Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
COVID-19: Systemic risk and response management in the Republic of Korea

Yong-kyun Kim a,⁎, Jean-Luc Poncelet b, Geumyoung Min c, Jaekyung Lee d, Yunjung Yang e

a Ministry of Interior and Safety, Republic of Korea
b Independent disaster management consultant, France
c Dongguk University, Republic of Korea
d SMG-SNU Boramae Medical Center, Republic of Korea
e Sungshin Women’s University, Republic of Korea

ARTICLE INFO

Article history:
Received 17 June 2021
Received in revised form 26 August 2021
Accepted 29 August 2021
Available online 3 September 2021

Keywords:
COVID-19
Systemic risk
Response management
Republic of Korea
Risk management flow

Abstract

This study aimed to investigate the different kinds of risks associated with the novel coronavirus infection in the Republic of Korea and how those risks have been changed by the countermeasures taken by the Korean authorities and citizens. To this end, the authors explored the official database of the Korea Centers for Disease Control and Prevention (KCDC) in order to extract risk-related data from January 2020 to April 2021, and then identified the disaster risks and countermeasures from the government press briefings and news media in the same period. Consequently, this study identified three important approaches to enhance the infectious disease response management. First, the government has to respond immediately, even when they lack information and knowledge about the new type of risk. Second, a multi-sectoral response must be prepared to cope with systemic risks. Third, the government should prioritize transparency, inclusive risk governance, and innovative technologies during the initial response stage against risks with high uncertainty and novelty. Aside from these approaches, the types of risks were divided into four categories based on the response measures: anticipated risk against which countermeasures can be planned in advance, lingering risk against which adaptive response should be taken promptly, amplified risk, and emerging risk; the last two risks require the established plan to be modified drastically in order to secure higher-level engagement and additional resources. Finally, the authors proposed a risk management flow that can be applied to an in-depth analysis of the intersection between risk and response.

1. Introduction

Since 2020, the global society has been facing unprecedented threats due to the coronavirus disease 2019 (COVID-19) caused by a new strain of coronavirus, officially named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). According to the World Health Organization (WHO), as of April 30, 2021, 148,207,325 people were confirmed to have COVID-19, and the death toll reached 3,127,129 with an estimated fatality rate of approximately 2.1% [1]. COVID-19 became quickly perceived as an unprecedented pandemic based on the speed of transmission, the spread at every corner of the planet, the continuous generation of contradictory information, and the most varied political reaction among and within countries.

Facing this evolving threat, many countries have adopted various measures ranging from setting control measures aimed at keeping the society open to implementing strong lockdown policies forcing the entire communities or cities into isolation. The Republic of Korea (hereafter “Korea”) has effectively managed COVID-19 through the implementation of a tapestry of proper responsive measures, such as a transparent management of information, inclusive governance, and the extensive use of innovative technologies, all benefiting from a mature sense of citizenry, and policies, which involved national or regional lockdowns or closure of borders. In January 2020, although the Korean health authorities lacked sufficient information about the new coronavirus strain, they provided quick initial response in accordance with the infectious disease response plan and regularly monitored the known or unknown occurrences of epidemics overseas, particularly those in neighboring countries. The number of confirmed cases of COVID-19 remained 30 within 30 days after the first case was confirmed on January 20, 2020.

The unexpected crisis started in Daegu City and Gyeongsangbuk province (hereafter “the Daegu and Gyeongsangbuk regions”) on February 19 when the 31st confirmed case was reported; the number of confirmed cases around the area sharply increased, reaching a peak on February 28, 2020, with 909 cases reported across the country on that same day. Korea drastically flattened its curve by the end of March after implementing various innovative responsive measures. After that, the country experienced two more waves of the COVID-19 outbreak until April 2021. The second wave occurred in August, reaching a peak of 441 cases. Meanwhile, the third wave started in mid-November, with the number of cases

⁎ Corresponding author at: Haemil 3-ro, 90 217-1604, Sejong City 30092, Republic of Korea.
E-mail addresses: unkim68@gmail.com, 007falcon@korea.kr (Y. Kim).

http://dx.doi.org/10.1016/j.pdisas.2021.100200
2590-0617/© 2021 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
continuously increasing, affecting every region, and with more than 1000 persons affected. A unique and maximum peak of 1240 cases was reported on December 13. The third wave was more dangerous in terms of number and territorial extension than the previous waves. However, Korea has progressively decreased the number of confirmed cases and death tolls by the first week of January 2021, with effective countermeasures taken by the government and preventive rules abided by the citizens.

From the perspective of emergency management and risk assessment, Korea’s response to COVID-19 demonstrates that a well-designed response plan and the no regret policy are critical for providing fast and systematic responses at the early stage of the pandemic, even when there is insufficient information, and that disaster risk with high uncertainty and systemic impact should be dealt with a flexible and innovative approach as it is difficult to predict when and how various risks occur and evolve. In addition, various types of COVID-19 risks can be characterized by systemic elements with high uncertainty, novelty, and interactions among system components, mostly resulting in catastrophic damage when handled naively.

This study aimed to investigate the emergence of various risks during Korea’s response to COVID-19 and the change in those risks due to the countermeasures taken by the Korean authorities and citizens, to identify the key lessons for the enhancement of the national response system against infectious diseases, and to propose a risk management flow that can be applied to an in-depth analysis of the interaction between risk and response. To this end, the authors first explored the official database of the Korea Centers for Disease Control and Prevention (KCDC) in order to extract risk-related data, such as the chain of transmission and the number of confirmed cases, from January 2020 to April 2021, and then identified the disaster risks and countermeasures from the daily press briefings conducted by the Korean government and news media in the same period.

2. Korea’s response system and characteristics of COVID-19

2.1. National response framework of Korea

Korea’s national response framework covers 41 types of disasters, such as infectious diseases, earthquakes, and wildfires, and has three components: (a) the Standard Risk Management Manual (hereafter “Standard Manual”), (b) the Working-Level Manual for Risk Response (hereafter “Working Manual”), and (c) the Manual for Actions-at-Scene (hereafter “Action Manual”) [2,3]. The Standard Manual, which will be developed for each type of disaster, defines the basic principle for responding to a specific disaster and describes the roles and responsibilities of the relevant response institutions. It will be developed by each disaster management supervision agency such as the Ministry of Health and Welfare (MoHW) for infectious diseases and the National Forest Agency for wildfire, and then finalized through interagency consultation, expert committee meetings, and administrative approval by the Ministry of Interior and Safety (MoIS). The Working Manual will be developed by related support agencies (e.g., the National Police Agency and the Ministry of National Defense), which will be designated to enhance the Standard Manual and will be approved by the Disaster Management Supervision Agency. The Action Manual will be developed by on-site response agencies, such as local government authorities. The three essential elements of the national manual system are the primary agency’s roles and responsibilities; 13 critical actions for emergency management, such as situation control and resource mobilization; and Korea’s crisis alert system: blue (Level I), yellow (Level II), orange (Level III), and red (Level IV). Accordingly, each responsible agency must develop and update its manuals so that these manuals can be executed for any disaster.

Infectious disease manuals are the main framework of Korea’s overall response to all types of infectious diseases. As of April 30, 2021, 1 standard manual, 17 working manuals, and 276 action manuals are available for use to cope with infectious diseases in Korea. These manuals have been improved based on the experience and knowledge gained in the course of dealing with various previous infectious diseases, such as SARS in 2003, H1NI in 2009, and Middle East respiratory syndrome (MERS) in 2015. Proactive establishment of screening centers and robust management of self-quarantined people are part of the enhancement [4,5]. The Standard Manual for Infectious Disease is used as a guide in regulating the step-by-step installation of emergency response institutions according to a national crisis level (Table 1), starting from the initiation of the Emergency Operation Center of the KCDC. The specific role of each emergency response institution in responding to COVID-19 is described later.

2.2. Systemic characteristics of COVID-19

The impact of COVID-19 has been significantly different from what was expected, featuring its rapid spread worldwide due to global interconnectivity and its impact on various fields such as the economy, culture, education, and physical mobility [5,7]. Recent research shows that such epidemic risks with high uncertainty and novelty are hardly estimated based on the current risk assessment concept, which assumes that past events are a reasonable criterion to plan for the next epidemic or those that will occur [8]. Hence, a new framework is required not only to understand this type of risk with high uncertainty, novelty, and dynamic interactions, but also to design an effective response system in a tightly interacting and interdependent society.

In this study, the researchers adopted the traditional concept of disaster risk established by the United Nations Office for Disaster Risk Reduction, defining disaster risk as “the potential loss of life, injury, or destruction or damage of assets that could occur to a system, society, or community within a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability, and capacity” [9]. Based on this definition, the disaster risk triggered by the new coronavirus can be interpreted as a function resulting from the combination of the hazard (virus in the present case), the exposure (of the Korean population), the vulnerability (the non-immunity of the population to the SARS-CoV-2), and the capacity (ability of societies to respond and prevent). Although this definition remains valid, it requires a larger interpretation to be operationally useful. During Korea’s response to COVID-19, various risks suddenly emerged as a result of unpredictable and uncontrollable dynamic interactions among the components of the society. Therefore, an effective response to this type of risk requires an understanding of a hyper-connected networking society and the dynamic interaction between system elements and requires authorities to ensure that the main system components will remain functional irrespective of the cascading impact. Howitt and Leonard argued that those risks – resulting from a scale of emergency far exceeding the expected scope, from hazards not previously seen, or from a complex combination of hazards not seen together – are likely to cause “crisis emergencies.” These involve significant elements of novelty, high uncertainty, and insufficient situational awareness. In responding to these novel conditions, the authorities cannot strictly adhere to the established procedures but must respond adaptively by improvising using available resources and considering the current capabilities or by securing collaboration and additional resources [10]. Such a response often necessitates the participation of a range of operational agencies not usually involved in more routine situations and, frequently, assistance from higher levels of government and the private sector. In addition, the adaptive response should be supported by the engagement of multiple stakeholders based on the concept of inclusive risk governance, which emphasizes the involvement of key actors in the decision-making process and integration of all the respective knowledge [11].

In this sense, the global pandemic crisis has forced many countries to change their dogmatic disaster response system to a more holistic and comprehensive system that considers the complex nature of systemic risk, the acceptable level of risk of society, and flexible planning beyond the resources allocated under the infectious disease response plan [12].

3. Korea’s COVID-19 response management

Korea has experienced three major waves of the COVID-19 outbreak since the government issued a Level 1 alert on January 8, 2020, to strengthen the monitoring of the influx of the new coronavirus in Korea.
In this study, we divided Korea’s response against systemic risks of COVID-19 into four phases (Fig. 1). Phase I began on January 8, 2020, with the Korean government’s issuance of the “blue” alert level, following an outbreak of an unexplained pneumonia in Wuhan, China, in December 2019. The phase ended on February 16, with 30 accumulated cases. In phase II, from February 17 to May 5, Korea experienced the first wave of COVID-19 outbreak, which occurred in Daegu and Gyeongbuk regions, with more than 900 cases in February and very few cases in early May. In Phase III, 100 daily confirmed cases were recorded from May to the middle of August; then, Korea experienced the second wave due to cluster infections that occurred mainly in sports facilities, markets, and religious facilities in capital areas; a total of 441 confirmed cases were recorded on August 27. In Phase IV, the third wave began to expand across Korea. The number of daily cases skyrocketed to over 1000 from December 12, 2020, to January 3, 2021. The number of confirmed cases gradually decreased, and Korean government started to control the spread of COVID-19, with daily confirmed cases ranging from 200 to 800.

The Korean government has kept the country at Level IV (red level) national crisis alert since its issuance on February 23, 2020. At this level, the government has been adjusting the social distancing rules according to the severity of the emergency situation, which will be described later.

3.1. Phase I (January 8 to February 17)

On December 31, 2019, the WHO China Country Office received information that pneumonia of unknown cause was detected in Wuhan, China, and the WHO was informed that a total of 44 patients developed pneumonia of unknown cause as of January 3, 2020 [13]. At that time, there was insufficient information about the cases, which could have triggered an improper response. However, the Korean government provided a quick initial response according to the infectious disease response manual, which had been enhanced through the lessons learned from previous events, such as MERS in 2015, H1N1 in 2009, and SARS in 2003.

Since the KCDC was informed about the unknown pneumonia cases from the WHO and the Chinese health authorities in December 2019, it started to strengthen the monitoring system for inbound travelers, especially from Wuhan, China, while keeping the infectious disease risk alert at Level I (blue level). On January 20, 2020, a 35-year-old Chinese woman who went to Wuhan, China, was confirmed as the 1st patient with coronavirus infection at the Incheon National Quarantine Station. The government immediately raised the alert level from “blue” to “yellow” and started to operate the Central Disaster Management Headquarters (CDMHQs) managed by the KCDC, emergency response teams in local governments, and a task force in the MoIS [14]. As confirmed cases were continuously reported and the risk of community transmission grew due to the upcoming big holiday season, which starts at the end of January, the alert level was further increased to “orange” on January 28, 2020, in order to strengthen the community response system of the local governments [15]. On the same day, the MoHW operated the CDMHQs in order to coordinate the health sector’s response to COVID-19, and the MoIS organizationally strengthened the task force to the pan-government countermeasure support headquarters in order to effectively coordinate the non-health sectors’ support for the KCDC and the MoHW and the implementation of national policies by the local governments.

During the process of responding to COVID-19 in Phase I, three risks suddenly emerged. When the Korean government brought Korean nationals residing in Wuhan back to Korea in January and decided to place them under a 14-day quarantine in temporary residential facilities, the local residents near the facilities fiercely complained due to concerns on the possible community transmission by Wuhan residents. The MoIS secured local residents’ approval by ensuring that Wuhan returnees should adhere to the quarantine rules through self-monitoring and administrative monitoring.

As the KCDC provided the public with all needed information, although the information was not enough at that time, it helped citizens trust and follow the government’s countermeasures. However, transparent information disclosure triggered two new risks in late January 2020: flooding of calls from citizens and dramatic shortage in the supply of face masks. Many citizens were concerned about the spread of COVID-19 and made telephone inquiries to the call center of the KCDC, with the highest record of 25,000 calls in a day. As citizens encountered difficulties in connecting to the call center owing to the insufficient number of call center personnel, the poor connection became a problem due to the citizens’ concerns rooted from the disease information needs and complaints to the government’s poor response [16]. The KCDC solved this problem by increasing the number of personnel who can respond to all 1339 calls and providing accurate and timely information about the COVID-19. Partly due to the increasing level of anxiety, citizens started to purchase large quantities of face masks, causing shortage in the supply of face masks. The Ministry of Food and Drug Safety (MFDS) tried to resolve this issue by inspecting the production process and cracking down on cornering the market. Since the demand was much higher than the supply, the problem was not resolved, which remained as a potential risk factor until Phase II.

In Phase I, the official number of COVID-19 confirmed cases was 30. Despite this successful initial response, several infected persons attended worship ceremonies at the Daegu Shincheonji Church on January 9 and 16 and a funeral ceremony held at Daenam Hospital in Cheongdo-gun, Gyeongsangbuk province, but were not detected by the monitoring system of the KCDC [17]. These events became severe risk factors that caused a sharp increase in the number of confirmed cases in the Daegu and Gyeongbuk regions in Phase II.

3.2. Phase II (February 18 to May 5)

After the 31st patient with confirmed infection, a Shincheonji Church member, was reported on February 19, the number of individuals with confirmed COVID-19 in the Daegu and Gyeongbuk regions skyrocketed, and many of them were Shincheonji Church members. The daily number of
confirmed cases reached 909 on February 29, 2020, the highest number since its influx in Korea [18]. In accordance with the Act on the Prevention and Management of Infectious Diseases, the government rapidly obtained the list of Shincheonji Church members and conducted extensive diagnostic tests in the Daegu and Gyeongbuk regions. The necessary information were shared to all citizens, and people with suspicious symptoms were asked to report to nearby public health centers. During this phase, two countermeasures were introduced in order to make extensive and quick diagnostic tests possible: the government’s emergency use authorization process to approve the diagnostic test kits and the adoption of innovative test methods, such as drive-through screening centers and walk-through booths [19]. As the sharp increase in confirmed cases continued at the end of February, the increasing shortage of hospital beds and medical staff became a serious risk. To mitigate this risk, the government decided to prioritize COVID-19 patients according to their symptoms; patients with severe cases were admitted in the hospitals, while those with mild symptoms or asymptomatic cases were assigned to residential treatment centers. The inadequacy in medical personnel was resolved by accepting volunteer doctors and nurses from all over the country and deploying public medical personnel [20].

The government issued a “red” alert level on February 23, 2020, to raise the national emergency response system to the highest level; then, the Central Disaster and Safety Countermeasure Headquarters (CDSCHQs) led by the Prime Minister started to operate on February 25, 2020. Under the CDSCHQs, the roles of primary agencies and support agencies were clearly designated, and pan-government cooperation and resource allocation were easily enabled. The commissioner of the KCDC3 acted as the head of the command center for responding to COVID-19 and preventing the disease; the Minister of MoHW took charge as the 1st deputy head of CDSCHQs to coordinate the health sector’s response, such as hospital treatment and quarantine; and the Minister of MoIS was designated as the 2nd deputy head of CDSCHQs and was responsible for coordinating the support from all other agencies and liaising with local governments [21].

On March 11, the WHO declared that COVID-19 reached the global pandemic level, and the declaration caused a new risk related to traveling and subsequently affected other foreign countries. The government implemented special entry procedures, and inbound travelers were thoroughly managed from the entry stage [22]. The MoIS established guidelines for local governments to support citizens’ self-quarantine by designating local public officials. As the demand for masks rapidly increased, the shortage of supply and the increase in prices became more severe, and civil complaints significantly increased. The government adopted a publicly distributed system for face mask supply, allowing each citizen to purchase face

---
3 The Korea Centers for Disease Control (KCDC), which was under the MoHW until September 11, 2020, was promoted to Korea Disease Control and Prevention Agency, an independent agency that has an authority to set and execute policies related to infectious disease to control over budgetary and personnel management. To avoid confusion, the term KCDC was used in the entire article except in the organizational charts and tables.
masks at the same quantities per week, which resolved the imbalance between supply and demand of face masks within a month. Finally, the number of confirmed cases gradually decreased in March, reaching 64 in March 23, 2020 [23].

In April and May, new risks came due to the need to hold the election of members of the National Assembly, which was planned for April 15, 2020. As the election might have increased the risk of the nationwide spread of COVID-19, there was controversy as to whether to postpone or resume the election as scheduled. The epidemic risk was balanced with the social and political risk of not having an election. The Korean government decided to conduct the election as already planned while strengthening the preventive measures; for example, disinfectants were placed in each polling place, and all voters were asked to wear a face mask. When big wildfires broke out in Gangwon Province and Gyeongsang Province in April and May, both the epidemic and fire risk were compounded by each other. The wildfire incident could have increased the disease transmission because the predetermined evacuation plan recommended that all displaced persons stay in a large single place. The MoIS, in cooperation with the KCDC, requested all local governments to distribute the displaced persons to the different evacuation shelters that had already completed the requirements for infectious disease prevention and control. As a result, the government was able to maintain the number of daily confirmed cases of COVID-19 at around 30 [24].

3.3. Phase III (May 6 to November 19)

Although the number of confirmed cases remained stable in April, its impact on the economy and society became more severe due to the decline in social activities. According to the data published by the Bank of Korea, the pandemic decreased the GDP by 3.7% and reduced the number of employed individuals by 460,000. In the second quarter of 2020, the manufacturing industry and exports recorded reductions in GDP rates by −6.6% and −13%, respectively, showing the largest recession; in the fourth quarter of 2020, the service industry, private consumption, and employment rates showed the highest decline, by −1.8%, −6.5%, and −1.6%, respectively [25].

The government continuously tried to balance the prevention of COVID-19 spread and boost the economy, and decided to alleviate the social distancing level from May 6 onward, allowing various facilities that had been closed to resume operations in stages. However, the negative effects suddenly increased. During the long holiday seasons in early May, a few infected people visited nightclubs in Itaewon, where many young generations gathered and enjoyed parties, which might have caused a large-scale mass outbreak. Moreover, many of the people who visited the nightclubs at that time did not provide their identification information properly, which was strongly recommended by the government. The visitors were even reluctant to reveal their presence at that time as they were afraid of being criticized. This forced the government to make a difficult choice between epidemic risk and political risk due to privacy issues. Two solutions were employed in this study. The Seoul Metropolitan Government temporarily conducted anonymous tests so that the infected visitors could take the diagnostic test without revealing their identification [26] and later developed an electronic visitor records keeping system called KI-PASS, utilizing QR codes to fundamentally block the false writing of the registers. The public strongly opposed the collection of their personal information as part of the measure to prevent and control disease transmission; however, during a severe COVID-19 situation, the public’s interest was prioritized. The government also provided COVID-19 relief funds to people whose

---

**Fig. 2.** Organizational Chart of CDSCHQs against COVID-19 (revised by authors from original CDSCHQ data).
businesses were affected due to the prolonged limitations in social activities owing to the implementation of social distancing measures. With these efforts, a nationwide outbreak of COVID-19 did not occur, and the COVID-19 situation was stabilized.

However, Korea experienced the second wave of COVID-19 outbreak in mid-August, which occurred around the capital areas. The guidelines for infectious disease prevention and control were not observed in a demonstration held on August 15 in the capital areas. In addition, a number of people who attended worship services at several local churches were infected with COVID-19. The number of confirmed cases sharply increased, especially around the capital regions, recording 441 cases on August 27 [27].

The government raised the social distancing restrictions in capital areas to Level 2 on August 16 and extended the Level 2 restrictions to the entire country on August 23 [28]. The number of confirmed cases peaked at the end of August and gradually decreased due to the implementation of social distancing and preventive measures; in the middle of September, the number of confirmed cases decreased to less than 100 per day. However, this has led the service industry to experience an unprecedented level of recession. Representative businesses include art and sports, leisure services, accommodation, food, and transportation. The art and sport businesses, which were severely affected, experienced a fall in the annual growth by 30% while the accommodation, food, and transportation businesses were also hard hit, showing a fall in the annual growth by 19% and 18%, respectively. In the art and sports businesses, and accommodation and food businesses, the employment rate also considerably declined (12.2% and 10.8%, respectively) in 2020 compared with that the previous year [25].

To address this problem, the government flexibly adjusted the social distancing level according to the risk level. In this policy-making process, the government did its best to build the citizens’ trust by ensuring the engagement of all stakeholders. When the government decided to change the social distancing level, multiple stakeholders discussed various impacts of the decision and reached an agreement on the implementation plan during the meeting. One of the policies of this inclusiveness process was to support economically damaged groups by providing COVID-19 relief funds to small business owners who experienced hardship due to the prolonged implementation of social distancing.

3.4. Phase IV (November 20, 2020 to April 30, 2021)

Phase IV was the most catastrophic period in Korea’s response to COVID-19. By mid-November, the number of newly confirmed cases remained under 100 per day. After that, the number of confirmed cases sharply increased, centering around the capital areas once again, and community transmission began to occur throughout the country. The government recognized the situation as the third wave of COVID-19 outbreak in Korea and raised the social distancing level to Level 2.5 in the capital areas and Level 2 in the non-capital areas on December 8 [29]. Nevertheless, the situation worsened. On December 13, the number of confirmed cases reached more than 1000 per day, about 70% of which occurred in the capital areas. The number of cases with unknown infection routes and asymptomatic cases significantly increased, which made it difficult for the government to respond. To detect asymptomatic cases in the very early stage, the government started to operate more than 150 temporary screening clinics around the capital areas so that anyone can undergo the diagnostic test freely and obtain the result within 6 h. From December 14, 2020, to January 13, 2021, the number of confirmed cases reported in the temporary screening clinics reached 3301, proving that the temporary clinics were effective in identifying asymptomatic cases [30]. At the same time, the government chose to strengthen social distancing measures, such as prohibiting private gatherings of five or more people, rather than imposing a lockdown. In order to prevent the spread of viruses that had mutated from other countries, the government strengthened the monitoring of all inbound travelers and requested them to stay in a 2-week quarantine and to submit a copy of their negative PCR test results before they can be released from isolation [31].

The shortage of hospital beds for COVID-19 patients has become a serious problem following the sharp increase in confirmed cases. The government, which experienced the seriousness of the shortage of beds in the Daegu and Gyeongbuk regions in Phase II, established measures to prepare for the surge in the number of COVID-19 patients, such as designating COVID-19 exclusive beds in large hospitals and conducting mock training for a joint hospital bed response system in the metropolitan area. As a result of these preparations, even in a situation where the number of confirmed patients increased rapidly in early December, the treatment of patients was stably operated without any major problems. However, as the emergency situation with more than 1000 confirmed cases a day continued, securing a bed for a COVID-19 patient has become an important issue. The government addressed this problem by issuing an administrative order to secure COVID-19 beds at large hospitals and national university hospitals, converting college dormitories into a life treatment center and installing a movable negative pressure treatment center.

As a result of these efforts, the number of confirmed cases from December 13, 2020, to January 4, 2021 (exceeding 1000) gradually decreased by January 8, 2021. From February to April, the numbers of confirmed cases were reported to be between 289 (February 8) and 797 (April 23). As of April 30, 2021, the total number of confirmed cases of COVID-19 in Korea was 122,007, with an incidence rate of 235 people per 100,000 population, which is significantly lower than that in severely affected countries.

4. Key findings and lessons

This study investigated and analyzed the different kinds of risks that have emerged during Korea’s response process against COVID-19 and how those risks have changed after adopting responsive measures by the Korean authorities and citizens. The key lessons for the enhancement of response management and risk assessment were as follows:

4.1. Enhancement of national response framework and risk assessment tools by considering the response managerial challenges caused by the systemic risk

First, countermeasures must be established and implemented immediately, even with the lack of information and knowledge. The government should take action as soon as it identifies the risk without full scientific information, since delayed action is highly likely to amplify the disaster risk. The Korean government provided a quick initial response based on the infectious disease response manuals, even though there was limited information about the new type of virus. The KCDC and the MoHW activated its multi-sectoral emergency procedures, putting in surveillance systems in high alerts, monitoring health facilities and laboratories, ensuring that all incoming travelers were quarantined, and closely communicating with China. In Phase I, appropriate response measures were adopted at the early stage of the pandemic, even though there were also shortcomings due to the lack of knowledge about the new strain of coronavirus. Table 2 shows the leading response institutions according to risk level.

Second, establishing a coordinating center with health and non-health response pillars during the early stage of the pandemic enabled the response to systemic risks more effectively. Moreover, the infectious disease manual and the quarantine system included descriptions of the roles and responsibilities based on the lessons learned from previous events. This allowed the health sector to lead the response. When the alert level increased, the impact was no longer limited to health. All other sectors had to strongly support this response. The central coordination center was rapidly activated under the coordination of the MoS to support the health sector by taking charge of monitoring and managing self-quarantined people, operating temporary living facilities for inbound travelers, coordinating with other central ministries for support, and implementing countermeasures by local governments. With this backup, the KCDC was better able to serve as the command center and totally focused on preventing and controlling the spread of infection. This integrated and inclusive approach has allowed accountable management of all issues from all sectors and made
possible the decision-making process ensuring multi-stakeholder engagement.

Third, the transparency and extensive use of innovative technologies made the response more effective. Since the early stage of the COVID-19 outbreak, the Korean government, led by the KCDC, has been disclosing, on a daily basis, the number of confirmed cases, patient treatment situation, and explanation of the results and degree of implementation of the government's countermeasures. This transparency has built citizenry trust and facilitated voluntary engagement and participation by all citizens. In addition, the Korean government's rapid response to COVID-19 was made possible by conducting solid diagnostic testing; performing contact tracing using ICT tools, a security protocol for data protection; and providing an enabling environment for technological innovation.

### 4.2 Understanding the risk management flow for the enhancement of the disaster response management system

This catastrophic pandemic has been characterized by the emergence of various risks to which the society and the government are not prepared to respond. The authors found that the novel coronavirus has triggered various risks in Korea and that these risks have been changed through the intervention implemented by the authorities and through the intersection between response measures and risk triggering factors. From the emergency management viewpoint, the risks that Korea is now facing can be divided into four categories: anticipated risk, lingering risk, amplified risk, and emerging risk. Understanding the features of each risk will play a critical role in enhancing the infectious disease response system.

The anticipated risk is the risk predicted before the event and is used to define the scope of a response plan. Korea prepared its infectious disease response plan and activated a national disaster response system based not only on the best scientific knowledge provided by the KCDC and WHO, but also on the lessons learned from the recent MERS, H1N1, and SARS epidemics. The major input came from the public health sciences, anticipating a health emergency response requiring strong multi-sectoral support.

The lingering risk remained even after the countermeasures were taken. This type of risk requires the authorities to closely monitor the situation and assess the effect of the pre-planned countermeasures so that adaptive measures can be taken expeditiously. For example, the government continued to implement the social distancing rules and quarantine measures to cope with the second wave of outbreak in mid-August. The number of daily confirmed cases in Korea remained below 200 from September to November 2020, and thus the COVID-19 situation seemed to gradually stabilize. However, asymptomatic infections or infections with unknown routes of infection continued to occur during this period. When these events were coupled with triggering factors, such as cold weather and increased indoor activities, it led to an explosive increase in confirmed cases in December 2020. Risk does not dissipate unless appropriate countermeasures are taken, and the lingering risk may cause massive damage when certain conditions are met.

The amplified risk mainly results from the implementation of inappropriate countermeasures. In the case of face mask shortage, the authorities not only underestimated the danger of the disease due to insufficient information or lack of knowledge, but also took the time to address the emerging problems. Since the MFDG did not identify the root cause of the problem, its initial measures were not appropriate, resulting in a severe imbalance between the supply and demand of face masks and public anxiety. Considering that it took more than one month to resolve the problem, the MFDG should have identified the problem quickly and responded to the risk more accurately.

The emerging risk is barely anticipated at the initial stage due to the insufficient information and knowledge about the novel coronavirus or is newly created when the countermeasures are coupled with high uncertainty, interconnectivity, and complexity of the society, which are increasing tendencies in a contemporary society. In Phase 1, it was difficult for the patient and even medical doctors to distinguish whether the symptoms of the infected person were caused by the coronavirus or not. Thus, a number of patients with mild cases with no activity restrictions were likely to act as vectors of infection. The 31st confirmed patient, for example, wandered for 20 days after she was infected with the new coronavirus. Another case is that an appropriate measure for dealing with a certain risk may create a new risk, although it can mitigate the targeted risk. For instance, when the government repatriated Korean residents from Wuhan, China, in January 2020, it reduced their infection risk, but created a new problem. The Wuhan residents had to stay in temporary living facilities for two weeks, which caused citizens living close to the facilities to feel seriously worried about the spread of COVID-19 and to protest against the government. Social distancing is another example of an emerging risk from a broader perspective. Strengthening the social distancing measures is effective in preventing the spread of COVID-19, but it is highly likely to cause economic regression and significantly harm the business sectors, such as restaurants, cafes, and theaters. The optimal way to deal with this type of emerging risk has not yet been clearly identified and is beyond the scope of this study. In-depth analysis of catastrophic events in various areas of disaster risk management is required.

Based on the categorization of risks, the authors tracked the flow of risks triggered by the novel coronavirus and the effect of countermeasures taken by the Korean authorities and citizens. When viruses emerge in an environment vulnerable to epidemics, the exposed people will be infected with the new virus. Since this type of risk is likely to occur, the government, although not equipped with sufficient knowledge about the cause or symptoms, can take response measures, such as strengthening monitoring and promoting quarantine, which are planned in advance to cope with infectious diseases. Although many risks are a part of our daily lives, when appropriately managed by pre-planned countermeasures, they are mitigated and do not lead to catastrophic events; however, some risks do not dissipate and may cause massive damage when certain conditions are met. In such cases, adaptive measures should be taken promptly. When inappropriate measures are taken and coupled with high uncertainty, interconnectivity, and/or complexity of the society, the risk is likely to be amplified. In addition, the unanticipated risks are likely to occur at the initial stage, and new risks can emerge, while the countermeasures reduce the targeted risk. This risk can be triggered by insufficient information causing situational awareness error and by the influence of high uncertainty, interconnectivity, and/or the complexity of the society. Both the amplified risk and emerging risk can result in a national crisis, and authorities should re-plan the established procedure to ensure the engagement of higher government levels and to receive support from pan-government agencies and private sectors beyond already allocated ones. Prompt implementation of adaptive measures is also
required. The risk management flow (Fig. 3) shows how various types of risks emerge or change through the response process.

5. Conclusion

The response management for COVID-19 shows the need to better understand the features of systemic risks and to develop innovative solutions to overcome the corresponding response managerial challenges. Traditional disaster response plans are usually prepared by each primary agency, targeting the anticipated risk. However, Korea's response to COVID-19 exemplifies that the established plan needs to be adapted when new or unknown risks emerge in such a prolonged response period and that various sectors, not usually engaged in routine emergencies, should collaborate in order to mitigate the overall systemic risk.

This study tracked the risks triggered by the new coronavirus and the impact of the countermeasures taken by the Korean authorities and citizens, and then identified three lessons for the enhancement of infectious disease response management. First, the government should take actions immediately, even when it lacks information and knowledge about the new type of risk. Second, a multi-sectoral response should be prepared to cope with systemic risk. Third, the government should impose transparency, inclusive risk governance, and innovative technologies from the initial response stage against risks with high uncertainty and novelty.

From the perspective of disaster response and risk assessment, this study categorized the risks posed by the new coronavirus into four types: anticipated risk against which countermeasures can be planned in advance, lingering risk against which adaptive response should be taken promptly, amplified risk, and emerging risk. The last two risk require that the established plan should be modified drastically in order to secure the engagement of higher government levels and the mobilization of additional resources.

Finally, the authors propose a risk management flow, hoping that it can be applied to an in-depth analysis of the intersection between risk and response in future research. A risk never disappears if ignored; it lingers and exacerbates, and is highly likely to trigger a catastrophic crisis when combined with high uncertainty and/or complex socioeconomic impacts. The risk management flow can be used as a tool to identify the types of risks that will emerge and can be amplified during the response process, and make an accurate decision-making scheme that adaptively moves with available resources beyond already planned or allocated ones.

Declaration of Competing Interest

None.

Acknowledgements

The authors would like to thank Dr. Arnold M. Howitt at Harvard University and Dr. Wanchul Yoon at the Korea Advanced Institute of Science and Technology for their valuable comments on the manuscript.

References

[1] Johns Hopkins University & Medicine Coronavirus Resource Center. COVID-19 dashboard by the Center for Systems Science and Engineering (CSSE). https://coronavirus.jhu.edu/map.html. (accessed 27 December 2020).
[2] Disaster and Safety Management Framework Act, Article 34–2. http://elaw.kri.re.kr/eng/mobile/viewer.do?hseq=37382&type=new&key=; 2021.
[3] Jeong BS. The Development Direction of Korea’s Risk Management Manual., vol. 19 Korea Disaster Prevention Association; 2014: 15–22.
[4] Kim YK, Sohn HG. Disaster risk management in the Republic of Korea. Singapore: Springer; 2018.
[5] Oh MD, Park WB, Park SW, Choe PG, Bang JH, Song KH, et al. Middle East respiratory syndrome: what we learned from the 2015 outbreak in the Republic of Korea. Korean J Intern Med. 2018;33:233–46. https://doi.org/10.3904/kjim.2018.031.
[6] Government of the Republic of Korea. Korea’s response to COVID-19 and future direction. http://www.mota.go.kr/eng/btl/w/22742/list.do; 2020.
[7] Kelland K, Nebhaj S. WHO officials rethink epidemic messaging amid pandemic debate. https://www.reuters.com/article/us-health-coronavirus-who-messaging-intl/who-officials-rethink-epidemic-messaging-amid-pandemic-debate-idUSKBN2110AY; 2020. (accessed 24 April 2020).
[8] United Nations. Shared responsibility, global solidarity: responding to the socioeconomic impacts of COVID-19. https://undg.un.org/sites/default/files/2020-05/SG-Report-Socio-Economic-Impact-of-Covid19.pdf. (accessed March 2020).
[9] United Nations Office for Disaster Risk Reduction. Online glossary: disaster risk. https://www.unisdr.org/terminology/disaster-risk; 2021.
[10] Howitt AM, Leonard D, Giles DW. Public health preparedness: Case studies in policy and management. American Public Health Association; 2017.
[11] Renn O, Schweizer P. Inclusive risk governance: concepts and application to environmental policy making. Environ Policy Gov. 2009;19:174–85.
[12] World Health Organization. Health emergency and disaster risk management framework; 2019.
[13] World Health Organization. https://www.who.int/csr/don/05-january-2020-pneumonia-of-unknown-cause-china/en/; 2020.
[14] KDCA. COVID-19 Press Release Report 20 January 2020. http://www.kdca.go.kr/board/board.es?mid=a20501000000&bid=0015; 2020. (accessed 20 January 2020).
[15] KDCA. COVID-19 press release report 28 January 2020. http://www.kdca.go.kr/board/board.es?mid=a20501000000&bid=0015; 2020. (accessed 28 January 2020).
[16] Lee YH, Yook SP. Effective crisis intervention approaches and activities post-COVID-19: focusing on crisis intervention amid COVID-19. Korean J Clin Psychol. 2020;39:368–81.
[17] Lee D, Lee J. Testing on the move: South Korea’s rapid response to the COVID-19 pandemic. Transp Res Interdiscip Perspect. 2020;5:100111. https://doi.org/10.1016/j.trip.2020.100111.

[18] KDCA. COVID-19 press release report 28 January 2020. http://www.kdca.go.kr/board/board.es?mid=a20501000000&bid=0015; 2020. (accessed 28 January 2020).

[19] Lee D, Lee J. Testing on the move: South Korea’s rapid response to the COVID-19 pandemic. Transp Res Interdiscip Perspect. 2020;5:100111. https://doi.org/10.1016/j.trip.2020.100111.

[20] MoHW. COVID-19 Q&As Press Release. http://www.mohw.go.kr; 2020. (accessed 28 February, 2020).

[21] Cheongwadae. Opening remarks by President Moon Jae-in at 7th Cabinet Meeting. https://english1.president.go.kr/BriefingSpeeches/Speeches/759; 2020. (accessed 28 March 2020).

[22] KDCA. COVID-19 press release report 11 March 2020. http://www.kdca.go.kr/board/board.es?mid=a20501000000&bid=0015; 2020. (accessed 11 March 2020).

[23] KDCA. COVID-19 press release report 23 March 2020. http://www.kdca.go.kr/board/board.es?mid=a20501000000&bid=0015; 2020. (accessed 23 March 2020).

[24] KDCA. COVID-19 press release report 5 May 2020. http://www.kdca.go.kr/board/board.es?mid=a20501000000&bid=0015; 2020. (accessed 5 May 2020).

[25] KIET. COVID Pandemic’s Impact on the Korean Economy and Industry: Interim Evaluation, vol. 109; 2021–8.

[26] Yang Y, Baik JS, Ahn SY, Jang E. Tracing digital contact tracing: surveillance technology and privacy rights during COVID-19 in China, South Korea, and the United States; 2020. https://doi.org/10.2119/87343491.

[27] KDCA. COVID-19 press release report 27 August 2020. http://www.kdca.go.kr/board/board.es?mid=a20501000000&bid=0015; 2020. (accessed 27 August 2020).

[28] KDCA. COVID-19 press release report 23 August 2020. http://www.kdca.go.kr/board/board.es?mid=a20501000000&bid=0015; 2020. (accessed 23 August 2020).

[29] KDCA. COVID-19 press release report 8 December 2020. http://www.kdca.go.kr/board/board.es?mid=a20501000000&bid=0015; 2020. (accessed 8 December 2020).

[30] MOHW. COVID-19 press release report 13 January 2021. http://www.mohw.go.kr/react/al/sal0301vw.jsp?PAR_MENU_ID=04&MENU_ID=0403&page=1&CONT_SEQ=363023; 2021.

[31] KDCA. COVID-19 press release report 26 December 2020. http://www.kdca.go.kr/board/board.es?mid=a20501000000&bid=0015; 2020. (accessed 26 December 2020).