrates how and why rapid reactions and responses to COVID-19 can be achieved through public-private partnership for collaborative innovation. Our study may provide some revealing insights into the organisational and institutional arrangement and preparations for other countries in the fight against COVID-19 by leveraging collaborative innovation.

Key words: collaboration, innovation, research and development, pandemic, COVID-19, Singapore

[1] *National Technological University, Singapore, Singapore*
[2] *Henley Business School, University of Reading, Reading, UK*
[3] *Shanghai Institute of Technology, Shanghai, China*
[*] *Corresponding author (kplee@ntu.edu.sg)*

1. Introduction

The coronavirus (COVID-19) pandemic has not only taken hundreds of thousands of human lives but also brought an unprecedented economic, social, and political crisis. While COVID-19 continues to spread rapidly around the world, countries are at different stages of the pandemic taking different measures to address it. Some Asian countries appear to have contained the virus and secure vital supply chains more effectively than other countries (ESCAP 2020; Liu, Lee & Lee, 2020). For instance, Singapore and South Korea (hereafter Korea) and China have enjoyed early success of flattening the curve on the virus within a month without enforcing extreme lockdown measures (Feuer 2020). These countries have commonly leveraged on advanced digital infrastructure and information and communication technology (ICT) capabilities to trace contacts and manage containment measures. Importantly, public and private sectors have made collaborative innovation efforts (Collinson & Liu, 2019) to mitigate and overcome the crisis. While there is no 'one-size-fits-all' approach, there are commonality in best practices that may provide useful lessons about how these countries have capitalized on ICT capabilities to respond to COVID-19 and what innovative approaches have taken to alleviate the impact of the pandemic.

This paper proposes a conceptual framework of collaborative partnerships for innovation by using the case of Singapore to illustrate *how and why* rapid reactions and responses to COVID-19 are contingent upon the readiness (infrastructure, ability, and willingness) and agility (speed and scale) of public and private sectors in achieving innovation in combating COVID-19. Singapore is well known for its proactive use of ICT in providing government services (WUIG 2017)[1]. The stable ICT infrastructure has bolstered society and economy to mitigate adverse impacts by assisting home-based learning, remote working, and virtual hangouts. The government has rapidly rolled out various innovative initiatives not only to contain the virus but also to maintain business continuity. COVID-19 has also stimulated the innovative collaboration of research and development (R&D) sectors in healthcare institutions and public agencies to improve the production of personal protective

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[1] According to a study by the Waseda University Institute of e-Government, Singapore garnered a total score of 91.057, ahead of Denmark (88.739), USA (87.117), Japan, (81.236) and Estonia (81.198).

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equipment (PPE) and the development of advanced test-kits. Manufacturing sectors have realized product and process innovation by rapidly adopting new technologies such as intelligent warehouse management systems, predictive maintenance, robotics, 3D printing, and artificial intelligence (AI) in effort to boost the production of PPE.

In this paper, we first survey briefly the existing collaborative innovation literature, follow by an illustration of the 'whole-of-government' approach of Singapore to contain endemic diseases in responding to the three waves of transmission. Next, we review collaborative innovation and best practice including the development and usage of mobile apps and portals for contact tracing, the advancement of R&D effort in developing test kits and PPE, and the systematic support for small and medium enterprises (SMEs) to adopt digital solution and e-commerce platforms. We further illuminate the generalisability of our framework by extending the discussion to the example of Korea.

2. Collaborative Innovation

Collaborative innovation denotes multi-actor collaboration between public and private actors as a superior innovation driver (Torfing, 2019). As alternative to market competition and organisational entrepreneurship, collaborative innovation is a strategy for public sector innovation by mobilising multi-actor engagement (Hartley, Sørensen, & Torfing, 2013). However, the extant literature on collaborative innovation has paid insufficient attention to the unique characteristics of emergency context and crisis management. Our paper aims to fills this gap by focusing on the collaborative innovation in the context of global health crisis, namely the COVID-19.

The collaborative partnership literature urges researchers to focus on micro-foundations to explain the macro-level observations (Liu, Sarala, Xing, & Cooper, 2017). We argue two constructs, namely readiness and agility, are particular salient from this perspective. Readiness is critical for organisational change with an emphasis on both the urgency of, and readiness for focal changes (Armenakis, Harris, & Mossholder, 1993). ICT infrastructure, such as big data, can foster organisational change readiness (Shah, Irani, & Sharif, 2017). Both individual and organisational readiness are essential components for the emergency management during a healthcare crisis (Lim, 2014). Agility denotes the organisational ability to organise internal resources to respond to external

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environment either crises or opportunities (Ahammad, Glaister, & Gomes, 2020). Agility can speed up the process of opportunity identification in the entrepreneurial team setting (Xing, Liu, Boojihawon, & Tarba, 2020). Individual and organisational action can determine the scale and scope of strategic agility initiatives (Doz, 2020), such as agility for innovation (Doz & Kosonen, 2008). Therefore, we posit that readiness and agility can help to provide a more nuanced understanding of collaborative innovation in the context of global emergency and public health crisis, as expertise, once narrowly focused on health outcomes alone, must now bring together multi-faceted and trans-disciplinary skill sets (Burkle, 2019). Readiness is essential in the establishment and implementation of an effective pandemic response system. Hence simulation exercises should be conducted to ensure individuals and social collectivities, such as communities, schools, hospitals, companies, and public agencies, can respond effectively during disasters (Lim, 2020). Agility is closely related to the quality of response processes and such responses can be pragmatic in the context of a global health crisis, as to bring the pandemics into control and containment stage whereby the state of emergency is lifted and business activities resume a phased-recovery. However, agility in real-world practices does not necessarily generate positive results during extreme events. The ignorance of capacity development and failure to assess it, by and large, points to highly ambiguous and flawed methodological approaches (Lai & Tan, 2012).

The readiness and agility framework is particularly relevant for the case of Singapore's whole-of-government approach (WOG) in responding to the COVID-19 pandemic. The community transmission in Singapore has been brought under control as of August 2020. The higher number of cases is due to the proactive testing of foreign workers in dormitories (see Figure 1). We illustrate how the WOG collaboration has supported Singapore battle against COVID-19 which embraced innovative and digital measures to shed light on how we can fight smarter against the invisible enemy. We discuss how government play a decisive role in orchestrating collaborative group actions with private sectors to rapidly disseminate critical information and swiftly implement innovative measures all over the nation. By doing so, we demonstrate that readiness and agility play an important role in achieving collaborative innovative partnerships to overcome the crisis. Specifically, we analysed secondary data from government archives, media reports, and research reports coupled with online

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interviews conducted with individuals (from medical, public and educational sectors) involved in relevant initiatives or gathered from the live media briefings conducted by the multi-agency taskforce.

[Insert Figure 1 about here]

3. Whole-of-Government Approach: Transferring Lessons from SARS

The Singapore government learnt the value of WOG collaboration when SARS hit the state in 2003 which infected 238 persons and took 33 lives. After the SARS outbreak, Singapore has introduced several key measures to strengthen its pandemic management capabilities. For example, the DORSCON framework (Figure 2) was established to serve as the foundation for the national responses to any epidemic outbreak.

[Insert Figure 2 about here]

The SARS crisis was contained within 2 months through a well-coordinated ministerial committee chaired by the Minister of home affairs and involved many other ministries (Lai 2012). It was apparent that clear leadership and efficient top-down system are essential for a government-wide coordinated response towards dealing with crisis (Lee 2018). The government has established the Homefront Crisis Management Committee as the national framework for coordinating WOG planning and response during a national crisis. The committee chaired by the minister for home affairs functions as a control tower, providing strategic political guidance during a crisis. Supporting the committee is the Crisis Executive Group chaired by the permanent secretary for home affairs, The committee is also supported by various Crisis Management Groups to ensure a comprehensive and integrated multi-agency system to prepare and implement plans (Figure 3) (MOH, 2014).

[Insert Figure 3 about here]

Based on this national framework, Singapore government could respond quickly to contain COVID-19. As early as 22 January (before lockdown in Wuhan on 23 January), a multi-ministerial task force involving all relevant government agencies was formed under the national framework, which is co-chaired by the Minister of Health (MOH) and Minister of National Development. This taskforce had the ability to recommend and implement WOG policies to deal with issues related to COVID-19 (Baker 2020). Singapore's approach to combating the pandemic in response to the three waves of transmission is summarised in Figure 4.

[Insert Figure 4 about here]

The government has also invested heavily in developing pandemic management capacity and infrastructure to deal with similar outbreaks. Pandemic response plans were also put in place with regular simulation exercises being conducted in public hospitals to evaluate and improve the plans. When the taskforce was formed, response plans were put into implementation with clear guidelines and directions coordinated from the top and disseminated to the respective workgroups formed by different government agencies including the Ministry of Manpower (MOM), the Ministry of Communications and Information (MCI), and the Ministry of Trade and Industry (MTI). Over the past 10-15 years, the government has also established digital infrastructure and engineering capabilities as the foundation of the Smart Nation initiative (Ng 2019). They enable Singapore to respond decisively and take swift measures at scale with a suite of digital tools. They also help to disseminate timely and accurate information to the public. In combat against COVID-19, a WOG concerted approach is paramount as its impact is not only limited to health, but also concerns other important issues such as social unrest, political instability, economic impact, and food security. The WOG collaboration embarked by Singapore has fuelled collaborative innovation approaches from both public and private sectors to prevent, mitigate and overcome the pandemic. Specifically, Singapore has rapidly developed and utilized applications (apps) and portals to effectively manage and control transmission,

escalated R&D efforts for more rapid and accurate diagnostic and care services and promoted resilience and agility in the SME sector.

4. Development of Apps and Portals for Surveillance, Movement/ Distancing Management, Public Education and Engagement

The national strategy for pandemic response in Singapore is to establish an effective community-wide surveillance system to detect, trace, and contain novel acute respiratory pathogen with pandemic potential (MOH 2014). A key thrust throughout the crisis has also to do with communicating with the public, educating people, and securing their co-operation with containment measures in a timely and dynamic manner. Further leveraging on its digital capability, the government agencies collaborated closely with external partners to develop platforms and apps to complement its efforts in surveillance, enforcement, and engagement.

4.1 Surveillance: Infrastructure Readiness

Contact tracing is Singapore's key strategy, by which every newly discovered infected person is mapped on to every individual that might have come in close contact with the infected person, so that they can be quickly tested, isolated, and quarantined within 24 hours. Though the process is overseen by MOH, the operation also involves various agencies and paramedics including hospitals, police force, and volunteers. The tracing effort is tedious, labour-intensive, and time-consuming which involves interviews, viewing of surveillance videos taken from CCTVs, and tracing of digital footprints. Considering that there can be lapses in memory and the fact that there is simply no way for people to retroactively identify strangers they might have come into contact with, the Government Technology Agency of Singapore (GovTech) in collaboration with MOH developed a mobile app called *TraceTogether* in March. GovTech is the implementing agency of the Smart Nation and Digital Government Office (SNDGO) which plans and prioritises key smart nation projects and drives digital transformation in Singapore (Smart Nation 2020). Taking advantage of Singapore's high mobile penetration rates, GovTech led the team to come out with a solution to supplement MOH's contact-tracing efforts. Understanding the shortcomings of GPS which only works well in open spaces and

considering users who might be hesitant to download the app for fear of revealing their movements, Mr Jason Bay, the leader of the app development team, explained that the app *"addresses contact tracing by answering the question of 'who' and not 'where'"* by using Bluetooth signals. GovTech has its own team of in-house software developers but hardware is new to them to characterise and calibrate across different models of phones as "*Bluetooth signal strength difference between two phones can be 1,000 present of even up to 10,000"* (GovTech, 2020). The team partnered with researchers at Nanyang Polytechnic and the Institute for Infocomm Research[2] that have anechoic chambers (rooms that block out radio signals) to test out and accurately measure signal strengths of dozens of different phone models. Another important development concern was to ensure privacy and personal information because the success of tracing using this app is dependent on the willingness of people using the app and consenting to share their data. Within eight weeks, the first national Bluetooth tracing solution in the world was successfully built with less privacy-invading Bluetooth technology that exchanges short-distance Bluetooth signals between phones to detect other participating *TraceTogether* users in close proximity. If someone with *TraceTogether* is diagnosed with COVID-19, he or she can simply upload their data to MOH, which will then be able to decrypt the information and begin contacting other *TraceTogether* users who have been in close contact of the confirmed COVID-19 case. Downloading of the app is voluntary and consent to send and share data has to be accepted from the user. As the effectiveness of this tracing measure through *TraceTogether* is entirely depending on its widespread penetration into the general public, the SNDGO works very closely with the public and private to raise awareness and encourage adoption of the app. As of 1 May 2020, more than 1 million people (1/5 of the population) have downloaded the app. GovTech has also decided to make the source code for the app freely available online so that the local and international communities can improve or adapt deployment elsewhere. Based on the successful experience in Singapore, Australia's newly developed contact tracing app is derived from *TraceTogether* (Hendry 2020).

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[2] The Institute for Infocomm Research (I²R) is a member of the Agency for Science, Technology and Research (A*STAR) family and is Singapore's largest ICT research institute.

During the extended circuit breaker, *SafeEntry* registration, a national digital check-in system is quickly developed to log visits by individuals to venues providing essential services, as well as employees of essential services (SafeEntry 2020[3]). This is a free-for-use cloud-based system that can be used to log key information: name, identification number, and mobile number of visitors to a location which will be essential to speed up contact tracing to prevent the spread in the community. Essential businesses such as supermarkets, clinics, and retail outlets have adopted *SafeEntry* system. To ensure smooth implementation, respective ministries (e.g. MOM and Ministry of Education) work together with operators of premises to deploy *SafeEntry* system in wider communities including schools, workplaces, healthcare facilities, malls, hotels, and so on. Operators are required to register for the deployment and can adopt by scanning the national registration identity card (NRIC) with a barcode scanner and/or scanning of a QR code displayed at the venue. The use of *SafeEntry* is now made mandatory as a registration platform that allows information who may have come into contact with cases to be sent automatically to MOH quickly. The list of places visited by confirmed cases are compiled and published online. The Land Transport Authority also worked with taxi and private hiring car operators to roll out the system for passengers taking street-hail trips. Considering its innovative features and a balanced approach in considering privacy and safety for the population, *SafeEntry* system carries the potential to be adopted in other countries that face similar challenges in controlling COVID-19. For both cases of *TraceTogether* and *SafeEntry,* the infrastructure readiness plays a crucial role in the rapid response and agile actions taken by the government.

4.2 Movement/Distancing Management: Government Ability Readiness

Rapid isolation of suspected cases, close contacts, and travellers from affected countries is critical to prevent further transmission. To ensure this, Singapore has strictly enforced stringent quarantine and stay-home notice protocols including the 'Leave of Absence & Stay-Home Notice Tracking Solution' (Information provided by a respondent who was under Stay-Home order), a SMS and mobile-web-based solution that allows people serving their notices to report their locations quickly and accurately

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[3] Safeentry.gov.sg is a Singapore government agency website that provides information on the registration system

to the MOM. This solution, developed by the Open Government Product Unit in GovTech in consultation with MOM and Immigration and Checkpoints Agency, plays a significant role in monitoring movements and penalising individuals who breach the notices.

As more stringent safe-distancing measurements are being undertaken during the circuit breaker including the compulsory wearing of masks when going out for essential needs and exercise, public is encouraged to co-police with the state and report on people or businesses that are flouting the rules of safe distancing. Public can report such defiant behaviours via the *OneService* app. Developed in 2019, the app was part of the municipal services office (MSO)'s effort initially to enable public to notify on municipal matters and feedback on services. As a unit formed within the Ministry of National Development, MSO acts as a network administrative organisation to coordinate with key government agencies, town councils, and community partners to lead and drive collaborative projects and initiatives (Lee, 2018). In light of COVID-19, the app has been modified to include a dedicated function for reporting cases where safe distancing is not being practised. Such information provided by the public will help the relevant agencies in the network to monitor hotspots, enforce, enhance patrolling, and even arrest delinquents. As of 14 April, about 700 safe-distancing infringements have been reported each day via the *OneService* app. The government recognizes that the use of *OneService* app not only alleviate the violation of containment measures but also saves state resources during the COVID-19 situation.

4.3 Public Education and Engagement: Readiness of Communication Platforms

Public education and communication are two indispensable components in health crisis management (Reddy et al. 2009; Reynolds & Seeger, 2005). Educating and engaging the public through public platforms has been a key approach in Singapore in ensuring compliance and are important components in managing COVID-19 pandemic. The practice of daily information sharing and updates by the taskforce to the public through press conferences not only showed transparency but also a mean to combat fake news circulated through social media.

The 'gov.sg' official government online portal is the primary authority source of the latest policy announcements, information, and news with regards to the COVID-19 in Singapore. As

WhatsApp has the highest penetration among social messaging apps in Singapore (used by 4 million people) and fake news are easily propagated through WhatsApp (Basu 2020), the website is complemented with a corresponding WhatsApp account. While the system was already in use for other purposes since the late last year, it was not built for such scale and time sensitivity. The technology had to be upgraded to ensure it can cope with the enormous demand and rapidly disseminating accurate information before fake news are being spread. This service is subscription-based and available in the 4 official languages in Singapore, i.e. English, Chinese, Malay, and Tamil. To ensure timely dissemination of accurate information in different languages, GovTech (original developer) together with MCI (user of the platform) and Agency for Science, Technology and Research (A*STAR) (technology partner) built an AI tool to translate the material first from English (official document) which the draft will be vetted by civil servants before being sent out. To scale up the delivery of messages, GovTech built an alternative government alert system (*Postman*) to replace the existing system run by MCI, which cannot fully deal with the increased load and required speed. Several online information and education platforms have also been co-developed through partnerships between the government and other sectors to educate the public (see Table 1 for examples). The collaborative partnership is the key organisational form that benefits the speedy redeployment of innovation projects and activities in combating COVID-19 in Singapore.

[Insert Table 1 about here]

5. Advancement of R&D: Test Kits and Protective Equipment (PPE)

Since the SARS outbreak in 2003, Singapore has placed emphasis on a multi-disciplinary and collaborative approach to R&D on infectious diseases and advancement of PPE. Over the years, Singapore has reinforced the importance of investment in R&D to managing pandemics. The effort of Singapore R&D ecosystem is led by the Agency for Science, Technology and Research (A*STAR)[4],

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[4] A*STAR is a key government organization that drives mission-oriented research to advance scientific discovery and technological innovation oversees 18 biomedical sciences and physical sciences and engineering research entities

which spans across various government agencies, the institutes of higher learning, healthcare institutions, and private sector (Figure 5). The supply and preparation of two important healthcare provisions, Test Kits and PPE, attests to the collaborative partnerships in driving and achieving innovation in Singapore.

[Insert Figure 5 about here]

5.1 Test Kit

The intensity of testing is a major factor that has helped to bring the cases down and contain the spread. MOH has rapidly increased testing capacity (from 2,900 to more than 8,000 tests per day within a month) and maintained a higher testing rate (i.e., 2,100 per 100,000 people) than most other countries (MOH 2020). This was made possible through a collaboration between A*STAR and Tan Tock Seng Hospital (TTSH). They developed Fortitude Kit 2.0, a test kit that can detect the presence of the SARS-CoV-2 virus causing COVID-19 quickly and accurately. Since February 2020, Fortitude Kit 2.0 has been implemented in 13 Singapore hospitals and public/private labs. In late March, the kits have been deployed in more than 20 countries globally. As expansion of testing is required to allow Singapore to open up safely, there is a need to ramp up testing kits locally. A*STAR has transferred the technology and know-how to companies with a non-exclusive license to scale-up and produce the diagnostic kits to fulfil local and international demands. While many of the test kits in the market can only detect the virus in infected persons, the research team at Duke-NUS Medical School in close collaboration with MOH's contact tracing and epidemiological teams, and police force, has developed a serological test. Being the first effort in the world to test for COVID-19 antibodies developed in recovered patients, it has significantly augmented Singapore's contact tracing efforts by tracing the source of infection of two major COVID-19 clusters.

5.2 PPE

It became critical for Singapore to secure mask supply as cases grew exponentially. Amid the global shortage of surgical masks and PPE, engineers from the Defence Science and Technology Agency

(DSTA) have designed an adjustable and reusable face shield to protect the country's frontline officers in various ministries. In partnering with Racer Technology (a leading OEM manufacturer), *FaceProtect+*, a reusable shield that has an adjustable frame to different face sizes and available for people who wear spectacles, is produced and supplied locally. Using their existing know-how and manufacturing capabilities, local SMEs have actively joined the nation's efforts to ensure supply of PPEs. In mid-February, Innosparks from ST Engineering (a government-linked company) and the MTI have managed to produce the first ever made-in-Singapore surgical mask for healthcare workers by rapidly recombining resources from multiple sources. MTI is also continuously working with local manufacturers and A*STAR to improve the materials used for reusable masks and ramp up supplies for the distribution to all households .

The pandemic has also driven ground-up partnerships in the private sector. Integrated Health Information Systems (IHiS) (a private technology company for the public healthcare sector) and Kronikare (a local start-up) have developed an AI tool to automate temperature screenings. The *iThermo* solution offers a quicker and safer alternative to scan people's temperature and screen those with higher temperatures to prevent crowds and queues during the screening process. Razer, a Singapore gaming company has also successfully converted one of its production facilities within 24 days to a fully automated line that can produce 5 million face masks a month. To support the Razer's effort and crowd-funding call for advance orders, three local-based companies (Frasers Property, JustCo, and PBA Group) committed upfront costs for the initial shipments of masks from the transformed line. Siege Advanced Manufacturing which specialises in 3D printing capabilities has also collaborated with Mdesign Solutions (a technology design house) to produce a reusable face mask respirator prototype. They invented '*Gill Face Mask*' that is six times more durable than normal surgical masks. Table 2 shows the different types of collaborative partnership for innovation driven by government and business sector. Depending on the initiator of the focal partnership, it is associated with different implications on the two manifestations of agility, either speed or scale.

[Insert Table 2 about here]

6. Driving Small and Medium Enterprises (SMEs) towards Digital Solutions and E-Commerce Platforms

SMEs are at the heart of Singapore's economy which employ two thirds of its workforce and contributing nearly half of GDP (Singstat 2018). Closing of workplaces and businesses amid the circuit breaker inevitably impacted SMEs if they are not ready to continue their business as usual remotely. Although many SMEs do not have sufficient resources and capabilities to digitalise their businesses, they are more agile and flexible to change. Therefore, it is essential that SMEs leverage on digital technologies and ICT ecosystem to improve operations and generate new revenue to support the national economy.

6.1 Digital Solutions

In the call for businesses to "Stay Health, Go Digital" since onset of the outbreak, Infocomm Media Development Authority ("IMDA") along with Enterprise Singapore (ESG) put in more resources to help SMEs to access digital solutions. Through the collaboration between the two agencies in engagement with relevant stakeholders, a suite of technology solutions was developed to help SMEs and businesses for remote working, visitor management, bill and pay online, and sell online. Enterprises also receive funding support to adopt pre-approved digital solutions which include online collaboration and virtual meeting tools as well as queue management and temperature screening systems. Businesses that switch to Nationwide E-invoicing Network also receive a one-time grant of S$200. To help enterprises deepen their digital capabilities to strengthen business agility and build resilience, IMDA and ESG provide funding support for enterprises to adopt advanced digital solutions and scale up online operations. To match the effort, together with IMDA, SGTech, a trade association in the tech industry, rallied companies in the industry to put together the Digital Solutions Directory (Table 3) for businesses to tap on. SMEs can gain access to an array of online courses and webinars to upgrade their workers' skills and also receive cost free digital consultancy from experts on best practices for crisis management.

[Insert Table 3 about here]

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6.2 Digital Presence and E-commerce

During this pandemic, Singapore's F&B sector has had to grapple with immense challenges from embracing food delivery and take-away, to meeting changing rules to stem the outbreak. The 'Food Delivery Booster Package' was launched by the government to support F&B businesses in managing food delivery costs. It helps to equip eateries with the tools and capabilities to optimise online delivery sales and build a strong digital presence. Similarly for retailers with little or no e-commerce capability, that had to be closed during the circuit breaker, the e-commerce booster package was also launched to support 90% of the cost for retailers to sell their products online for domestic and overseas markets. In addition, a series of online coaching sessions on digital storytelling with consultants was also arranged for enterprises to create narratives for their brands, digital products, and services that resonate with their customer base. To increase the online presence of the SMEs, a consolidated effort by the government to fund media partners (e.g. Facebook and Warner Media Entertainment Networks) was also embarked to develop content to profile SMEs to reach out to potential customers (IMDA 2020).

7. Conclusion

We conclude with a conceptual framework of collaborative partnership for innovation. Importantly, we identify two conditions that enable the collaborative partnerships in combating COVID-19 readiness (infrastructure, ability, willingness) and agility (speed and scope) as summarized in Figure 6. Singapore possibly offers the 'gold standard' of using ICT to implement an adage of public administration, upscaling rapidly and effectively during the COVID-19 pandemic as the situation evolves. The government's heavy investment in ICT infrastructure and digital connectivity has definitely paid off because its administrative healthcare capabilities in public health have been strengthened by the strategic deployment of digital solutions. It also enabled swift shift of SMEs to adopt digital solutions and E-commerce platforms. The success of the deployment of such digital driven measurements is not only dependent on the nation's readiness i.e. its resilient broadband and internet networks infrastructure which are capable of accommodating to the increased data traffic but

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also on the ability of people who have the skills and know-how on how to make use of them and to create content and applications on demand, i.e. the competently trained public officers in digital skills. Most importantly, it is the willingness and agility of multiple stakeholders working together in a coordinated effort. Recognising SARS as a 'black swan' event that might occur again, the government realised that new structures and processes that synergise and cut across agencies and sectors to eliminate red-tapes are required address wicked problems such as climate change, terrorism and pandemic. (Ho, 2012).

The collaborative WOG framework advocated by the government, has led to multiple top-down and ground-up collaborative efforts of various sizes (from inter-agencies to Whole-of-Nation) in various domains such as vector control (Anti-dengue Inter-agency taskforce - interagency), rehabilitation of ex-convicts (CARE Network – inter-sectoral), Education for the elderly (National Silver Academy – inter-organisational), counter terrorism (Youth Olympic Games Organising Committee - WOG), and digitisation (Smart Nation Initiative – Whole-of-Nation). To complement this collaborative governance approach, the Ministry of Finance published the Singapore Public Sector Outcomes review biennially to take stock of how the nation has fared in key areas of national interest based on WOG outcomes and indicators. Investing in time and effort to nurture collaborative networks has never been more important and fruitful than in a crisis. Working closely together to co-govern and co-create solutions has fostered an environment of trusts between the state and society actors that seek to achieve common goal. It has nurtured friendships and spin-off formal and informal networks. Perhaps this is why it has inculcated an R&D ecosystem that is capable of incubating innovation and ideas not only within the R&D community but also with private companies to ramp up supplies of essential medical supply. In particular, multiple stakeholders are willing to share and contribute resources and expertise to work together in a fast, coordinated manner to achieve the same goal of rapidly containing the virus and stopping the spread. A direct straight-line administration structure that requires agencies to directly report only to the parent ministries has also enabled deployment and assignment of manpower and resources across more efficiently.

[Insert Figure 6 about here]

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Today while many countries are still grappling to contain the transmission of COVID-19, Singapore has already successfully brought the community transmission under control and has already entered into phase 3 since 28 December 2020 with re-opening of social, religious and community activities as well as increasing of group size of social gatherings. Although we acknowledge the heterogeneity of national contexts and potential limitations concerning the size of countries, the Singapore case can be useful in other country contexts, and our discussion provides useful recommendations for policy and practice. When countries decide to develop their own trace and track system in monitoring and controlling COVID-19 virus, the Singapore experience and examples of rapidly developing innovative solutions can offer valuable insights concerning collaborative partnerships between government and private sectors. In particular, we highlight that the two salient aspects, readiness and agility, may support the rapid action and quick responses across multiple stakeholders and actors in different national contexts. For example, readiness and agility also play a decisive role in achieving collaborative innovative partnerships to handle the COVID-19 crisis in Korea. Despite the much larger population than Singapore, Korea managed to flatten the curve quickly (i.e., within a month) by leveraging public-private collaboration (KOR-GOV, 2020). The Korean government actively capitalised on advanced ICT infrastructure to take control of the COVID-19 crisis. To slow the virus spread and facilitate social distancing, the government shared key emergency information efficiently and effectively through "cellular broadcasting service" that transmits the public emergency alert text messages to cell phones through three major mobile telecom carriers in Korea. The service can send key information without delivery bottleneck as it does not use general text messaging system when an emergency occurs. It also delivers a customised alerts and guidelines to the citizen only in the areas where emergency warning is needed (e.g., by informing the public of the movement paths taken by confirmed patients, residents who receive the related information can check if they have been anywhere that overlaps with a movement of a confirmed patient and get tested quickly if necessary). This service implemented by the government and telecommunication carriers together with the citizens' willingness to follow the guidance and take subsequent actions contribute to slowing the spread of the virus across the nation in critical time. The

government makes a full effort to use Korea's research capabilities to support the decision-making process of the infection control authorities. By collaborating with KT corporation, the government provides researchers with data concerning the levels of foot traffic and international roaming to support accurate and reliable COVID-19 spread forecasting. It also develops multiple mobile apps (e.g., Self-Diagnosis app, Self-Quarantine Safety app, Coronavirus Map app. Telemedicine app) together with start-ups and businesses to support the virus spread control ranging from tracing and testing to self-quarantine and monitoring. The start-ups and businesses moved quickly to develop the COVID-19 related apps, and the government support the effective utilisation of various apps by collecting and sharing accurate information related to the virus. In addition, the government and biotech companies (e.g., KogeneBiotech, Seegene, Solgent) work closely together to speed up the development and utilization of the COVID-19 diagnosis kits. Companies used ICT capabilities, high-performance computing, and AI algorithms to dramatically shorten the process of developing a virus diagnostic kit from several months to around two weeks, while the government has quickly approved emergency use of the kit. The agile supply of sufficient diagnostic kits early in the initial contamination stage of the virus spread has helped Korea to flatten the curve rapidly (see KOR-GOV (2020) for more detailed information). While the Korean case is summarized in Figure 7, it demonstrates that the readiness and agility that enable collaborative innovative partnership between public and private sectors can play a key role in combating the COVID-19 in different national contexts other than Singapore.

[Insert Figure 7 about here]

This paper presents how collaborative partnerships between public and private sectors play a critical role in developing and deploying innovative practices in Singapore to overcome the COVID-19 crisis against which almost all countries fight. Although a single country case cannot be a universal key for all countries' combat against COVID-19, we hope this study provides some revealing and meaningful implications for the international community and for the global practicalities of curtailing the pandemic by leveraging collaborative partnerships for innovation.

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Acknowledgements

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Table 1: Online Government Resources Developed during COVID-19 (compiled from various sources)

Websites	Purpose	Partnership
COVID-19 online symptom checker	Perform self-diagnosis to decide next course of action if the person have the symptoms	National University Health System (NUHS), the National Centre for Infectious Diseases (NCID), and the MOH Office for Healthcare Transformation (MOHT)
OVID-19 Situation Report	Presents the key statistics and figures on the current situation in Singapore	Inter-ministerial COVID-19 Taskforce
FluGoWhere	Provide a list of Public Health Preparedness Clinics (PHPCs) providing special subsidies for those diagnosed with respiratory illnesses.	GovTech, MOH and PHPCs
MaskGoWhere	Help Singaporean households find the designated location, day and time to collect their allocation of masks.	GovTech and People's Association
OneMap	Locate the shortest traveling route to nearby PHPCs and essential amenities including hawker centres and supermarkets	Singapore Land Authority (SLA) and multiple relevant agencies
Space Out	Check how crowded malls, supermarkets and post offices are before going	Urban Redevelopment Authority and various retail mall operators
SG United Jobs Portal	List opportunities for jobseekers and workers affected by the current COVID-19 situation	Workforce Singapore, Ministry of Manpower, Public Service Division, Singapore Business Federation and the Trade Associations and Chambers
Parent Kit	Provide tips on how to support child's learning from home	Ministry of Education, Ministry of Social and Family Development, Health Promotion Board, National Library Board

Table 2: Types of collaborative partnership for innovation

Collaborative partnership for innovation	Speed agility	Scale agility	Examples from Singapore
Government-driven	- Fast in the beginning - Businesses respond to government call and need to adapt their capabilities	- Rapid scale-up based on relatively abundant resource and sourcing capabilities - Setting clear target for appropriate/optimal scale	- Fortitude Test 2.0 - Serological test - FaceProtect+ - Surgical and reusable masks
Business-driven	- Businesses identify needs and opportunities organically	- Takes longer time and needs to crowdsource to scale up	- iThermo solution - Face mask - Gill Face Mask

Table 3: Digital Solutions Directory put together by various companies in the tech industry (extracted partially from IMDA, 2020)

Company	Name of Digital Solution	Types of Support	Purpose
7-Network	COVID-19 BCP Productivity Suite - Employee management platform	Free	Remote working
8x8	8x8 Video Meetings - Host Video Conferencing and Online Meeting	Free	
Alibaba Cloud Singapore	DingTalk - All-in-One Mobile Workplace	Free	
Amazon Web Services, Inc	Amazon Remote Work & Learn Solution Suite - WorkSpaces, Amazon WorkDocs, Amazon Chime, Amazon Connect, Amazon AppStream	Free	
Talenox	Talenox - Self Service HR Software	Free	Workforce Management
Capps Solutions	PayAdvisorMobile@HRM	Supported by grant	
Enable Business	QuickHR - Workforce Management Solution	Supported by grant	
Rockbell	Million Accounting Solution	Free	Bill & Pay Online
Sesami	Online eProcurement System	Free	

Figure 1: Epidemic Curve of the COVID-19 Outbreak in Singapore (Source: extracted from Situation Report 23 August 2020, Ministry of Health)
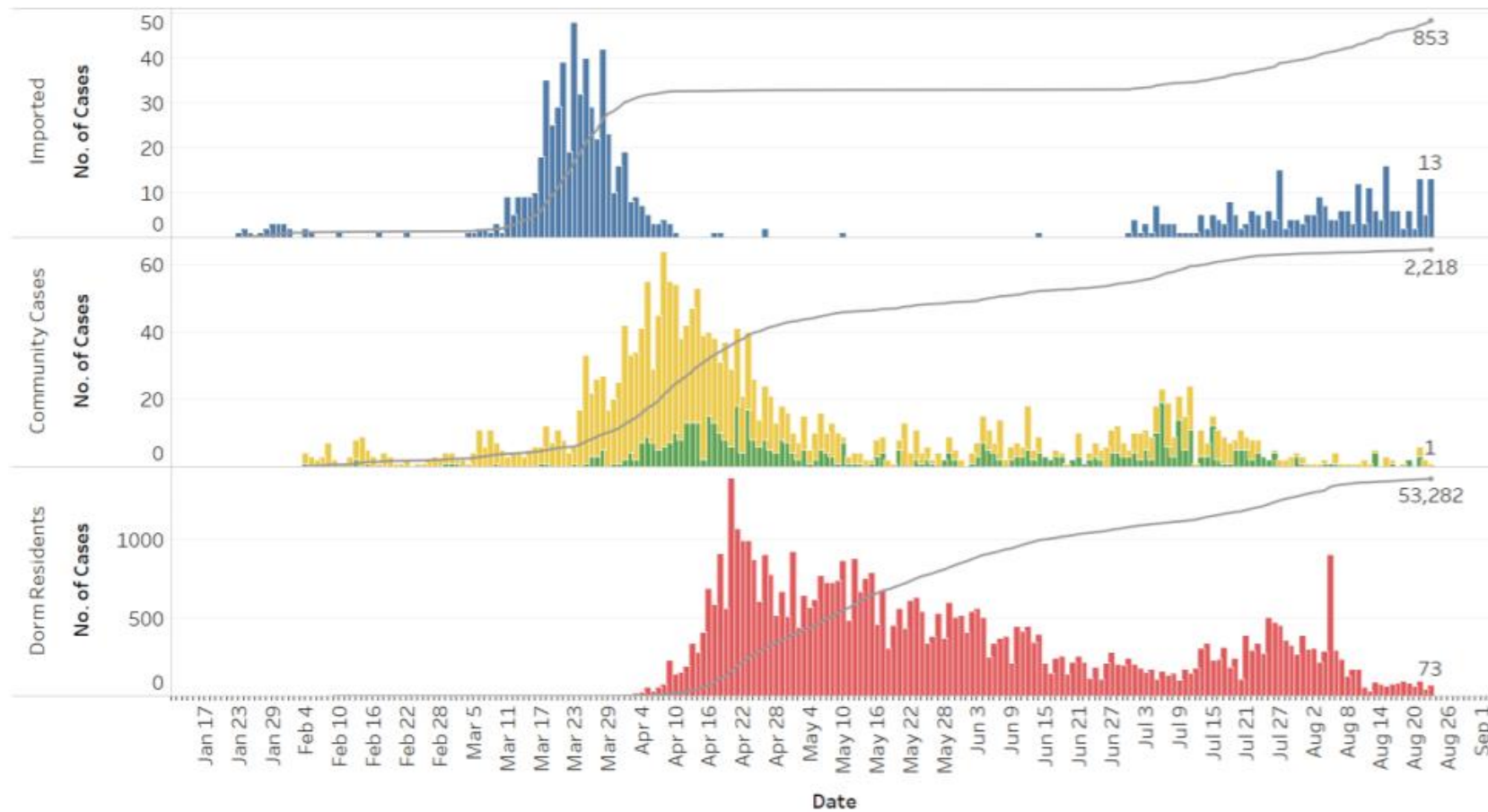
COVID-19 Cases
- Imported
- Community Cases: SC/PR + G or F (other pass types) + Visitors
- Community Cases: G or F (work permit)
- Dorm Residents

Figure 2: Disease Outbreak Response System Condition (DORSCON) alert level (source: extracted from Gov.sg, 2020)

	GREEN	YELLOW	ORANGE	RED
Nature of Disease	Disease is mild **OR** Disease is severe but does not spread easily from person to person (e.g. MERS, H7N9)	Disease is severe and spreads easily from person to person but is occurring outside Singapore. **OR** Disease is spreading in Singapore but is (a) Typically mild i.e only slightly more severe than seasonal influenza. Could be severe in vulnerable groups. (e.g. H1N1 pandemic) **OR** (b) being contained	Disease is severe **AND** spreads easily from person to person, but disease has not spread widely in Singapore and is being contained (e.g. SARS experience in Singapore)	Disease is severe **AND** is spreading widely
Impact on Daily Life	Minimal disruption e.g. border screening, travel advice	Minimal disruption e.g. additional measures at border and/or healthcare settings expected, higher work and school absenteeism likely	Moderate disruption e.g. quarantine, temperature screening, visitor restrictions at hospitals	Major disruption e.g. school closures, work from home orders, significant number of deaths.
Advice to Public	• Be socially responsible: if you are sick, stay at home • Maintain good personal hygiene • Look out for health advisories	• Be socially responsible: if you are sick, stay at home • Maintain good personal hygiene • Look out for health advisories	• Be socially responsible: if you are sick, stay at home • Maintain good personal hygiene • Look out for health advisories • Comply with control measures	• Be socially responsible: if you are sick, stay at home • Maintain good personal hygiene • Look out for health advisories • Comply with control measures • **Practise social distancing: avoid crowded areas**

Figure 3: National framework for coordinating WOG planning and response during a national crisis in Singapore (Source: reproduced from MOH, 2014)
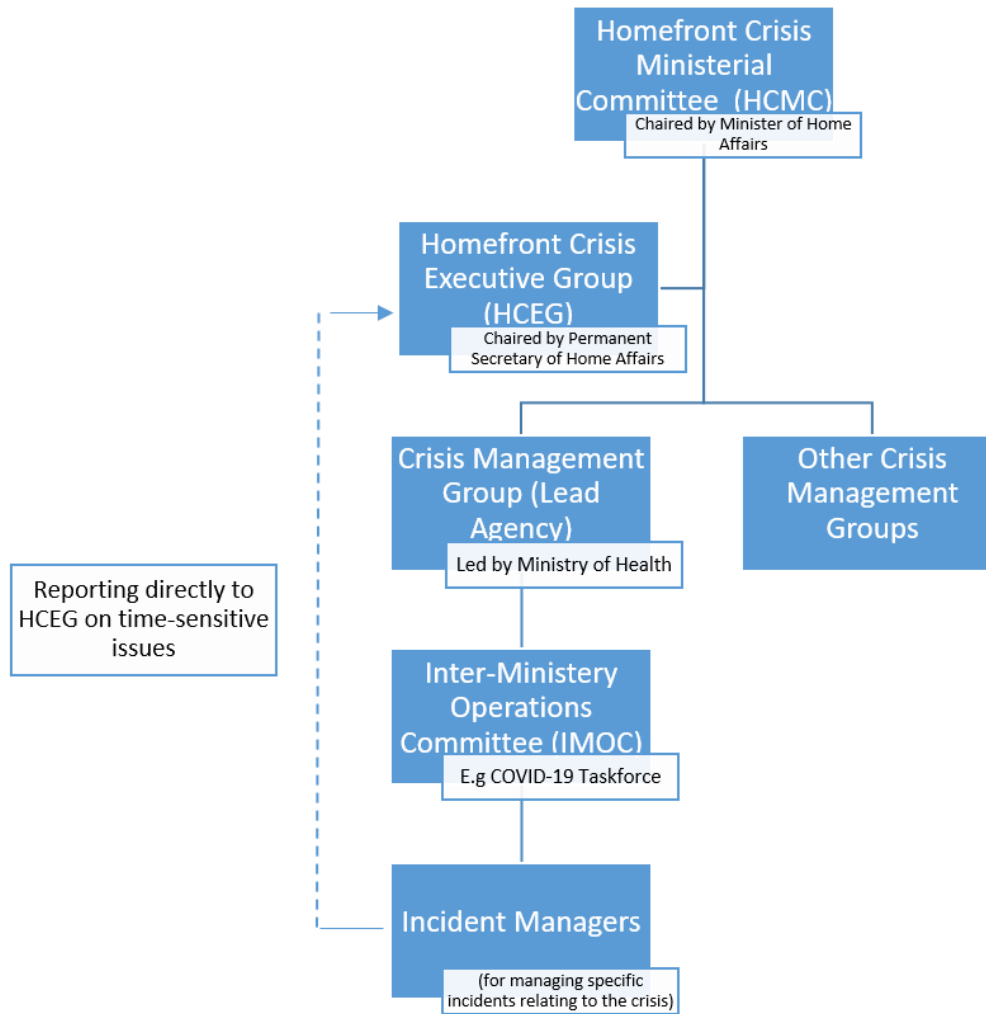
Figure 4: Singapore's approach in response to three waves of transmission

Phases of Transmission	January to February: Imported Cases	March to 7th April: Community Transmission	7th April to 1st June: Outbreaks in Migrant Workers Community
Main Control Measures	• From screening to banning of travellers from China • Enforcement of isolation protocols (Quarantine, LOA and SHN) on residents and long-term pass holders returning from China • Contact tracing conducted by police force and Ministry of Health through interviews, CCTV and digital footprints	• Travel Ban imposed on all COVID-19 affected countries including in ASEAN • Residents returning from affected countries placed on SHN in designated hotels • Contact Tracing augmented by *TraceTogether* App • Safe-distancing measures to limit crowds	• Circuit Breaker or partial lock-down of economy • Banning of all short-term visitors from entering • Gazetting of foreign worker dormitories as isolation areas and placing workers with mild symptoms in made-shift accommodation and healthy ones in other housing avenues • Wide-scale testing of migrant workers, frontline healthcare workers and high risk groups • Mandate contact tracing with *SafeEntry*
Financial Assistance	• Unity budget: support for household, businesses and workers as well as increase of budget for healthcare sector • Testing waived for everyone and treatments paid for residents and long-term pass holders • S$100 per day allowance for employees and self-employed under isolation protocols	• Resilience Budget: Enhanced Support for households, workers, SMEs, Tourism and Hotel industry. Deferment/ waivers of fees, loans and tax rebates • Withdrawal of treatment payments for residents and long-term pass holders who travel after 27 March	• Solidarity Budget: Further support for households and workers, waiver of foreign workers' levy • Continued payment of wages to migrant workers • Working with non-profit organisations to provide food, healthcare and other needs
Business and Societal Responses according to DORSCON Level	DORSCON Level raise to orange: • Masks to be worn only when ill • Cancellation or deferment of large-scale events • Suspension of inter-schools and external activities • Mandatory temperature screening and travel declarations at workplaces, schools and religious establishments • Workplaces advised to implement working from home for non-essential work and staggered work arrangements	DORSCON Level remain at orange: • Deferment and Cancellation of all private and public events/ functions with 250 or more participants to subsequent limiting social gatherings to groups of 10 • Closure of Entertainment outlets (i.e. bars), places of worship, attractions and group-based tuition centers • Enforce safe-distancing measures in malls and other public places	DORSCON Level remain at orange: • Masks to worn at all times when outside • Closure of all schools and shifting to home-based learning • Closure of all workplaces and implementation of working from home except for essential businesses • Closure of Preschools closed except for parents in essential services with no alternative childcare arrangements. • F&B outlets only offer takeaway and delivery • Public urged to stay at home, only go out (preferably one person) to buy food, groceries and exercise and no gatherings outside household allowed
Enforcement Approach	• Surveillance and monitoring of people put on isolation protocols via SMS and mobile-web-based solution • Penalties imposed on people breaching protocol orders such as revoking of residential status and work passes	• Safe-Distancing ambassadors deployed in malls, F&B outlets, markets, parks etc. • Penalties i.e. fines and imprisonment imposed on malls and establishments failing to comply with safe-distancing measures	• Penalties imposed on first time offenders without warning including not wearing masks outside • Police officers deployed • Tap on *Oneservice* app to report on defiant behaviours or gatherings whether in public or private

Figure 5: Singapore's Infectious Disease R&D Ecosystem led by A*STAR (Source: reproduced from A*Star website, 2020)
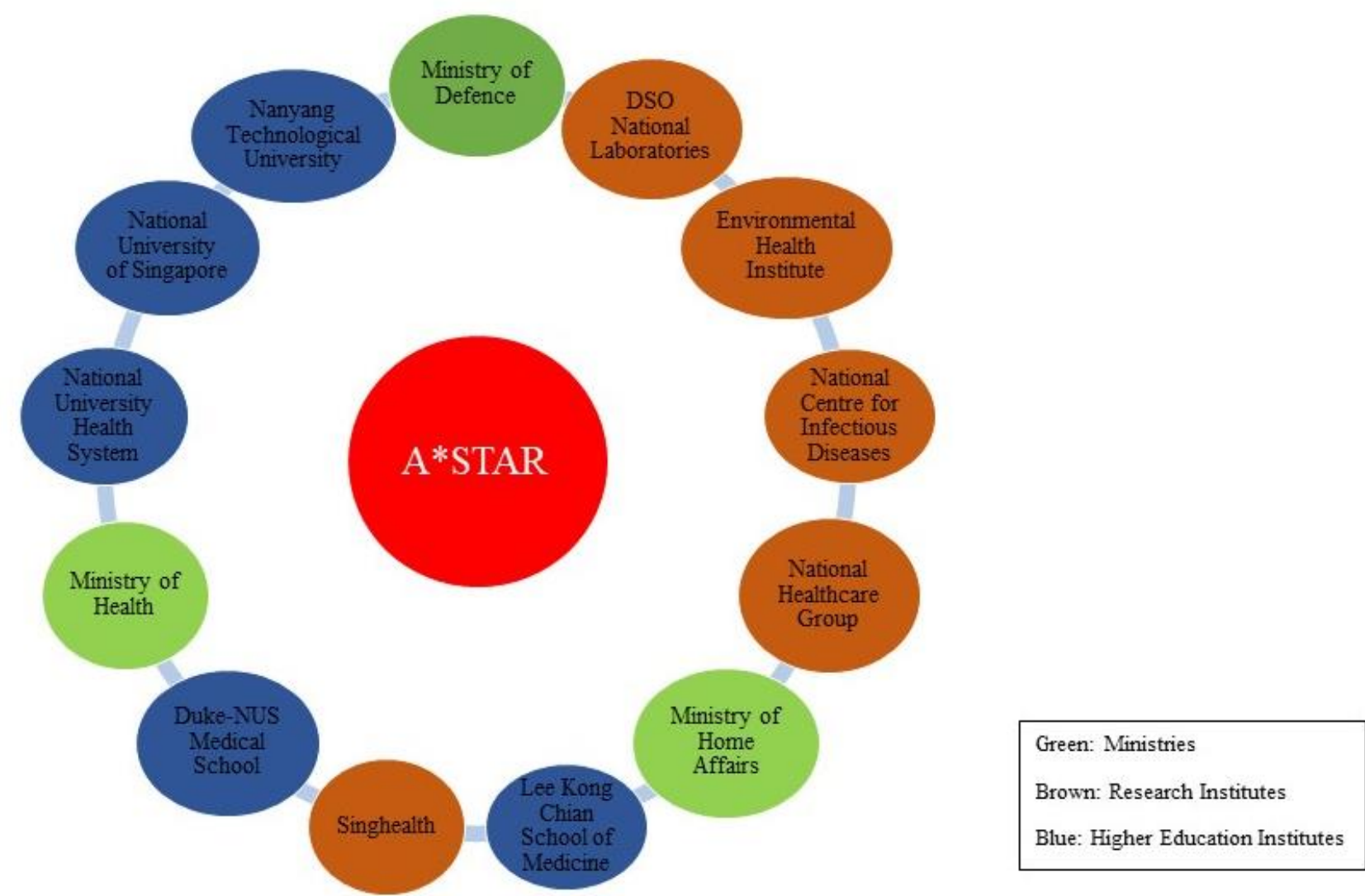
Figure 6. Collaborative innovative partnership framework in Singapore context

Collaborative innovative partnership between public and private sectors to combat COVID-19 in Singapore

Readiness of actors

Agility to act

ICT infrastructure

National Framework

Government 's ability to control actions and integrate resources

Society's willingness to accept and cooperate

Speed of implementation

Scaling up

● The government established 'pandemic preparedness plan' (e.g., DORSCON) based on experience from SARS

● The 'Smart Nation Initiative' enabled the state to expand and improve its ICT infrastucture and capacity to facilitate online/untact economic activities without online traffic disruption, complemented the 'pandemic preparedness plan' as well as ease of upscaling of available platforms

● Top-down coordination of expertise and resources from different agencies e.g. forming of multi-ministry taskforce to direct the national whole-of-government response to the novel coronavirus outbreak

● Available structures to work across agencies and mobilise resources i.e. WOG approach to form various networks

● Shared vision with State i.e. rapid containment of pandemic and resume economy by adhering to rules and regulations as well as co-policeing using app

● Trust and relationship between State and Society over the years through co-creation of ideas and solutions (through labs and design thinking workshops)

● Transparency of State to update information daily using digital platfiorms and counter 'fakenews' promptly

● Access to information made avail able to partners through existing industry networks

● Initiation and funding by State actors e.g. Razer's initiative to produce mask for local consumption

● Leveraging on relationship with past & existing partners through the Infectious Disease R&D ecosystem to quickly develop new test-kits

● Enable open access of R&D know-how and source code e.g. opening up tracetogether source code to allow local communities to make improvements and sharing of information among medical community to develop the PCR testing

● Expand digital opportunities for SMEs through funding schemes through various schemes, training and support from ESG
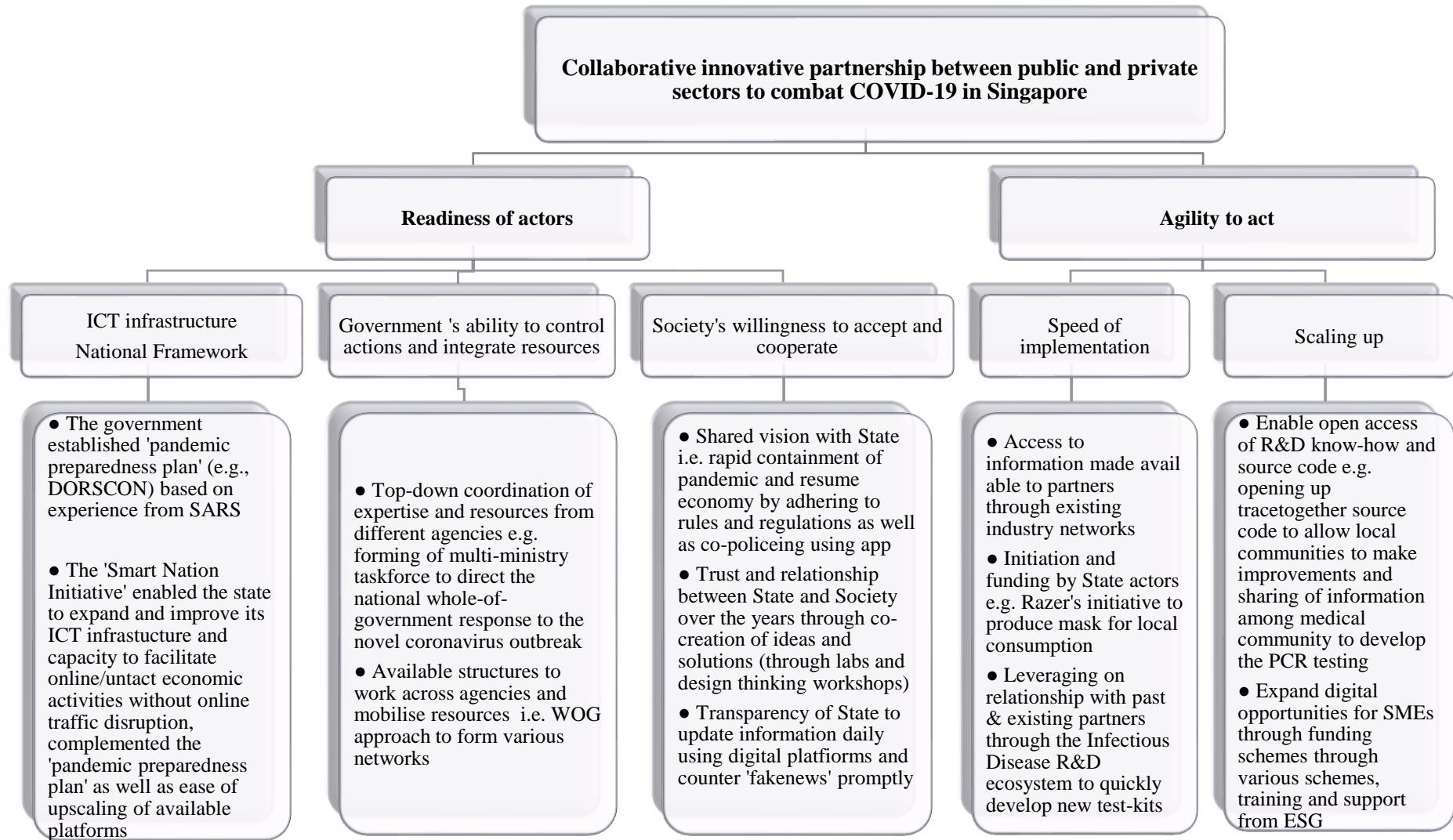
Figure 7. Collaborative innovative partnership framework in the Korean context

Collaborative innovative partnership between public and private sectors to combat COVID-19 in Korea

Readiness of actors

Agility to act

Advanced ICT infrastructure

Government 's ability to control actions and integrate resources

Society's willingness to accept and cooperate

Speed of implementation

Scaling up

● Advanced ICT infrastructure enables the government to gather and spread key emergency information about the novel virus and support people to maintain extensive social distancing (e.g., by flagging infection hotspots with text alerts on testing and local cases)

● The government has utilized ICT to effectively locate COVID-19 with speedy testing and quickly trace the virus by supporting self-quarantine monitoring

● The government has supported innovative responses of the private sector to COVID-19 by providing large-scale health and epidemiological data required for predictive research

● The government formed a council to integrate the capabilities and resources of relevant agencies for effective drug repurposing research to secure the treatment for COVID-19 as quickly as possible

● Most people wear face masks to slow the spread of the virus following the state recommendation

● Citizens and start-ups develop mobile apps to provide key local information related to COVID-19 for free

● Transparency of the government to update information daily using digital platforms and counter 'fakenews' and scams preying on fears of the virus promptly

● The government permits an 'emergency use authorization' for biotech companies, allowing swift authorization of diagnostic reagents in a simplified process

●Innovative measures to meet the extensive testing needs, such as drive-thru and walk-thru screening centers, were quickly adopted across the nation

● To maximize the capabilities and resources of relevant agencies in both public and private sectors, large-scale data were collected, processed and shared quickly and emergency R&D fundings were availble to support COVID-19 predictive research, effective tracing, and the development of treatment