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Resilience in risk communication networks: Following the 2015 MERS response in South Korea

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This study investigates regional and local governmental agencies resilience in their use of risk communication with other governmental agencies. Analyses are based on the case of South Korea's response to the 2015 outbreak of the Middle East Respiratory Syndrome Coronavirus. Based on a survey of governmental organizations, the study indicates that governmental agencies seek either reciprocal or redundant communication ties with other governmental agencies while they aim to secure crucial information from high-level organizations to tackle the transboundary nature of the infectious disease during the outbreak response. Semi-structured interviews with South Korean officials confirm that subnational governmental agencies rely on the national government and also seek information from other regional and local agencies to improve the resilience in interagency risk communication and to prevent the further transmission of the infectious disease in their local jurisdictions. This study empirically demonstrates how governmental agencies cope with the uncertainty of infectious disease transmission by expanding risk communication channels when hierarchical communication channels and information systems do not meet the needs of outbreak response. The research findings contribute to the understanding of the interactions across organizations in addressing the needs of public health crises that are transboundary in nature and provide important lessons for outbreak responses in South Korea as well as in other countries.

1 | RISK COMMUNICATION IN RESPONSE TO A CATASTROPHIC EVENT

Risk communication is referred to as an action of "exchanging information about health and/or environments between interested parties" (Covello, von Winterfeldt, and Slovic 1986, p. 172). Such information includes the factors of health and environment risk itself and policy decisions for controlling and managing those risks. Due to increasing complexities of risks embedded in modern society (Beck 1992), risk control and management have become interactive and mutual efforts of multiple organizations. Particularly, a response to an extreme event requires joint efforts between the direct interested parties and others regardless of the fact that their information and communication channels are under the usual chain of communication (Doerfel, 2016; Dynes & Quarantelli, 1976; Quarantelli, 1997) . Communication between these organizations enables them to collaboratively assess their common problems, and it is also essential for them to take the required actions in preparing for the emergencies brought on by the extreme event, not to mention for recovery from devastation (Comfort, 2005; Comfort 2007; Ganor and Ben-Lavy 2003; Prezelj, 2015).

With an effective flow of information, organizations involved in an emergency event are better able to coordinate their response efforts as well as meet the response needs of other organizations in their communication network (Comfort, 1999; Kapucu, 2006). Conversely, a lack of communication or the absence of accurate information exchange between disaster response organizations results in a lack of coordination among them (Celik & Corbacioglu, 2010; Eikenberry, Arroyave, & Cooper, 2007; Kapucu & Van Wart, 2006). For instance, during Hurricane Katrina in New Orleans, insufficient communication between the US Federal Emergency Management Agency and other relief organizations created confusion in the coordination of relief efforts to meet the victims' needs immediately (Eikenberry et al., 2007). In contrast, effective interorganizational communication helps organizations survive after a disaster. When nonprofit and business organizations communicated with other related organizations after Hurricane Katrina, the focal organizations were able to gain support from their partner organizations in recovering from devastation (Doerfel, Lai, & Chewning, 2010).

Effective flow of risk information is especially important for response to a contagious virus outbreak. Governmental agencies would be unable to protect their country's residents from such a virus outbreak without securing crucial information about the nature of the infectious disease and the contagion path (Ansell, Boin, & Keller, 2010). High mobility of residents across jurisdictions deepens the interdependence between agencies in vertical and horizontal relationships in such an outbreak response. Even though governmental officials may have an understanding about the nature of the disease, they may not know the accurate path of the disease transmission without relying on information from other public organizations, which may occasionally be in foreign jurisdictions. Thus, governmental agencies have an immediate need to develop communicative resilience to improve interorganizational risk communication and gain essential information about the impending public health or environmental hazards. This, in turn, would enable them to respond better to an outbreak in their regional or local areas. As building a resilient network infrastructure is important for the uninterrupted provision of communication services and data processing for users (Smith et al., 2011), governmental agencies must have the capability to adapt communication actions with other agencies in a virus outbreak situation.

In this sense, this study examines how organizations set up and improve their communitive resilience in response to a contagious virus outbreak. Moreover, it proposes and tests two hypotheses about managerial strategies to improve resilience in interorganizational risk communication. The case used for this study is the Middle East Respiratory Syndrome Coronavirus (MERS) outbreak that occurred in South Korea in 2015. Many South Korean governmental agencies suffered from a lack of risk information regarding the nature of the infectious disease and contagion path when responding to the outbreak. The governmental agencies strived to obtain risk information from other agencies because of the transregional nature of the outbreak. However, they failed to get risk information shared by the national public health authority in the initial response period due to their incomplete provision of up-to-date information. We believe this study will enhance understanding about the manner in which governmental agencies build resilience in interorganizational risk communication during an outbreak response. Current literature highlights the importance of strategic management of emergency response networks (e.g., Choi & Brower, 2006; Demiroz, Kapucu, & Dodson, 2013; Hu, Knox, & Kapucu, 2014; Jung & Song, 2015; Jung, Song, & Feiock, 2017) and interorganizational risk communication in responses to virus outbreaks with a transboundary nature (Ansell et al., 2010). However, the existing research does not provide a systematic understanding about managerial strategies to build a resilient communication network with other organizations during a virus outbreak response. To bridge the gaps in the literature, this study examines several hypotheses to investigate the managerial strategies that governmental agencies can take to build a resilient communication network during an outbreak response.

2 | NETWORKING FOR RISK COMMUNICATION

Existing literature highlights the importance of an overall network structure that represents interactions among organizations during an actual emergency response. The pattern of an emergency management network is not static but a dynamic one, and the actual interaction between the network participants may not be same as what was planned. A public agency that is supposed to lead an emergency response according to a plan might not play a central role in coordinating it during the actual response (Choi & Brower, 2006; Hu et al., 2014; Petrescu-Prahova & Butts, 2008). Because a mass emergency or catastrophic disaster affects the routinized flow of information among emergency response organizations, such organizations face the challenge of being able adapt to the changing conditions (Kapucu & Van Wart, 2006).

Most studies have examined the network position in the organizations' interaction or communication during emergency preparedness and response. Previous studies have also investigated which organizations participated in the emergency response for a specific mass emergency or disaster (e.g., Choi & Brower, 2006; Demiroz et al., 2013; Hu et al., 2014; Jung & Song, 2015; Jung et al., 2017; Petrescu-Prahova & Butts, 2008). The research was useful for informing which organization plays a central role in coordinating emergency preparedness or response efforts. For example, Hu et al. (2014) identified which governmental agencies, nonprofit, and private organizations were involved in the response to the Boston Marathon bombing. Based on an analysis of the emergency operation plan and a content analysis of newspaper reports and other documents, they found that the Boston police agency and American Red Cross played the most central roles in the emergency response.

However, few studies have focused on the risk communication strategies adopted by emergency response organizations in networked relationships to address the needs of a virus outbreak response. Governments and organizations must rely on their counterparts in other countries because of the transboundary nature of infectious disease transmission (Ansell et al., 2010). High mobility has facilitated the transmission of viruses between people who live in various administrative jurisdictions, thereby deepening the interconnectedness of governmental and nongovernmental organizations in an outbreak response. This study examines the manner in which organizations set up and improve their resilience in risk communication in response to a contagious virus outbreak. Furthermore, it proposes and tests two hypotheses about managerial strategies to improve resilience in interorganizational risk communication.

3 | RESILIENCE IN INTERAGENCY RISK COMMUNICATION NETWORK

Resilience is broadly defined as the ability of societal systems, such as country, city or organization, to bounce back from an extreme event (Wildavsky, 1988). As many communities that have experienced extreme events have not smoothly recovered from them, research has moved its focus on resilience instead (Boin, Comfort, & Demchak, 2010). In addition, the issue of reliance has caught the attention of researchers because it has little to do with preparedness and preventive measures for natural and man-made disasters. Reports from the Community & Regional Resilience Institute have constantly highlighted that the ability to bounce back implies the systems' capacity to preserve its primary function from external disturbance; however, maintaining primary function has little to do with being prepared and having in place preventive measures (Rose, 2009). Instead, the concept of resilience lies mainly in the form of "achievement of positive adaptation" after "exposure to threat or stress." (Bakker, Raab, & Milward, 2012; Brunner, 1994; Ireni-Saban, 2012; Quick & Feldman, 2014) In a catastrophic event, resilient communities or organizations not only withstand the negative consequences of disaster and return to their normal states (Aldrich 2012) but also adapt their existing skills and resources to the new conditions (Comfort, 1999, p. 21). Therefore, resilience is considered to be a response system that is tested after a newly developed and developing situation.

Scholars in resilience studies have argued that resilience in a process can be improved through multiple dimensions. For instance, Norris et al. (2008) provided four dimensions of community resilience: economic equity, social capital, information and communication, and community competency. Communities with equitable distribution of resources among members and high levels of social capital (i.e., linkage and sense of community, active information sharing among members, and competency to collaborate together) have a strong ability to bounce back from an extreme event and adapt to the new circumstances. In addition, Bruneau et al. (2003) argued that there are four dimensions of resilience that are applicable to communities and organizations: robustness, redundancy, resourcefulness, and rapidity. Communities or organizations can respond better to an extreme event by improving their ability to withstand a stress without losing their primary functions, ensuring substitutable elements of operation, mobilizing resources to achieve desirable goals, and meeting needs in a timely manner. From a communication perspective, organizations can improve their ability to bounce back from an extreme event and adapt their actions to the devastated circumstances by establishing multiple channels of cooperation and ensuring an overlap in information sources. In other words, redundancy in a risk communication network will secure robustness in the communication network structure, which in turn will highly guarantee that the necessary crucial information is not missed.

Indeed, viewing resilience as a process as proposed by Paton & Hill (2006), principal agencies coordinating emergency response operations have adopted various strategies to maintain the functional relationships embedded in risk communication networks and to meet the needs that emerge from affected communities (Paton & Johnston, 2001). In the case of an emergency, principal organizations in the emergency response system should be able to access the crucial information that describes the nature of the problem accurately to respond to the needs immediately (Comfort, Ko, & Zagorecki, 2004). For instance, to address the response needs of a virus outbreak, governmental organizations should have the essential information to manage uncertainty regarding the nature of the outbreak and the contagion path (Ansell et al., 2010; Olsson 2015). For local agencies, however, the situation may put them in greater uncertainty. While local agencies receive information from regional or national agencies (Park, Barnett, & Kim, 2004; Park, Kim, & Barnett, 2004), the transmitted risk information may be incomplete or may be disseminated with belated information in the first place. Because the higher level governmental organizations also depend on numerous local agencies, the latter would seek to find redundant or reciprocal ties with other agencies to build resilience in their risk communication network so as not to miss critical information.

This, in turn, would prompt emergency response organizations to form an interdependent or cohesive risk communication structure to secure essential information from other response organizations (Jung & Park, 2016). The organizations that seek reliable sources of information tend to use a close-knit structure in communicating timely information. (Uzzi, 1997). A cohesive structure helps organizations to avoid the narrow pursuit of individual interests, enrich relationships through trust, and promote the pooling of resources, cooperation, and adaption to unexpected circumstances. Close-knit relationships mobilize solidarity and provide social and psychological support for low-performing members (Putnam, 2000).

The presence of interdependent risk communication structures is also characterized by close-knit relationships with community organizations that share a strong sense of belongingness with members of the community (Perkins et al. 2002). The close relationships can help forge a bond for the sharing of timely information during an unexpected crisis and a willingness to share responsibilities. Emergency response organizations often establish such linkages to make use of local knowledge and experience and to gain associational benefits. These actions foster trust between organizations and, thus, develop communication strategies to address the impact of a crisis (Pfefferbaum, Reissman, Pfefferbaum, Klomp, & Gurwitch, 2007). In a similar vein, Doerfel et al. (2010) demonstrated how closed-knit communication structures are important for emergency responses. After Hurricane Katrina, private business owners and leaders of nonprofit organizations in New Orleans communicated with other organizations through personal or professional ties, and their own organizations were able to gain resources and support from the other organizations that were critical for adapting to the devastated situations and for organizational survival.

After a catastrophic event occurs, emergency response organizations formulate a reciprocated risk communication structure to take advantage of close-knit relationships, ultimately building resilience in their risk communication network. This is because reciprocal risk communication can facilitate the circulation of timely information through the development of a relationship of trust between two organizations (Kenis & Knoke, 2002). In addition, a redundant communication tie will help organizations obtain better quality of information and respond to dynamic circumstances in a timely manner. An emergency response agency can access the crucial information needed to address public health or environmental risks and adapt to any failure of the main information channel through the redundant tie. Thus, we hypothesize that

> ***H_1***. In responding to a catastrophic event, emergency response organizations maintain a resilient risk communication structure by forging a reciprocal tie with others.

> ***H_2***. In responding to a catastrophic event, emergency response organizations maintain a resilient risk communication structure by forging a redundant tie with others.

4 | BACKGROUND OF THE 2015 SOUTH KOREA MERS OUTBREAK

This study uses the case of South Korea's response to the 2015 MERS outbreak in the country to examine the pattern of its interagency communication network. In the summer of 2015, South Korea suffered from an outbreak of MERS, which is caused by a virus called MERS Coronavirus (CDC, 2015). The virus is transmitted among people through close contact, and it affects respiratory systems that include lungs and breathing tubes. The common symptoms of MERS patients include severe shortness of breath, fever, and cough. Thirty or forty per cent of the patients tend to die. After the disease was first reported in Saudi Arabia in 2012, other cases were identified in nearby countries. The first MERS patient in South Korea was identified on 20 May 2015, when a man aged 76 years visited four hospitals 7 days after his return from the Middle East (Ministry of Health & Welfare 2015a). His symptoms at the fourth hospital were reported to the South Korea Center for Disease Control and Prevention (CDC), the national disease control agency. Upon investigation, the South Korean government isolated the patient's family members and 64 clinicians. The quarantine range was, however, not comprehensive enough to cover all those who had contact with the first patient (the National Assembly Special Committee 2015). This failure of the initial government response led to the transmission of the infectious disease from the untargeted people to other hospital patients and visitors.

The continued transmission of the virus increased the number of MERS-infected patients over time. As of 5 July 2015, the outbreak resulted in the quarantine of around 17,000 people (usually 14 days at home), and 186 cases were confirmed as MERS infection. The MERS outbreak affected three metropolitan regions and five provinces. On 27 July 2015, the national government decided to take follow-up measures based on the consensus of experts that there would be no more cases of MERS infection in the country (the World Health Organization 2015). The outbreak resulted in the death of 36 people, the second highest mortality for MERS in the world (Ministry of Health & Welfare 2015b).

The response to the MERS virus outbreak involved national agencies, regional, and local governments, as well as police and fire agencies. These organizations suffered problems in risk communication. The principal national agency was reluctant to disclose the name of the hospitals visited by the first MERS patient, and only released the information 17 days after the patient was identified (Ministry of Health & Welfare 2015c). After more people had tested positive for the virus, the Ministry of Health and Welfare then disclosed the name of the hospitals that had MERS patients. The government then designated MERS-free hospitals all over the country to respond to the safety concerns of the general public. Growing concern about the transmission of the infectious disease highlighted the formal and informal risk communication among the national and subnational governments.

5 | DATA AND METHODS

5.1 | Data

The data used in this study have been collected by the authors, with one of them listing 169 governmental organizations for this study's survey. These organizations comprise three ministries/national agencies, 10 regional governments/agencies, 50 district/county governments, 58 local police agencies, and 48 local fire agencies. The organizations were selected on the basis of the role they played during the MERS outbreak. The three ministries/national agencies were responsible for coordinating or supporting the MERS outbreak response efforts at the national level. The selected local agencies and subnational governments were responsible for the jurisdictions where MERS patients lived or were identified before they were admitted to hospitals for treatment. Subnational governments are the local police and fire agencies that coordinated the outbreak response, cooperating with regional or local agencies.

The survey was administered and sent to the selected governmental organizations via email during January and February 2016. This was followed by up to 10 reminder calls, made to facilitate their responses. The overall response rate of the survey was 81.7%. A total of 138 organizations responded to the survey, comprising three national organizations, seven regional governments/agencies, 38 district/county governments, 43 local fire agencies, and 47 police agencies. Due to some missing answers for our network survey question items, however, our final data set includes responses only from 130 organizations.

The survey questions aimed to understand the communication pattern among the surveyed organizations. The exact wordings of the questions are (1) "from which organization did your organization receive information regarding MERS (e.g., patient, people under quarantine, hospital, & response) during the outbreak directly?" and

(2) "to which organization did your organization send information regarding MERS (e.g., patient, people under quarantine, hospital, & response) during the outbreak directly?" In other words, the questions were designed to identify their information resources and communicating partners. The answers from each organization were initially recorded on a sheet with a 169 × 169 original matrix but later, a 130 × 130 matrix was used to construct the network data set by excluding respondents who had fully answered all survey questions.

When compiling and coding the survey data, we found mismatches between the sender information and receiver information. For example, a local agency had identified that they had received information from a national agency, but the latter's answer sheet did not identify the former as a receiver of information. In this case, we have noted that the local agencies have received the information from the national agency, which has been considered to be a sender. The rationale for this coding lies in the fact that first, in an emergency situation, organizations at a higher position of a government's hierarchical structure tend to send information as an announcement or notice rather than as direct communication; it is often up to the organizations lower in the hierarchy to decide whether the information received is regarded as useful. Second, those mismatches fit into the purpose of this study, which is to reveal how organizations obtain information from multiple sources in a mass emergency by maintaining their communication network. Among these multiple sources, information from some organizations would weigh more than others even though it may not be in the form of direct communication. Thus, it is more appropriate to consider it as a reflection of actual organizational recognition rather than deficiencies of the data.

Additionally, this study uses interviews to provide contextual explanations for the quantitative findings. With the support of the Quick Response Grant Program administered by the Natural Hazard Center at the University of Colorado in Boulder, one of the paper's authors was able to visit South Korea in January 2016 to collect qualitative information about the virus break response. The investigator conducted face-to-face, semi-structured interviews with 11 public officials whose agencies had played critical roles in coordinating the national, regional, and local response to the outbreak: four ministries, two national agencies, and five subnational governments. The interviewees were responsible for the outbreak response by their respective agencies. The investigator selected the interviewees by considering the roles of their agencies in the outbreak response as well as their availability for an interview. Eight interviewees were introduced by an acquaintance of public employees who were familiar with the investigator, while three interviewees were identified by the investigator. The investigator conducted the interviews in Korean, with each interview lasting between 30 and 60 min.

As most of the structured interview questions primarily aimed to understand a broader context of the outbreak response, we focused on the following questions to help us elaborate the research question: (1) Which organizations are important sources of information related to the outbreak response? (2) Please rate how much did the organization trust the sources you mentioned; (3) If there was a difference in the organization's perception of trust regarding the sources, why was this so? and (4) What challenges did your organization face in addressing the needs of the MERS outbreak? Although more interviews may have generated a more comprehensive understanding of the contexts of interagency risk communication, limitations of time, and budget did not allow the investigator to travel to interview public officials of governmental agencies that were geographically dispersed. Despite the small number of interviews, the results will help enhance the contextual understanding of how governmental agencies improve resilience in risk communication during a virus outbreak response. The interview results are presented in the discussion section with the quantitative findings.

5.2 | Methods

Exponential Random Graph Modeling (ERGM) method is the main analysis method employed to analyse the pattern of the interagency risk communication network. ERGM allows researchers to specify a model of network generation in a flexible manner and accommodate a wide range of theories (Desmarais & Cranmer, 2012). ERGM models recognize complex dependencies among network ties, which violate the assumption of standard regression models, in predicting the formation of these ties (Robins, Lewis, & Wang, 2012). The modelling procedure will help examine the effects of dependencies among network ties and of attributes on the formation of interagency communication ties. The ERGM analysis is then conducted with R package statnet, an ERGM modelling package (Handcock et al. 2016). Our model converged in three iterations, and the log-likelihood iteration improved through three iterations. We checked for the model's goodness of fit by simulating a large number of networks based on the estimated coefficients (see Appendix Figure A1).

5.3 | Measurements

5.3.1 | Network structure

Reciprocity

This term measures whether the two actors receive and send information to each other (Figure 1a). The reciprocated relationship helps the actors develop a strong commitment to each other.

Geometrically weighted edgewise shared partners (GWESP)

The term is used to determine the amount of closure (redundant ties) that occurs in the interagency risk communication network. GWESP accounts for triangles to form ties with many shared partners as an extension of transitivity, which helps ensure the reliability of information exchanged among actors and build trust (Berardo & Scholz, 2010; Carpenter, Esterling, & Lazer, 2004) (Figure 1b).

Edge

The edge term represents the formation of an additional communication tie. We used the edge term as a control variable to catch the propensity for formation of a communication tie.

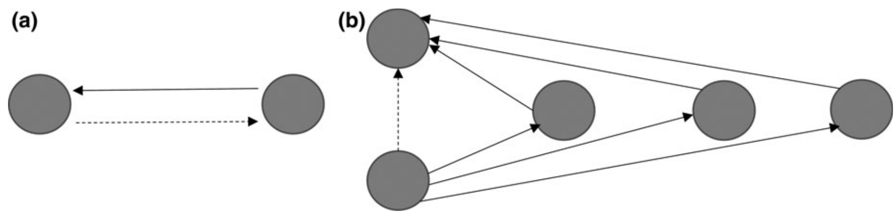

FIGURE 1 Hypothesized network structures. (a) Reciprocity, (b) Geometrically weighted edgewise shared partners

5.3.2 | Attributes of organizations

Characteristics of organization

We measured attribute effects based on whether an organization is a national agency, local agency or subnational organization. In addition, we classified a network tie as one that is received from an organization in the same region. These variables are introduced to discover whether a higher position in a governmental hierarchy has any effect on network formation. As national ministries/agencies and regional governments/agencies have coordinated the outbreak response at national and regional levels, we believe they can be differentiated on the basis of the number of network ties.

6 | ANALYSIS RESULTS

6.1 | Descriptive statistics of network

Table 1 describes the overall characteristics of the network that we investigated. Based on the summary measures, the network seems to be quite centralized in its connections. The degree centralization is 39% (0.39), while the density of the network is 3% (0.03). This means that the connections between organizations have clustered around some of those located in the centre of the network. As our data set is the emergency response organizations whose organizational structure is hierarchical in the first place, it is natural to anticipate that the networking pattern would align with the organizational structure and that fairly little connection exists between organizations on the same level in the hierarchy. Indeed, the two E-I indexes—which measure whether or not network ties are connected with the nodes in a same attribute group category in Table 1—indicate that the network ties are mostly connected with the network nodes in different attribute groups. Considering this characteristic, we conducted the ERGM analysis.

6.2 | EGRM results

We tested our two hypotheses regarding the structural effects of reciprocity and GWESP on communication ties. We found that the EGRM result supports our first hypothesis on reciprocal ties between emergency response organizations. The coefficient of reciprocity is 3.06 and statistically significant. Emergency response organizations are 21.3 times more likely to form a reverse tie if there is an existing tie between them, holding another factors constant. This statistical likelihood compares the probability that the tie relation would be a random phenomenon with the actual occurrence. Thus, reciprocity is rigorously pursued effort structuring the network relation (Table 2).

The finding indicates that the emergency response organizations have a reciprocal exchange of information when responding to the virus outbreak. Thus, during the outbreak, if there is a communication tie between organizations, they would have mutually cooperated by exchanging information between themselves. Note that this relationship holds true even after controlling for attribute effects based on the organizations' position in the organizational hierarchy.

Compared with local governments and agencies, the ties with national agencies and regional agencies are, respectively, 4.54 and 4.33 times more likely to be present in the network (H2). Again, the occurrences of the network configurations are compared with random graph with the same number of actors and ties. The finding

TABLE 1 Summary statistics of communication network

Index	Value
Number of organizations in main component	130
Collaborators per organization (average degree)	3.22
Clustering coefficient	.36
Distance-based cohesion	.39
Density	.03
Degree centralization	.39
Outbound E-I Index (to lower hierarchy)	.89
Inbound E-I Index (to higher hierarchy)	.83

TABLE 2 EGRM results: communication tie distribution

Formation of communication ties	Estimated coefficient	Standard error
Network effects		
Reciprocity	3.061***	.197
Transitivity (GWESP, Fixed at .5)	.422***	.074
Attribute effects		
National agency	1.513***	.143
Regional agency	1.466***	.120
Controls		
Same region	.957***	.101
Edge	−5.427***	.102
AIC/BIC	2661/2707	

***$p<.001$.

indicates that local emergency response organizations communicate with regional or national agencies to access the overall contagion path of the infectious disease efficiently. Organizations in the same regions are also 2.60 times more likely than those in different regions to exchange information.

In addition to the attribute effect and reciprocal ties, more importantly, the EGRM result supports GWESP (shared partner) relation in the network, which is our third hypothesis. Emergency response organizations with shared partners are 1.53 times more likely than pure chance to have direct ties, holding other factors constant. The probability of the relationship is compared with random graph with the same number of actors and ties. The finding indicates that emergency response agencies tend to have multiple transitive closed ties. As shown in Figure 1, the shape of GWESP is influenced by the existence of many intermediary or indirect organizations that send information between an organization that directly sends information and an organization that receives information. We believe that this is one of the critical network connections with regard to the flow of timely and reliable information in the emergency response and communication system.

Nevertheless, the EGRM result has a limitation in terms of informing about the direction of this transitive closure structure of the communication network. Specifically, it is unable to describe whether the information in the GWESP structure flows from national to local agencies or vice versa. Thus, we have further examined ties between organizational groups. As we have indicated earlier in the E-I index, ties within the communication network are mostly connected to organizations in other group categories. This provides a hint that the density of the network within and between organizational groups will identify the information flow and allow a further understanding of the direction of the GWESP structure. This implies that the density of the network in terms of organizational groups will show whether the direction of information flow with the GWESP tends to stream between higher level governments and lower level governmental agencies or between same levels of governments. Table 3 presents the densities of the network in line with organizational attribute categories. The lower half of the matrix indicates inbound communication flows from organizations in lower hierarchy positions to those in higher hierarchy positions, whereas the upper half indicates outbound communication flows from organizations in higher hierarchy positions to those in lower hierarchy ones.

TABLE 3 Structure of connections: densities

Level	Type of organizations	[1]	[2]	[3]	[4]	[5]
National	Ministry/National Agency	.667[a]	**.722**	**.297**	**.093**	**.122**
Regional	Metropolitan/Provincial Gov't & Agency	.389	**.133**	.153	**.085**	**.122**
Local	Local Govt./Public Health Agency	**.288**	.158	**.014**	.025	.018
	Police Agency	.023	**.062**	.013	.001	.003
	Fire Agency	.049	**.106**	.008	.001	.001

Note: Inbound and outbound densities differ in here; [a]indicates outbound from higher to lower hierarchy.

According to Table 3, the GWESP structure tends to result from information flow between governmental agencies that are not in direct hierarchical relationships. The densities in the upper half of Table 3 indicate that the density between national and local agencies is similar to that between regional and local agencies. This means that these local agencies can obtain information through the communication channel directly from the regional and national agencies. As manpower on the ground, local agencies and their mobilization was key to preventing further dissemination of the virus. Thus, they would have received information through all possible channels. Meanwhile, local police and fire agencies have mainly sent information to regional governments. The lower half of Table 3 indicates that the densities of information flow from local agencies to regional governments are more than double for local fire agencies and triple for local police agencies. We believe that enquires or reports from the local agencies tend to be made within the direct reach of actual operation.

Table 3 also highlights the flow of information across administrative jurisdictions. Interjurisdictional communication is important for addressing the transboundary nature of infectious disease transmission, although the horizontal information sharing between governmental agencies occurred less frequently than hierarchical communication. Regional governments exchange information with other regional governments that have an overall understanding about the virus's contagion path in their respective regions. The low-level governments obtained information from neighbouring as well as other local governments that have hospitals with many MERS infection cases. Figure 2 summarizes the findings about information flow between governments' agencies.

7 | DISCUSSION AND CONCLUSION

The analytical findings confirm the hypotheses that governmental agencies form reciprocal or redundant communication ties during an outbreak response. The findings suggest that governmental agencies seek to have reciprocal or redundant ties with other governmental agencies to build resilience in interorganizational risk communication. This is to enable them to tackle the transboundary nature of outbreak response although governmental agencies obtain information from high-level ones. Regional governments or local public health agencies needed to communicate with national agencies as well as subnational governments to identify the contagion path when the national government provides limited information. Local police and fire agencies strived to obtain information from regional as well as national agencies to better understand the nature of the infectious disease, to monitor residents who had contact with virus-infected patients, and to transport high-risk patients to hospitals.

The interview results provide a contextual understanding of the patterns of interagency risk communication during the outbreak. The results support the notion that governmental agencies rely on other

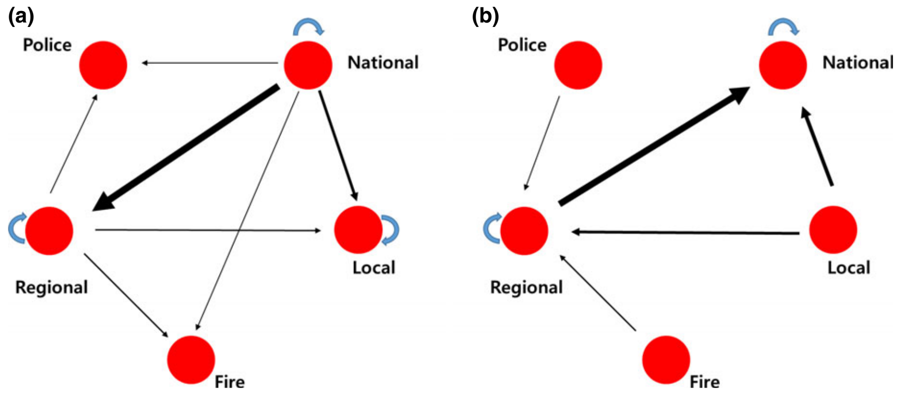

FIGURE 2 Flow of risk information. (a) Receiving risk information (b) Sending risk information [Colour figure can be viewed at wileyonlinelibrary.com]

governments as important information sources for the outbreak response. These agencies seemed to rely more on official government information than on media reports although they obtained their information from both governmental as well as nongovernmental sources, such as the media and hospitals. Most agencies reported that government information was the primary source for recognizing the outbreak problem and taking response actions. The governmental agencies' reliance on other governmental agencies as sources of risk information became apparent when the interviewees were asked to rate the trustworthiness of information sources. Due to time constraints, only six interviewees were asked to rate trustworthiness on a scale between 1 and 10 points. On average, the interviewees rated other governmental agencies 3.6 points higher than mass media.

One of the interviews provided the following reasons:

> *Interviewee A: My agency mainly relied on other governmental agencies as sources of risk information while we used media coverage to check the public perception of the agency response. Mass media tends to exaggerate the truth while reporting.*

Interviews with national and subnational public officials also confirm our analytical findings that subnational governmental agencies sought risk information from the responsible national ministry as well as other sources, such as subnational governments. The national ministry/agency officials showed dissatisfaction with their communication with the responsible ministry, and subnational governments especially criticized the national government's low levels of transparency about the path of the infectious disease transmission. Interviewees reported as follows:

> *Interviewee B: My agency sought risk information from the public health ministry, but the responsible manager of the ministry did not pick up the phones during the two weeks after the first case had been confirmed.*

> *Interviewee C: My agency had difficulties in identifying the contagion path because the national public health authority was passive in sharing information about MERS patients and hospitals exposed to the virus infection. My agency missed an important opportunity to prevent the infectious disease transmission in my jurisdiction early because of the low levels of transparency.*

Incomplete operation of the information system may foster the formation of communication ties. The interviewees indicated that incomplete operation of the public health information system hindered the effective flow of risk information among public health agencies. Although the Public Health Information System, the South Korea public health information system, was supposed to facilitate the exchange of information among public health agencies about high-risk patients and people who had contact with MERS patients, the system did not fulfil this promise during the outbreak response. One of the interviewees reported a problem with the national public health information system as follows:

> *Official D: My agency experienced several problems in updating information regarding suspected cases. The system does not allow public health officials to input and revise information about epidemic investigation easily. The system also does not have a back-up function. Whenever new risk information was added, the existing information disappeared.*

This study provides key implications for both theory and practice in interorganizational risk communication in response to a virus outbreak. Further, it advances the understanding of how governmental organizations communicate information when responding to a public health emergency. While literature stresses strategic management of interorganizational networks for emergency response (e.g., Choi & Brower, 2006; Demiroz et al., 2013; Hu et al., 2014) and intergovernmental communication in response to a virus outbreak (Ansell et al., 2010), there is a lack of systematic understanding about what communication strategies emergency response organizations can take in response to a public health emergency. As illustrated in the results section, this study suggests that a systematic examination of the interactions between public organizations during the MERS response can contribute to the understanding of interorganizational communication in responding to the outbreak of an infectious disease, for example Zika and Ebola viruses that may have a broad impact on South Korea as well as other countries.

Interorganizational or intergovernmental risk management is also critical for the United States in responding to such an outbreak. A virus outbreak is the problem not only of one jurisdiction or region but also of multiple jurisdictions and regions. The recent outbreaks of the Ebola and Zika viruses demonstrate the transboundary nature of infectious disease transmission. The man aged 45 years who arrived in Dallas from Liberia transmitted the Ebola virus to one of the nurses who directly cared for him. Even though Dallas was not the original location of the virus outbreak, the city was nonetheless affected by it (Centers for Disease Control and Prevention, 2016). As of 9 March 2016, 194 cases of Zika virus infection has been associated with international travel while 173 cases were locally acquired. If those people who had come into close contact with these cases travelled across the United States, the virus would spread out of the states, regions, and local jurisdictions (Centers for Disease Control and Prevention, 2016).

The transboundary nature of infectious disease transmission highlights the importance of hierarchical communication among different levels of governments, horizontal communication and cooperation between same or different types of agencies, and information systems.

7.1 | Intergovernmental communication

This research points to advantages when all levels of governments and sectors in the United States cooperate in sharing information regarding the transmission of an infectious disease. Specifically, communication between local health agencies, state governments and the US CDC can improve the identification of infectious disease contagion paths. In addition, in metropolitan areas where residents travel frequently across local jurisdictions, local governments must strive to communicate with each other regarding disease transmission to collectively improve the ability of the communities to adapt to a virus outbreak.

7.2 | Information system

National and subnational governments could improve potential outbreaks with the use of disease surveillance information systems. For instance, the U.S. CDC operates the National Notifiable Diseases Surveillance System (NNDSS) that facilitates the exchange of public health information between public health agencies (CDC, 2015). The system provides information standards for states so that the subnational governments share information with the CDC and other health agencies. The more public health agencies rely on it, the better the system functions. The U.S. CDC may need to test whether the NNDSS is effective in sharing information among public health agencies and the national disease control agency regarding the contagion path of any infectious disease.

This study has limitations in understanding interorganizational risk communication for a virus outbreak response and proposes areas for future research. First, the study does not provide an empirical understanding of the strategies' effectiveness. Although this study helps in understanding what communication strategies public organizations can take in responding to a virus outbreak, the findings do not indicate which strategy is more beneficial for improving outbreak response. Future studies may examine the effects of interagency communication strategies on the outcomes of the outbreak response, such as understanding the contagion path or interorganizational collaboration effectiveness. Such a study may help governmental agencies identify the most beneficial communication strategies to access and transmit crucial information. Future studies are recommended to test the applicability of this study's findings to public agencies in the United States.

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APPENDIX

GOODNESS OF FIT

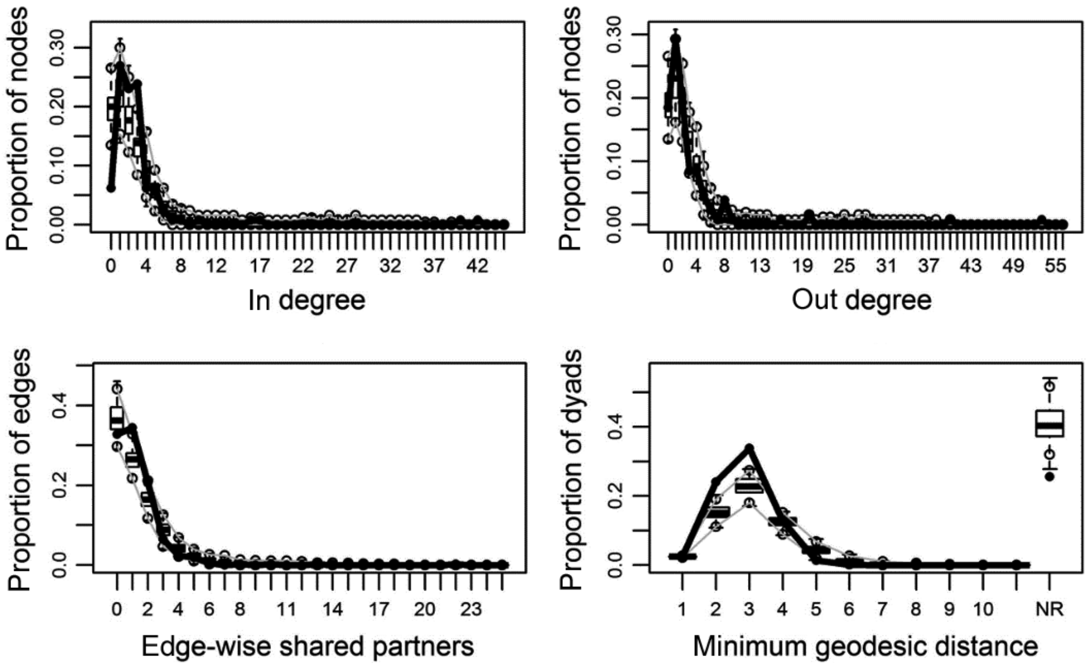

FIGURE A1 Presents four graphs for model diagnostics that compare the estimated network statistics to a large number of simulated network statistics. The box plot and the dark lines represent each statistics of the simulated networks and the observed networks. The first and the second graphs on the top indicate the proportion of nodes that have one or more receiving or sending ties. The third graph shows the proportion of ties between two actors connected jointly to one or more actors, and the fourth graph indicates the proportion of dyads that are connected by a certain length. The graphs show that estimated network statistics of degree and edge-wise shared partners are similar to the most simulated network statistics, while the estimated network statistics of the minimum geodesic distance are less similar to the simulated network statistics. Of 112 network statistics, only 13 show poor fit. Overall, the results indicate that the model generates networks with similar characteristics to the observed network