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A strategic response map for cascading pandemics: Lessons learned from the response to COVID-19 in the Republic of Korea

Yong-kyun Kim, Wan Chul Yoon, Jaekyung Lee, Jean-Luc Poncelet, Glenn Dolcemasco, Hong-Gyoo Sohn

ABSTRACT

COVID-19 is a still-on-going fatal risk that affects the whole world. COVID-19 pandemic has been characterized as a systemic risk. Accordingly, this paper aims to identify the features of systemic risk of COVID-19 and draw policy implications for effective response. For this, we traced the COVID-19 related risk in Korea from January 2020 to August 2021 by utilizing the official data of the Korea Disease Control and Prevention Agency. Analyzing the relationship between anticipated, emerging, amplification, and resilience risk response through actual data, it was revealed that the risk flow model for cascading risk proposed by the author can be readily applied. In addition, through the analysis of actual response measures against the risks for 1 year and 8 months, the authors proposed a strategic response map against cascading pandemics. Five policy implication derived through this study can be extended for identifying strategic approach against cascading pandemics and for developing guidelines for effective preparedness, risk reduction, and resilience building.

1. Introduction

Coronavirus SARS-COV-2 disease 2019, known as COVID-19, hit the world in December 2019 and is still ongoing. According to the World Health Organization (WHO), a total of 223,022,538 cases were confirmed as COVID-19 as of September 10, 2021, including 4,602,882 deaths [1]. COVID-19 has had a dramatic effect on all sectors of society, including the economy (the deepest global recession since the end of World War II [2]), education (100 million additional children are expected to fall below the minimum proficiency level [3]), and tourism (export revenues from tourism fell by $910 billion to $1.2 trillion in 2020) [4–6]. The challenge is that most of its impacts were unexpected and have a nonlinear causal relationship with the novel coronavirus. Such systemic risk is an emerging research area in disaster risk reduction and crisis/emergency management [7,8]. Understanding the nature of systemic risk is essential for developing an effective response system for future crises like COVID-19.

The Republic of Korea (hereafter “Korea”) has faced various risks affecting most societal sectors during the COVID-19 pandemic and has coped with those risks through a well-designed response plan and an openness to innovate and learn. The intersection of risks and response measures includes the rapid implementation of the existing response plan in the early stage of the pandemic, the introduction of innovative measures against the emergence of unanticipated risks, and the adoption of adaptive response as the pandemic evolves. From the risk management perspective, Korea’s case has significant policy implications for effective response against a future pandemic with high uncertainty, complexity, and catastrophic impacts [9].

This paper aims to identify the features of systemic risk of COVID-19 and draw policy implications for effective response to future cascading infectious diseases like COVID-19. To this end, the authors first develop a conceptual framework for the analysis based on recent achievements in practical and academic fields about systemic risk, cascading disasters, routine/crisis emergency management, and the risk management flow. This study then explores the emergence of risk by tracking the official data of the Korea Disease Control and Prevention Agency (KDCA) and applying the result to the risk management flow that shows the relationship between risk environments, risk types, and response measures. Finally, the authors propose a strategic response map for pandemic crises. Political leaders and emergency managers can utilize the map to understand the nature of systemic risk during catastrophic contagious disease crises and develop an effective response strategy based on a shared understanding of the features of systemic risk.
2. The conceptual framework for the analysis

2.1. Systemic risk and features of COVID-19

The concept of systemic risk was first applied in the economic discipline. It has been recently used for disaster risk reduction (DRR) and resilience building [10]. In particular, since the 2010 eruptions of Eyjafjallajökull in Iceland and the impacts of Japan’s triple disaster of earthquake, tsunami, and nuclear catastrophe in 2011, the DRR academia [7] and UN system [11] have investigated the characteristics of systemic risk and cascading disasters. Schweizer and Renn [12] identified the features of systemic risk as having high complexity, transboundary impact, a stochastic relationship among the triggers and effects, a nonlinear character that includes tipping points, and underestimation by public policymakers and the public. The Global Assessment Report on Disaster Risk Reduction 2019 associated the nature of systemic risk with the complex networks and increasingly interconnected world [11].

Systemic risk is related to the uncertainty of the consequences of an activity or event affecting something that humans value [13]. Uncertainty can pertain to the type, likelihood, severity, time, or location of these consequences. The concept assumes that failure in one sub-unit or cluster of the system will lead to cascading events in other system units. These cascading events may lead to significant disturbance or even complete failure of the whole system. Pescaroli and Alexander [14] proposed to define cascading disasters as “extreme events, in which cascading effects increase in progression over time and generate unexpected secondary events of strong impact.” Cascading disasters can be caused by several conditions, including induced damage by the hazard itself, the amplified threat by inappropriate countermeasures, and the system’s interconnectivity. The occurrence of cascading disasters is complex, and its damage evolves unless appropriate actions are taken [7].

Responding well to the first impact but failing to control its cascading implications may result in secondary emergencies. Thus, the concept of systemic risk has become more critical to the development of an effective response system. Irrespective of various efforts to explore the nature of systemic risk and cascading disasters, the mechanism of systemic risk, the emergence of cascading disasters, the evolutionary process of risk, and the vulnerability paths have not been sufficiently explored. The complexity comes from the interaction of a vast number of risk factors. Risk factors and response measures interact and generate new vulnerabilities, causing the risk to evolve. In this sense, more in-depth research on such emerging issues needs to be conducted from collaborative and multi-systematic viewpoints [15].

The COVID-19 pandemic has been characterized as a systemic risk because its appearance and cascading developments took advantage of these increasing global interconnections. The health crisis cascaded in a nonlinear fashion onto the economy and grew exponentially to disrupt every aspect of our interdependent world [16]. Beyond the impact on the health sector, COVID-19 has affected most societal sectors, including the economy, transport, energy, trade, finance, and natural events, such as climate change and natural disasters.

The pandemic has triggered a global recession, and lockdown in various countries has had a cascading effect on the worldwide supply, with a sharp drop in supply and demand from a wide range of products and industries [17]. The pandemic also has a devasting impact on small business owners and socially vulnerable classes. In addition, COVID-19 caused the health facilities to be overwhelmed. Similarly, outcomes are not universally adverse and socially vulnerable classes. In addition, COVID-19 caused the health facility to be overwhelmed. Similarly, outcomes are not universally adverse and socially vulnerable classes. The World Meteorological Organization (WMO) announced that an analysis of changes in significant pollutants in the atmosphere, such as sulfur dioxide, nitrogen oxides, carbon monoxide, and ozone revealed that the concentration of contaminants worldwide has decreased. The systemic features of COVID-19 underscore the importance of better coordinated, collective, and multi-dimensional governance.

2.2. Response management against systemic risk

The conventional driving principle for hazard-specific response is to plan against well-defined risks based on recognizable patterns and management regimes [18]. The response authorities predict risk by assessing risk factors, such as hazard, vulnerability, and exposure, and develop a disaster response plan based on the risk assessment [19]. This way is effective for responding to anticipated risk. But the systemic risk featured by high uncertainty, complexity, and nonlinear causal relation is hardly predictable, not being described in the disaster response plan. COVID-19, caused by the novel coronavirus, is a typical example. Due to a lack of knowledge about the virus, it was difficult for responsible authorities to cope with the emergencies appropriately in the early stage. Also, the pandemic caused various risks in most social sectors, such as the economy, humanitarian, security, and human rights [20]. Therefore, it is urgently needed to prepare for future cascading disasters such as pandemic crises by developing an effective response system based on understanding its systemic nature. Kim et al. [9] investigated Korea’s response to COVID-19 and found that anticipated risk, emerging risk, amplified risk, and lingering risk had appeared and been affected, for better or worse, by the intervention of responsible authorities and citizens. The study also emphasized that the early implementation of preplanned response measures and the flexible adjustment of the response plan are essential for coping with systemic risk. The classic “anticipated risk” requires preparing the Infectious Disease Response Plan and implementing it at the very earliest stage [9]. The response plan relies on the best recommendations and scientific knowledge of health authorities, including WHO, and integrated knowledge and experience lessons from the response process to the previous events, such as MERS in 2015, H1N1 in 2009, and SARS epidemics in 2003.

The second type is “emerging risk,” which is particularly difficult to anticipate primarily due to a lack of scientific and verifiable information and society’s complexity and interconnectedness [9]. As the virus was new, the responsible authorities had no choice but to implement the infectious disease response plan developed on the basis of the knowledge gained from the previous events. The third is the “amplified risk,” which comes from implementing measures that later appeared to be inappropriate [9]. The amplified and emerging risks can cause secondary emergencies that probably result in a national crisis, requiring authorities to re-plan the established procedure. Those secondary crises are likely to involve various other sectors, such as education, supply chain, economy, and tourism [21]. Prompt implementation of adaptive measures is also required to mitigate the corresponding risk sufficiently to end the crisis.

The last is “lingering risk,” which is sustained even after responsible authorities take action. It is necessary to analyze the existing plan and adjust it quickly when the previously established response plan is executed, but the risk is not mitigated [9]. The risk management flow (Fig. 1) shows that risk environment, risk types, and response measures are related nonlinearly. Various risks emerge or change by the intersection with the response measure [9].

When a transmissible and pathological virus emerges in an environment vulnerable to the corresponding epidemic, the exposed people will be massively infected. The government must take the best response measures to address the anticipated risks by following its preplanned response manual, such as strengthening monitoring and promoting quarantine to mitigate the risk. Probabilistic risk modeling has been widely used for responding to these anticipated risks by assessing hazard, vulnerability, and exposure. Howitt and Leonard [8] argued that the effective response to routine emergencies mainly caused by anticipated risks requires establishing a response plan based on the anticipated scenario, training skilled workers with extensive field experience, implementing a Standard Operating Procedure (SOP) through precise situational awareness, and mobilizing resources in a timely way [8]. Even after the initial actions were taken based on the pre-designed response plan, some risks do not dissipate and become a lingering risk, and they may cause massive damage when certain conditions are met. In such cases, an adaptive response must be developed promptly. In the case of Korea’s reaction to COVID-19, this was especially relevant for the underestimation of transmission through asymptomatic cases, which turned out to be the main trigger.

The difficulties of response come from the novelty of the hazard; in the very early stage, insufficient information may cause situational awareness
error, resulting in the emergence of unanticipated risk. As the pandemic lasts, various unanticipated risks emerge due to the influence of high uncertainty, interconnectivity, and/or the complexity of society. Also, the risk may be worsened due to inappropriate actions taken by responsible authorities. In many cases, the crisis caused by emerging or amplified risk often is beyond the capacities of preplanned response measures. In this sense, the systemic risk usually demands a flexible response by modifying the existing plan, rapid mobilization of available resources, and the engagement of higher government levels and the private sectors [8].

2.3. Unit of analysis and data acquisition

The units of analysis in this study are the organizational unit and the citizen as a whole, which are divided into (a) the Central Disaster and Safety Countermeasures Headquarters (CDSCHQs) including all line ministries, which are chaired by the prime minister; (b) the Ministry of Health and Welfare (MoHW) and the KDCA organizing medical units in charge of preventing infectious disease; (c) the Ministry of Interior and Safety (MoIS) coordinating support functions from all non-medical entities; (d) expert advisory groups that represent the opinion of medical experts, and (e) the citizen as a whole group.

This paper takes the number of new confirmed cases each day as the basis for the severity of the risk caused by COVID-19. The number of new confirmed cases was identified using the official database by the KDCA. For example, from February 19 to February 26, 2020, the average number of new confirmed cases per day was 152, which is a significant increase from 1.14 in the previous 2 weeks (from February 5 to February 8). Additionally, the number of deaths and the frequency of cluster infections that were announced by the KDCA were also used as auxiliary data to understand the severity of the COVID-19 risk.

Analysis of the impact of COVID-19 on other sectors, such as the economy or education, is beyond the scope of this paper. However, it is a critical part of effective response system to consider that catastrophic infectious diseases significantly interact with other fields, such as the economy and education, due to the systemic features of COVID-19. The impact on the economy, education, etc., was cited by the Korean government's COVID-19 official report. For example, from January 2020 to April 2020, about 476,000 jobs were lost, which was the largest number since the 1997 Asian financial crisis [22].

3. Assessing risk environment, systemic risk, and response measures

Since the first confirmed COVID-19 case was reported in Korea on January 20, 2020, there have been four tipping points in Korea, when the number of daily confirmed cases increased significantly. Using the Risk Management Flow, the authors traced the COVID-19 related risk in Korea from January 2020 to August 2021 and identified the emergence of systemic risk and cascading disasters through the vulnerability paths.

3.1. Preplanned response to anticipated risk

Since December 2019, reports of an increase in the number of patients with pneumonia of unknown cause in Wuhan, China health authorities reported to the WHO [23]. The former Korea Centers for Disease Control and Prevention (KCDC) activated its Emergency Operation Center (EOC) corresponding to the blue level in the National Crisis Alert and strengthened monitoring of people entering Korea from China. Nevertheless, with the continuous increase of the infected persons by the novel coronavirus in the Wuhan area, the possibility of the unknown virus entering Korea continued to grow. After the first confirmed case was identified on January 20, 2021, the risk of an infectious disease outbreak in Korea increased as more people were exposed [24].

The government issued a national crisis alert (yellow) and activated the quarantine countermeasure headquarters. However, despite all government efforts, the possibility of spreading the virus persisted due to the inability to scrutinize all people entering Korea from China, relying on methods such as self-reporting and thermal testing. In addition, the lack of information and knowledge about the virus increased citizen anxiety. The KCDC started providing information about COVID-19 at the 1339 call center (the call center provided instructions on emergency treatment and disease counseling). Citizens who inquired were relieved of their anxiety by receiving the necessary information. However, as the response to the call center was delayed due to the sudden increase in inquiries and the shortage of human resources, the complaints of citizens who could not access the call center rapidly increased, and the citizens’ anxiety also increased. As a result, the government reinforced the workforce at the 1339 call center and disclosed the acquired information as transparently as possible [25]. Due to these efforts, civil dissatisfaction with the call center

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1 The KCDC was promoted to the Korea Disaster Control and Prevention Agency (KDCA) as an independent agency level in September 2020.
had gradually decreased, but citizens' anxiety about COVID-19 persisted without being entirely resolved. Increasing citizens' fear caused a sharp increase in the demand for face masks, which resulted in the increased risk of an imbalance between supply and demand. Although the Ministry of Food and Drug Safety (MFDS) made efforts to inspect the production process of masks and investigate unfair practices such as cornering and hoarding, there was no solution to the fundamental problem of the shortage of face masks. As a result, the risk of a shortage of face mask for citizens continued to exist.

Another emerging risk was that Koreans residing in Wuhan, China was at risk of being exposed to the novel coronavirus. As a result, the Korean government took actions to transport Koreans living in Wuhan to Korea and quarantine them in temporary living facilities for 2 weeks. While this response measure had reduced the risk of infection for Korean residents living in Wuhan, residents in areas surrounding temporary living facilities were concerned about the spread of the coronavirus. Insufficient knowledge about COVID-19 was also a cause of these concerns.

By February 18, 2021, the total number of confirmed cases of COVID-19 in Korea was 30 due to the Korean government's disclosure of transparent information, preemptive response, and enhanced monitoring at the entry stage [26]. However, there was a hidden risk. To prevent the inflow of the novel coronavirus, the KCDC relied on entry screens at the airports or ports by self-diagnosis or thermal check. Such measures were not sufficient to find all potentially infected persons due to its long incubation period. There might have been persons infected by confirmed patients who had already entered Korea. Some attended funerals related to the Sincheonji Church in Cheongdo-gun, Gyeongbuk-do in January 2020, and worship ceremonies on January 9 and 16, 2020, held in Daegu City. As a result, the risk of regional spread infection increased in the Daegu City and North Gyeongsang Province (henceforth “the DG regions”). Using the risk management flow, the authors summarized the interaction among risk environments, risk types, and response measures during Phase I. Fig. 2 along with the detailed explanation in the Tables 1–3 indicates the link between Risk Environment (RE), Response Measure (RM), and Risk Type consisting in Anticipated Risk (AtR), Emerging Risk (ER), Amplified Risk (ApR), Lingering Risk (LR), and Mitigated Risk (MR). Each element was numbered sequentially according to the order of occurrence or its connectivity with other elements. However, the number does not necessarily mean the order in which it occurs since many parts are often connected complexity.

### Table 1

| Number | Contents | Relation |
|--------|----------|----------|
| RE1    | Occurrence of pneumonia of unknown cause in Wuhan, China in Dec. 2019 | ER1 |
| RE2    | Continuing increase of the infected persons by the new coronavirus in Wuhan, China | LR1 |
| RE3    | New coronavirus; High uncertainty of transmission path of the new virus; A highly interconnected society with no immunity; No comparable previous experience; The complexity of the society | AtR1 |
| RE4    | Insufficient information about the novel coronavirus | ER2 |
| RE5    | Delayed response of call center due to surge of inquiry calls | ApR1 |
| RE6    | Entry screening through self-diagnosis or temperature check | LR3 |
| RE7    | Lack of knowledge about the COVID-19 | ER4 |

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### Table 2

| Number | Contents | Relation |
|--------|----------|----------|
| AtR1   | Anticipated probability of the occurrence of the new infectious disease in Korea | RM2 |
| AtR2   | Increase of at-risk Korean residents in overseas countries including Wuhan | RM8 |
| ER1    | Possibility of new infectious disease | RM1, AtR2 |
| ER2    | Increased anxiety of citizen | RM3, ER3 |
| ER3    | Increased imbalance between supply and demand due to the surge of demand | RM6 |
| ER4    | Increased anxiety of residents nearby temporary living facilities | RM9 |
| ApR1   | Increased complaint and anxiety by disinfomed citizens | RM4, RM5 |
| LR1    | Sustained possibility of the influx of the new coronavirus to Korea | AtR1 |
| LR2    | Sustained imbalance due to the lack of root-case solution | Phase 2 |
| LR3    | Possible failure of entry screening of the infected persons | RM7 |
| MR1    | Reduced anxiety of citizens informed by call center | |
| MR2    | Reduced complaint and anxiety of informed citizens | |
| MR3    | Ensured safety of at-risk overseas residents | |
| MR4    | Reduced concern of residents | |

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* Risk in the first column necessitated response measure or affected another risk in the third column.

* LR2 persisted to Phase II and affected ApR3 in Phase II.
when those actors were able to be identified clearly. If the response measure does not include a specific actor, it means that the Citizen or all the nation works together to implement the response measure.

| Number | Contents | Relation |
|--------|----------|----------|
| RM1    | (KCDC) Monitor the inbound passengers from China | LR1 |
| RM2    | (KCDC) Issue Level II (Yellow) on January 20 and operate the Central Disease Control Headquarters (CDC) by KCDC | ER2, LR3 |
| RM3    | (KCDC) Issue Level III (Orange) on January 28 and establish the Central Disease Management Headquarters (CDM) by MoHW | |
| RM4    | (KCDC) Increase call center personnel | MR2 |
| RM5    | (KCDC) Disclose citizens with information about the novel coronavirus that the government obtained | MR2 |
| RM6    | (MFDS) Inspect the production process, quell the market disturbance, and promote manufacturing face mask | LR2 |
| RM7    | (KCDC/MoIS) Conduct epidemiological investigation of confirmed cases and open their movement paths to the public | ApR2 |
| RM8    | Return residents to Korea and quarantine them for 14 days in temporary-living facilities | ER4, |
| RM9    | (MoIS) Persuade residents near the temporary-living facilities | MR3 |
| RM10   | (MoIS) Persuade residents near the temporary-living facilities | MR4 |
| RM11   | (KCDC) Issue Level II (Yellow) on January 20 and operate the Central Disease Control Headquarters (CDC) by KCDC | |
| RM12   | (KCDC) Disclose citizens with information about the novel coronavirus that the government obtained | |
| RM13   | (KCDC) Issue Level III (Orange) on January 28 and establish the Central Disease Management Headquarters (CDM) by MoHW | |
| RM14   | (KCDC) Increase call center personnel | MR2 |
| RM15   | (KCDC) Disclose citizens with information about the novel coronavirus that the government obtained | MR2 |
| RM16   | (MFDS) Inspect the production process, quell the market disturbance, and promote manufacturing face mask | LR2 |
| RM17   | (KCDC/MoIS) Conduct epidemiological investigation of confirmed cases and open their movement paths to the public | ApR2 |
| RM18   | Return residents to Korea and quarantine them for 14 days in temporary-living facilities | ER4, |
| RM19   | (MoIS) Persuade residents near the temporary-living facilities | MR3 |
| RM20   | (MoIS) Persuade residents near the temporary-living facilities | MR4 |

We refer to the specific responsible units described in Table 3, and later Tables 6 and 9 when those actors were able to be identified clearly. If the response measure does not include a specific actor, it means that the Citizen or all the nation works together to implement the response measure.

3.2. Adaptive response to emerging or amplified risk

Since the 31st confirmed case appeared with massive contacts in the Daegu City on February 19, 2020, transmissions in the DG regions had increased significantly. Therefore, based on the Infectious Diseases Control and Prevention Act (IDCPA), the government immediately secured a list of Sincheonji church members and conducted a full inspection of suspected infectious people. In addition, on February 23, 2020, the alert level was raised to the critical level, and the CDSCHQs was initiated and headed by the Prime Minister [27]. These measures prevented the risk of spreading infections nation-wide, but the spread of DG regions by people who were already infected continued to increase. In addition, the problem of a lack of medical staff and hospital beds had become severe due to the explosion of confirmed cases.

The government classified the confirmed patients according to their severity. The triage solved the problem of the lack of wards and improved the treatment system by allowing severe patients to be hospitalized and treated with priority. The risk of a shortage of medical staff was also reduced through reinforcement of medical staff, such as voluntary involvement of doctors and nurses across the country and dispatch of public health doctors. However, the shortage of masks that started in January also became more severe during this time. Irrespective of the MFDS’s continuous efforts to encourage face mask production and to strengthen its crackdown on unfair trade, the increase in demand for face masks, price hikes, supply shortages, and public fear got much worse after the explosion of confirmed cases in DG regions in February. The problem persisted for a month and was solved after the government began to allow each citizen to purchase the same quantity of face masks.

The spread of the DG regions by infected people continued to increase until the end of February, and there were 909 confirmed cases per day on February 29. The government implemented a 3T (Testing, Tracing, and Treatment) strategy, supported by Information and Communication Technology (ICT), medical technology, reliable data, and communication networks. These innovative methods include RT-PCR diagnostic test kit, emergency approval for rapid diagnosis, creative testing methods such as drive-through testing facilities, Smart Quarantine Information System, and Self-quarantine safety protection Application. It also provided information about the movement of confirmed patients to the public. Citizens also actively participated in preventing the spread of infection by observing precautions and reporting any suspected illness to the public health center. As a result of these efforts, the number of confirmed cases in the DG regions decreased significantly, and the daily number of confirmed cases nation-wide recorded 64 on March 23.

COVID-19 had not ended, and the risk of group and community transmission continued across the country. In addition, the parliamentary elections scheduled for April 15 and the massive accommodation of victims of the large wildfires that frequently occur in April were likely to increase the risk of group and community infection. The government thoroughly quarantined all polling stations and requested voting citizens to continue social distancing and wearing masks. Those measures helped Korea prevent a nation-wide outbreak [28].

Due to the government’s strengthening of social distancing and citizen participation, the cumulative number of confirmed cases in April remained...
under 1000, and the risk of group and community transmission across the country decreased. However, the adverse effects of a vital quarantine had led to an increased risk of recession and reduced sales of small business owners. Although the government temporarily reduced the risk of economic recession by mobilizing various methods such as support for the affected industries and payment of disaster support, it was not a fundamental solution. Another adverse impact of the social distancing rules was that the students who were not equipped with ICT tools suffered reduced economic recession and reduced sales of small business owners. The digital divide in the COVID-19 era is a severe problem [29]. This type of risk is beyond the scope of this paper and needs to be addressed in more depth in other studies.

While the risk of a small-scale group infection in the region persisted, during the Golden Week holiday in early May, confirmed patients entered a nightclub located in Itaewon-dong in Seoul, where many gathered in a crowded environment, increasing the risk of mass infection. The government wanted to conduct a full investigation of the people in the nightclub at the time. However, visitors made false lists. Those afraid of criticism did not voluntarily respond to the epidemiological investigation; the risk of group infection was very high in the metropolitan area. After much deliberation, the Seoul Metropolitan City government conducted an anonymous test only for nightclub visitors. Only then did the visitors respond to the test and reduce the risk of group infection. To reduce the possibility of tracing failure, the government developed and operated an electronic visitor record-keeping system, which automatically identified visitor information using QR codes. While the system reduced the risk of not identifying people for epidemiological investigation, it increased the exposure of personal information.

As COVID-19 was a global pandemic, the risk of domestic spreading by inbound travelers continued to increase. Therefore, the government implemented monitoring of all people entering Korea. Furthermore, it requested all inbound passengers to self-quarantine for 2 weeks, resulting in the reduced risk of transmission by overseas travelers. In addition, social distancing was also applied flexibly according to the risk situation to prevent nation-wide spreading. The risk management flow in Fig. 3 and Table 4–6 tracked the intersection among risk environments, risk types, and response measures during Phase II.

### 3.3 Explosion of lingering risk, the similarity of risk occurrence, and learning effect

The total number of confirmed cases in October 2020 was around 2700, which was within the manageable level of the health authorities. However, the continuous transmission by asymptomatic cases [30] and inbound travelers who might have been infected by mutant virus remained as an unresolved lingering risk. In addition, the prolonged social distancing rules, under 1000, and the risk of group and community transmission across the country decreased. However, the adverse effects of a vital quarantine had led to an increased risk of recession and reduced sales of small business owners. Although the government temporarily reduced the risk of economic recession by mobilizing various methods such as support for the affected industries and payment of disaster support, it was not a fundamental solution. Another adverse impact of the social distancing rules was that the students who were not equipped with ICT tools suffered reduced economic recession and reduced sales of small business owners. The digital divide in the COVID-19 era is a severe problem [29]. This type of risk is beyond the scope of this paper and needs to be addressed in more depth in other studies.

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such as reduced business hours, caused severe economic losses to business owners. The government tried to balance between quarantine and the economy by adjusting social distancing rules. Irrespective of these efforts, the situation got worse again in December 2020. A combination of transmission by asymptomatic cases, cold weather, and increased indoor activities in closed facilities led to a sudden rise in the number of confirmed cases and the increase of unknown infection routes in the capital area.2 In addition, since many people frequently visit the capital area, the probability of a nation-wide outbreak also rose.

From the middle of December 2020 to early January 2021, almost 1000 newly confirmed cases occurred every day. The sudden increase in the confirmed cases caused the delayed hospitalization of the COVID-19 patients. The government took emergency action to secure hospital rooms by utilizing large hospitals and university dormitories and hospitalization of confirmed patients, which was lessons learned from its experience during the first wave in February. The Seoul Metropolitan City government decided to operate temporary screening clinics where anyone could receive diagnostic tests, successfully reducing the risk of transmission by asymptomatic cases. Furthermore, more thorough monitoring of overseas entrants was carried out to prevent a mutant virus from entering the country. A smartphone app, which was linked with GIS smart board managed by the CDSCHQs and local governments, made it possible for the government authority to monitor the status of self-quarantine 24 h a day. Very stringent social distancing rules, such as restricting restaurant operations after 9 p.m. and banning private gatherings for more than five people, were implemented.

From March to June 2021, the daily number of confirmed cases remained under 800. For this period, various elements for keeping the society stable, such as social distancing rules, vaccination, management of the self-quarantined, efforts to recover the stagnant economy, and an increase in vulnerable sectors to infection due to continued quarantine fatigue, coexisted. Irrespective of these efforts, on July 7, 2021, the daily number of confirmed cases exceeded 1000, and on August 11, it recorded 2222, the highest number of confirmed cases.[31] Since then, the confirmed cases have shown a gradual decrease trend, and on September 22, 2021, the number reached 1721. Fig. 4 and Tables 7–9 show the summarization of Phase III.

4. Strategic response map and policy implications

4.1. Strategic response map for cascading pandemics

Based on the findings above, this study proposes a “strategic response map against cascading pandemics (Fig. 5)”, along with a detailed explanation of each element of the response map (Appendix 1). This study suggests that political leaders, emergency managers, and other stakeholders utilize the strategic response map to identify the emergence of systemic risk at the earliest stage and prepare appropriate response measures against national health crises in a timely way. This response map can be further extended to identify overall strategic approach to cascading pandemics and to develop guidelines for effective preparedness, risk reduction, and

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Table 7

| Number | Contents | Relation |
|--------|----------|----------|
| RE13   | The emergence of the mutant virus in overseas countries | ApR5 |
| RE14   | Relying on self-diagnosis or thermal diagnosis by inbound travelers | | |
| RE15   | Social activities of asymptomatic cases, resulting in silent transmission | | |
|        | Cold weather | | |
|        | Increase of indoor activities in closed areas with high density | | |

* Risk environment in the first column produced risk in the third column.

Table 8

| Number | Contents | Relation |
|--------|----------|----------|
| AtR4   | Failure of entry screen of inbound travelers infected by a mutant virus | RM22 |
| ER10   | Delayed hospitalization due to surge of confirmed cases | RM24 |
| ER11   | Increased risk of exposing personal information | RM27 |
| ApR5   | Increase of cases with unknown infection routes and asymptomatic cases | RM23; ER10, RM26 |
| L97    | Lingering risk of nation-wide outbreak | RM25 |
| L8     | Sustained transmission by asymptomatic cases | ApR5 |
| L9     | Lingering threat of sporadic group/community | ApR5 |
| MR15   | Reduced risk of mass infection by inbound travelers | | |
| MR16   | Reduced transmission by asymptomatic cases | | |
| MR17   | Secured treatment system | | |
| MR18   | Reduced probability of a nation-wide outbreak | | |
| MR19   | Reduced risk of transmission by asymptomatic cases | | |
| MR20   | Reduced risk of mass infection | | |
| MR21   | Secured protection of personal information | | |

* Risk in the first column necessitated response measure or affected another risk in the third column.

b L99 persisted until the termination of the pandemic.

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2 The capital area in this paper means Seoul Metropolitan City, Incheon Metropolitan City, and Gyeonggi Province, of which the total population is about 26 million (about 50% of the Korean population).
Infectious disease resilience building. Consequently, the proposed response map has the following implications for effective response management.

First, the infectious disease caused by the new virus is likely to escalate into a national crisis. Thus, the government should issue a national crisis alert and set up a coordinating center that integrates health and disaster management authorities as soon as it is informed of a suspected case. The emergency coordinating center prevents infection through contact tracing, rapid testing, patient treatment, and social distancing rules, provides the public with the exact information about the new virus, and operates an entry screen system to block infections from foreign countries. The government should inform citizens of the identified and confirmed person’s movement and help those suspected of infection be tested and self-quarantined. The best strategy is to prevent the spread of infectious diseases at the earliest stage by taking all response measures by the government and citizens and mobilizing all available resources.

Second, the government should prepare the high probability that infectious diseases may not be terminated at an early stage. The increasing uncertainty, interconnectivity, and complexity in a contemporary society may cause the confirmed cases by the new virus to be skyrocketed. For example, infected persons may attend a large gathering without knowing that they are infected due to a lack of information and knowledge about the virus and symptoms, resulting in mass infection with which already allocated resources may not be enough to deal. When the government recognizes the occurrence of systemic risk, it must operate a higher level of emergency response institution so that additional resources can be mobilized from all relevant ministries. The government also must assess the existing response plan and adopt adaptive response measures, such as a further mobilization of human and financial resources, an additional allocation of emergency response budget, and strengthened rules for social distancing. In addition, the government should prepare for a high possibility of a shortage of hospital beds and doctors, a need of infectious disease response equipment, and a lack of personal protection equipment.

Third, the government should anticipate and prepare for problems if the infectious disease is prolonged. The potential problems include the emergence of mutant virus and the cascading negative impacts to other sectors, such as business loss of restaurants and retail stores due to prolonged social distancing rules, economic recession, education gap caused by non-face-to-face classes, and business loss of tourism companies due to reduced travel and sightseeing tour. The government should be equipped with the capacity to identify the existing response plan’s shortfalls and adjust it against emerging risks. It should also establish an inclusive risk governance system that ensures multi-stakeholders participation and decision-making. Such a governance system needs to be utilized to provide financial support to affected business sectors and resolve the digital divide problem by supplying information and communication devices to the low-income classes.

Fourth, disclosing the movement of the confirmed cases and keeping the visitors’ records may create a risk that personal information may be exposed against the person’s will. The government should pursue the balance between the public purpose of preventing infectious diseases and the right of individuals to have their personal information protected. To this end, the government should achieve a social consensus on disclosing personal data for the safety of the citizens and establish a legal basis for preventing the abuse of personal information. In addition, it must take measures to minimize the personal information or to anonymize it when there are risks of disclosure of personal information.

Last but not least, if nationals are residing or temporarily staying in countries with severe infectious diseases, the government should prepare measures to return them home. To this end, it is vital to establish a cooperative system within the government, such as initiating diplomatic channels with countries suffering from infectious diseases and securing necessary means for transportation. In addition, if returning people are to stay in the temporary living facilities, it is needed to obtain the consent of the residents living around these facilities in advance. The government should inform the residents that the quarantined people in the temporary living facilities will have no effect on the spread of the virus and seek the consent of residents by providing accurate information on the infectious disease.

4.2. Policy implications of the strategic response map

(1) A disaster response manual that is well prepared in advance and mastered through training is very effective in dealing with anticipated risk. However, it can also provide the necessary basis for responding to systemic risk with high uncertainty and lack of knowledge. Korea’s response to COVID-19 in the initial period exemplifies this finding. Although the Korean government did not have enough information and learning about the novel coronavirus in the early phase, it quickly implemented the infectious disease response manual as soon as it was informed of pneumonia patients with unknown cause in Wuhan, China. It also operated emergency response institutions according to the national crisis alert system. Such rapid response helped Korea record under 30 confirmed cases for the first month.

(2) The infectious disease response manual should be continuously improved through the lessons learned from the on-going and previous events. Among the initial response measures, some were implemented appropriately by predicting the situation in which a risk emerges while others are introduced when trying to solve unexpected risks and problems when they occur. For example, while monitoring inbound travelers worked well in the early stage when it was based on the infectious disease response manual, providing information to the citizen through the 1339 call center was implemented in earnest as citizens’ concerns grew. Therefore, it was proposed in the strategic response map, that all necessary measures ranging from RM3 to RM8 should be implemented at the earliest stage, which forced the evolution of the infectious disease response manual. In addition, it was proposed that the consideration of the impact of the cascading pandemic on society as a whole; such as economic recession or the loss of employment, and the cooperation with economic and social ministries should be reflected in the strategic response map and response manual. The current response manual described the collaborative relationship between the health sector and disaster management authorities through the lessons of the 2015 MERS response, but did not include the consideration of economic, social, and cultural impacts. Therefore, the infectious disease response manual should include the analysis of systemic features of the cascading pandemic, the effect of the pandemic crisis on the other sectors of society, and the importance of the engagement of higher-level officials and their crisis leadership.

(3) An effective response system against pandemic crises like COVID-19 should be urgently developed based on analyzing its systemic features and cascading impacts. To this end, the concept of lingering risk, amplified risk, and emerging risk can help emergency managers prepare for hidden threats or undesired results by the response measures. The

Table 9
Response measure in Phase III.

| Number | Contents | Relation |
|--------|----------|----------|
| RM22   | Strengthen entry screen | LR7, MR15 |
| RM23   | (KIDCA/MoHW) Operate temporary screening clinics available for every citizen | MR16 |
| RM24   | (KIDCA/MoHW) Secure hospital beds through an emergency order | MR17 |
| RM25   | (CDSHQs/MoIS) Strengthen social distancing level | LR8, MR18, MR19 |
| RM26   | (CDSHQs) Strengthen preventive rules | MR20 |
| RM27   | (CDSHQs/MoIS) Operate temporary screening clinics available for every citizen | MR21 |

* Response measure in the first column produced risk or necessitated following actions in the third column.
Fig. 5. Strategic response map against cascading pandemics.
responding authorities should not assume that the response manual could describe all possible risks. It must identify emergent problems using the risk management flow and mobilize resources beyond allocated ones to solve them. Furthermore, to prevent cascading impacts caused by systemic risk, the national government should prioritize the decision-making process, ensuring the engagement of relevant ministries and local governments and the empowerment of local governments to take spontaneous measures that suit the local problem.

(4) The prolonged period of COVID-19 implies that a new type of risk is highly likely to appear. In addition, many disaster damages in modern society are not limited to the area to which the hazard originates. The typical examples include the trade-off between the quarantine and the benefits of other sectors, such as the business boost and opening the school. Therefore, responding authorities should monitor all the risk environments closely and should establish an inclusive risk governance system, in which the stakeholders of related societal sectors are engaged in analyzing systemic risk from the initial stage and implementing the adaptive response plan as the pandemic evolves.

(5) The responsible authorities should operate risk communication channels at the earliest stage and provide precise information to the public, which will contribute to building trust with citizens. The shortage of face mask supply shows the importance of risk communication. The insufficient information about the novel coronavirus in the early stage increased the anxiety of citizens, and then it caused the soaring demand for face masks and got worse due to the delayed countermeasures, which might have resulted in citizens’ distrust about the government. The problem was solved after the citizens were informed of the novel coronavirus, and the government adopted the innovative 5-day rotational purchase and the improvement of the production system. The other benefit of risk communication was that disclosure of infectious disease information, along with health education, has dramatically helped citizens conduct COVID-19 prevention activities on their own and cooperate with quarantine guidelines.

5. Conclusion

The impacts by COVID-19 were unanticipated and had a nonlinear causal relationship as the pandemic has affected most societal systems, requiring a systemic risk approach. This study tracked Korea’s response to COVID-19 and explored what types of risks emerged and have been changed by the intervention of response measures using the risk management flow that was developed based on the systemic risk approach.

The results reveal that Korea’s response to this catastrophic event was appropriate by constantly adapting to the new risk environment but would have benefited from a systemic risk approach. Based on the analysis, the authors proposed the strategic response map against cascading pandemics. The response map includes the emergence of various types of risks, the unanticipated impact on many societal sectors, the change of risk by the intervention of response measures, and the path to the termination of the pandemic crises. With the response map, the responsible authorities and multi-stakeholders can identify the emergence of systemic risk and develop appropriate response measures based on the common understanding of the emergency and response status. The strategic map consisting in the risk environment, various risks, and response measures can provide a valuable basis for responding effectively in crises.

Furthermore, this study identified four vital lessons for effective response against cascading infectious diseases. First, a well-prepared response manual is not only effective in dealing with anticipated risk, but also can help the responsible authorities cope with systemic risk with high uncertainty in the initial stage. Second, the responsible authorities should prepare the future pandemic crises based on understanding systemic features and cascading impacts of catastrophic infectious diseases and the concept of anticipated risk, emerging risk, lingering risk, and amplified risk. Third, the cascading pandemic crises will affect many societal systems to which the hazard does not belong. The inclusive risk governance system is an essential part of coping with this type of risk so that all stakeholders take part in risk assessment and decision-making. Fourth, the risk communication channels should be established to build trust in citizens at the earliest stage.

While this study focused on the Korea’s response to COVID-19, the findings, recommendations, and analysis of this study can be applied to other countries, particularly where the response has been inappropriate or slow in the early stage.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1. Detailed explanation on the elements in the strategic response map

| Number | Detailed explanation | Remarks |
|--------|----------------------|---------|
| 0      | • Conventional Risk Environment: Hazard(virus); Vulnerability; and Exposure  
• Increasing features of contemporary society: High uncertainty; Interconnectivity; and Complexity | RE |
| 1      | • Occurrence of suspected cases or confirmed patient | ArR |
| 2      | • Issue a national crisis alert according to the level of severity  
• Activate Emergency Operation Center and initiate coordinating center integrating health authorities and disaster management authorities | RM |
| 3      | • Screen inbound passengers | RM |
| 4      | • Conduct contact tracing or epidemiological investigation  
• Disclose the movement path of the confirmed cases to the citizen | RM |
| 5      | • Test suspected cases | RM |
| 6      | • Counsel the public and provide the correct information about the new infectious disease to the citizen  
• (Health Authorities) Operate 1339 call center and provide information about the infectious disease, and secure enough personnel of the call center in case of surge calls  
• (Disaster management agency and local governments) Promote the preventive rules to the citizen | RM |
| 7      | • Maintain supply chain for personal protection, such as face mask and sanitizers  
• Initiate social distancing rules | RM |
| 8      | • Place potentially infected persons under self-quarantine and monitor them closely through designated local officials | RM |
| 9      | • Terminated outbreak of the infectious disease in the early stage | MR |
| 10     | • Relaying the screen entry on inbound passengers’ self-diagnosis and thermal check | RE |
| 11     | • Continuing social activity of uncontrolled confirmed cases due to lack of knowledge of the new infectious disease | RE |
| 12     | • Large gathering or massive population movement events (e.g. National Assembly Election and Holiday seasons) | RE |
| 13     | • Other types of disasters (e.g. wildfire causing large displaced people to stay in temporary shelters) | RE |
| 14     | • Probability of the failure of existing response measures and/or the increased risk of group transmission due to the existing evacuation plan | ER |
| 15     | • Increased citizens’ anxiety in case of insufficient information  
• Skyrocket of confirmed cases and increased probability of group/community transmissions and nation-wide outbreak | ArR |
| 16     | • Insufficient hospital beds and medical personnel due to the surge of patients | ER |
| 17     | • Insufficient hospital beds and medical personnel due to the surge of patients | ER |
| 18     | • Enhance the treatment system  
• Secure hospital beds through an emergency order | RM |

10
| Number | Detailed explanation | Remarks |
|--------|----------------------|---------|
| 19     | Dispatch national public health personnel | MR |
| 20     | Promote volunteer of medical staff | ER |
| 21     | Resolved problem of insufficient beds and medical personnel | RM |
| 22     | Increased imbalance of face masks due to the surge of demand | ER |
| 23     | Estimate the demand and supply of face masks precisely | RM |
| 24     | Adjust the existing supply chain management and enhance the supply and distribution system | ER |
| 25     | Beyond capacities of local government due to the surge of the self-quarantined | MR |
| 26     | Apply state-of-the-art technology for monitoring the self-quarantined | RM |
| 27     | Enhanced capacities of local governments for maintaining the self-quarantined | MR |
| 28     | Enhanced local government emergency plans for the self-quarantined | RM |
| 29     | At-risk Korean residents in the infected regions of overseas countries | RM |
| 30     | Return at-risk overseas Koreans to Korea and quarantine them for 14 days in temporary living facilities | MR |
| 31     | Ensured overseas residents’ safety | ER |
| 32     | Increased anxiety of residents by the reduction of social distancing rules | ER |
| 33     | Increased uncertainty and lack of knowledge about the new Infectious Disease | RE |
| 34     | Reduced concern of residents | MR |
| 35     | Transmission by asymptomatic cases and continuing occurrence of cases with unknown infection routes | RM |
| 36     | Large-gathering with infected persons’ participation in activities without social distancing rules | RE |
| 37     | High probability of contact tracing failure | ER |
| 38     | Develop and operate a system for the mandatory keeping of visitor records | RM |
| 39     | Increased risk of exposure of personal information | RM |
| 40     | Prevent the exposure and the abuse of recorded personal information | ER |
| 41     | Achieve social consensus between epidemic risk and political risk due to privacy issues | RM |
| 42     | Secure protection of personal information | MR |
| 43     | Conduct anonymous tests for the visitors, and later for all citizens | MR |
| 44     | Reduced transmission by asymptomatic cases and resolved probability of contact tracing failure | MR |
| 45     | Occurrence of mutant virus | RE |
| 46     | Increased probability of failure of existing countermeasures | ER |
| 47     | Increased economic recession due to prolonged social distancing rules | RM |
| 48     | Cascading negative effects to other societal sectors, such as education and tourism | ER |
| 49     | Issue the highest national crisis alert level | RM |
| 50     | Operate the highest emergency response institution | RM |
| 51     | Diagnose the problem of existing policies, such as 3 T, self-quarantine, social distancing, and enhance the preventive rules | RM |
| 52     | Strengthen contact tracing, testing, and treatment | RM |
| 53     | Adjust social distancing level according to the crisis | RM |
| 54     | Promote preventive rules | RM |
| 55     | Avoid large-scale gathering and sterilize the shelters and event places | RM |
| 56     | Prevented nationwide outbreak and/or terminated pandemic | MR |

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