Epidemic Response Coordination Networks in "Living Documents"

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Abstract

Response plans developed thoroughly are suggestive of a successful action, but there is a gap in the literature with respect to the way concerted efforts among organizations are planned and change during crises. Using organizational network data extracted from the South Korean government's MERS response manuals, we examined the changes in the response coordination network planned during the epidemic's distinct stages. The greatest difference in predicting tie formation was found in the networks planned before the event and revised during the outbreak. Local and governmental actors tend to form more ties consistently in the revised manuals. Two actors that are intended to transfer medical and/or personnel resources tend to form more ties across all stages. These findings suggest that transferring material and/or human resources are key activities in the epidemic response and planners tend to increase the connection of local and governmental actors over time.

1. Introduction

The Middle East Respiratory Syndrome Coronavirus (MERS-CoV; MERS) is a global pandemic threat that attacked Saudi Arabia first in September 2012. As of May 15, 2019, 2,374 cases were confirmed in the laboratory and 823 deaths have occurred in 27 countries [32]. On May 20, 2015, South Korea reported its first confirmed MERS-CoV case, and the outbreak ended with 38 deaths, 186 confirmed, and 16,752 suspected cases [16]. Until now, South Korea remains the country with the second largest number of confirmed MERS-CoV cases after Saudi Arabia [32].

Because MERS-CoV is not transmitted socially, in that the infection occurs primarily within a closed environment, such as the hospital, it has been announced that there is no community-acquired case [32]. Therefore, the widespread outbreak and the high mortality in the country are attributed primarily to the inadequate response and policy failures rather than biological factors. Follow-up studies generally have agreed on the ineffectiveness of the response by the government and the country in general and expressed concerns about their epidemic response capacity [17] [18] [7] [19].

The country's health authorities, for example, Korea Centers for Disease Control and Prevention (KCDC) and the Ministry of Health and Welfare (MOHW), had been aware of the MERS-CoV outbreak since 2012, and prepared the MERS-CoV specific response manual in July 2014 [21]. However, the government's preparation for the MERS response does not necessarily mean that stakeholders and the public were aware of such a manual or ready to implement (or capable of implementing) the response plans stated in it. Further, the manual was updated multiple times before and during the outbreak (eight times by the end of 2015). The response failure is more troubling given the health authority's multiple revisions (i.e., efforts to improve response coordination by adapting to the evolving situation).

To understand the way the Korean government's efforts ended with unwanted outcomes, one must ask how the efforts to coordinate key stakeholder organizations were planned as well as implemented [20]. While limited, this study analyzes planned coordination networks among key stakeholder organizations in the nine versions of the MERS response manual as the epidemic progressed. This study contributes to the emergency management literature by addressing the lack of empirical studies on the way epidemic response plans are designed and revised.

2. Emergency response plans

2.1. Emergency planning and written plans

The emergency management literature has noted distinctions between emergency planning and written plans. Perry and Lindell differentiated the planning process from written plans, suggesting that planning is an on-going process or activity, including plan-making,

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training, and exercises [27]. In contrast, a written plan is a snapshot of the planning process at a specific time, but it includes procedural documents, checklists, extended plans, and principles learned in the planning process. Written plans are "living documents" embodied in the planning process that should be revised and changed as the crisis proceeds.

Plans, in general, are bureaucratic products that describe formally what society expects of stakeholder organizations and what organizations expect of themselves [4] [5]. Brown and Eriksson suggested that unrealistic plans with a formal expectation alone may lead directly or indirectly to response failures, and thus, emergency management plans need to be written in a more realistic form that reflects the spectrum of threats and organizational capabilities' inadequacy [4]. However, lengthy, detailed, and threat-specific plans are costly (time-consuming and laborious) to maintain because they require constant revision to avoid the risk of irrelevance [27]. Previous studies have revealed that planners' uniqueness at the individual level (i.e., their political power, capability, and dedication in making plans for an emergency [1] [12] [11]), and bureaucratic realities on the organizational level [4], affect the development of an ideal emergency response plan.

Nevertheless, response plans are likely to include two crucial pieces of information, first, which tasks are prioritized and need to be performed in a given crisis context. For example, the U.S. Centers for Disease Control and Prevention (CDC)'s public health emergency response guide specifies functions and tasks during different phases [6]. As an example, activities in the immediate response include assessing the situation; contacting key health personnel; developing initial health response objectives; establishing an action plan; involving public health participation in the emergency operation center; ensuring that the health and safety plan is established, reviewed, and followed; establishing communications with key health and medical organizations, and so forth. Second, the plans also may include the way to coordinate or collaborate with other stakeholder organizations and individuals during the crisis. However, response plans only are blueprints, in that they do not, or cannot necessarily specify all partners or stakeholders in detail [5]. They are more likely to define only the key actors and their relations in a general way. These key stakeholders and their relations constitute the planned response coordination networks.

Lack of coordination among stakeholders has been perceived as the greatest weakness and the greatest source of difficulties in emergency response [10]. Understanding the changes in planned coordination networks in the domain of emergency management is particularly important given an emergency response's inherently collaborative nature [9]. Because of the difficulty acquiring appropriate data and inferential techniques, little research has been conducted on the network changes in emergency management [28]. In this paper, we use the response manual dataset Kim, Ku, and Oh collected and analyzed [20]. However, unlike Kim and her colleagues, we examine the critical components of tie formation in the network planned by examining particular types of actors and activities during different stages of the epidemic.

2.2. Predicting planned coordination networks

Which actors are intended to play a significant role and also coordinate most with other actors in epidemic response plans? In several countries (e.g., U.S., Canada, and South Korea), a nation's public health system addresses public health emergencies [21] [22], which implies that all levels of government (local, provincial, and national) are involved in the response. However, before the outbreak, uncertainty about the likelihood that a disease will occur in a country is high. Although not always, infectious diseases can be introduced from the outside through a human or animal vector. Therefore, a major effort in response plans is to establish quarantines in airports and harbors where people enter from outside the country. Further, suspected cases that enter the country or are infected within the country are most likely to visit a local hospital, and the hospital or local health clinic that the suspected case visits is required to report the case to the country's health authority immediately. This situation demands local first-response actors, such as local quarantine stations, health clinics, and hospitals, to coordinate their response to suspected cases because they are on the frontline in the fight against the disease. Local actors' importance may not change during the outbreak because they remain the first line of defense in the response and perform crucial tasks such as surveillance and patient management.

H1: A local actor is more likely to establish a connection with other actors than its counterparts at higher ranks (i.e., national, provincial).

As any emergency tends to cross jurisdictional and departmental boundaries because of its geographic scope and broad range of consequences [14] [15] [28], it is reasonable to assume that the responding actor's sector is an important attribute to examine in its participation in the response. That is, emergency response involves diverse agencies in multiple sectors (i.e., governmental or non-governmental sectors, including the private—i.e., airlines, medical waste treatment companies—or the non-profit sectors—i.e., medical professional and academic associations). Previous studies have noted that voluntary civil society organizations also participate in the response, for example, non-profit organizations in the local community [23]. Considering the government's public responsiveness and major duty in emergency response, however, it is reasonable to assume that governmental actors are required to play a more important role during the response, particularly in such public health emergencies as infectious disease outbreaks.

H2: A governmental actor is more likely to establish a connection with other actors than are non-governmental actors.

The key stakeholders may change as the crisis type varies [8]. For example, in a wildfire or hurricane crisis, we may expect fire departments to play a leading role because of their expertise in managing such disasters [26]. In attacks people perpetrate, such as 9-11, the police department is supposed to make a significant contribution. It is reasonable to assume that health actors, such as hospitals, medical research centers, and the government's health department, will play the leading roles in response to an infectious disease outbreak. Similarly, as the major duty of non-health actors, such as fire departments, is saving lives and extinguishing fires, they are less likely to be prioritized in a health agency manual. Therefore, it is reasonable to assume that health actors will be intended to be the first responders in the case of infectious diseases, and to establish connections with others than will non-health actors.

H3: Health actors are more likely to establish connections with other actors than are non-health actors.

The four crucial response activities in public health emergencies are surveillance, patient management, epidemiological investigation, and laboratory testing [31]. Surveillance and patient management are related to recognizing and reporting suspected cases to health authorities promptly, as well as managing confirmed cases and their close contacts [31]. Once a suspected or confirmed case is reported, public health agencies perform epidemiological investigation to identify the disease's cause and consequences at the locations where the cases are identified, such as hospitals. Laboratory testing is necessary to identify the pathogen that causes the disease or diagnose suspected cases, which rely on protective equipment and facilities. Therefore, we assume that the activities related to requesting or providing such medical equipment as screening tools and protective equipment, and human resources, such as epidemiologists and disease professionals, were most likely to be included in the response manuals.

Homophily hypotheses can be used to examine such transfer activities. The homophily effect refers to reciprocal ties' influence in predicting tie formation, which can result from two mechanisms: 1) two agencies that are assigned to conduct key activities, such as exchanging medical and/or human resources, and 2) two agencies that are not intended to conduct key activities, but other activities instead. Because key activities are more important in the epidemic response, we do not expect that the second mechanism contributes to tie formation. Thus, we focused on the first mechanism and differentiated the homophily effect and proposed *H4* and *H5*.

H4: Two agencies, both of which are intended to transfer materials, are more likely to form a tie.

H5: Two agencies, both of which are intended to transfer human resources, are more likely to form a tie.

When responding to a public health emergency, stakeholders' appropriate roles and responsibilities in all phases must be assigned in advance [3]. As planners acquire knowledge about the disease outbreak, they are likely to revise the written plans to respond to the changing situation. Regardless of the activities included in response plans and the way they are specified, plans in an action field have inherent limitations in their ability to guide an emergency response, and their usefulness has long been debated [5] [27] [30]. By examining the actors, activities, and coordination plans in the written documents, we can obtain a basic understanding of what priorities the government set during the emergency and which agencies were intended to act in the critical and supportive tasks.

3. Data and methods

3.1. Data

KCDC prepared the first MERS-CoV response manual in July 2014 and revised it eight times before the epidemic ended on December 23, 2015 [21] [22]. The manual's nine versions were obtained when they became available online on the Korean government's MERS-CoV website. The stages' division of the epidemic is based on the way the Korean government distinguished the epidemic's progress. Table 1 below shows the MERS-CoV epidemic's stages and the month each version was published.

Table 1. Response manual version list

Stage	Versions

Before (before May 20, 2015)	• ver. 1: July 2014 • ver. 2: December 2014
Early (May 20, 2015– June 8, 2015)	• ver. 3-1: May 2015 • ver. 3-2: June 2015
Peak (June 9, 2015– July 27, 2015)	• ver. 3-3: June 2015 • ver. 3-3-1: June 2015 • ver. 3-3-2: June 2015
Waning (July 28, 2015– December 23, 2015)	• ver. 3-4: July 2015 • ver. 3-5: August 2015

The author of the paper and a graduate student, both of whom are fluent in Korean, analyzed the response manuals' content and collected the planned coordination networks among the key actors in the manuals.

3.2. Response coordination networks

The response manuals were designed to direct coordinated efforts among key stakeholder organizations in the four critical tasks during the disease outbreak—reporting suspected cases, laboratory testing, epidemiological investigation, and patient management [20] [21] [22]. These tasks involve transferring information, specimens, equipment, human resources, or patients between organizations because different organizations possess different resources, skills, and knowledge. The manual also listed other supporting activities in addition to the four critical tasks, and most of the critical and supportive tasks were required to be performed through direct or indirect coordinated actions with other organizations.

The manual defined actors in two different ways: individual organizations and collectives (groups of organizations; i.e., local fire stations) because the location of an outbreak is uncertain until it actually occurs. Central government departments are easy to identify, but organizations at the local level or in other sectors (e.g., airlines) are difficult to list in the response manual. To be consistent with actors in our analysis, we use groups of organizations (i.e., collectives) as network actors. To do so, individual organizations and groups of organizations were grouped based on their scope of service (national, provincial, or local), function/specialty (e.g., police, fire, health), as well as whether they are governmental or non-governmental organizations. We were able to identify 16 planned actors. Table 2 summarizes the list of actors in the manual.

Table 2. Actor list

ID	Actors
A(HA)	Academic Associations (Medical)
A(MP)	Professional Associations (Medical)
C(MW)	Medical Waste Treatment Companies
C(TP)	Airlines or Ships
H	Hospitals
HD	Designated Hospitals
LFS	Local Fire Stations
LG	Local Governments
LHC	Local Health Clinics
LPS	Local Police Stations
LQS	Local Quarantine Stations
NHD	National Health Departments
NPE(TP)	National Public Enterprises
NSD	Other Central Government Departments
PG	Provincial Governments
PHR	Provincial Health and Environmental Research Institutes

Note that in Table 2, IDs with an H refer to health actors, while those without an H are non-health actors. IDs with an N refer to national level actors, those with a P to provincial level actors, and those with an L to local level actors. In addition, A(HA) and A(MP) are national, non-governmental, and health related, while C(MW) and C(TP) are national, non-governmental, and non-health-related actors.

3.3. Exponential random graph models

Exponential random graph models (ERGMs) are tie-based statistical models used to understand social structures. ERGMs are based on the idea that a larger network can be analyzed by studying the presence of smaller network configurations [25]. The network configurations (or smaller constituent parts) provide mathematical explanations for the way the ties might be present in a network [25]. For example, the homophily configuration is a local structure in which two actors with the same attributes (e.g., conduct the same task) tend to form a reciprocal tie. ERGMs give each configuration a parameter estimate and a standard error, whereby we may: 1) infer whether each parameter increases or decreases the likelihood of tie formation in the network by looking at the sign of the estimate (positive or negative), and 2) assess the results' statistical significance by comparing the difference in the absolute value of the standard error and estimate.

ERGMs equation describes the probability distribution for a graph with n nodes and l configurations, which can be written as follows:

$$Pr(X = x|\theta) \equiv \frac{1}{k(\theta)} exp\{\theta_1 z_1(x) + \theta_2 z_2(x) + \cdots + \theta_l z_l(x)\}$$

in which $Pr(X = x|\theta)$ is the probability distribution of the network given all of the smaller configurations described in the equation; $\frac{1}{k(\theta)}$ is the normalizing constant that ensures the sum of the probability remains within 0 to 1; θ_l is the coefficient of the network statistics of interest, and $z_k(x)$ is the counts of configurations that include statistics k .

We included four configurations related to our hypotheses. For the actor/node-level, we focused on three attributes: the scope of service, government level, and specialty. The scope of service refers to the level (i.e., local, provincial, or national) that an agency can control or influence, with which we can examine the way an actor's scope of service influences the likelihood of forming a tie. The government refers to the sector to which an actor belongs. Whether the actor is a government agency will affect the probability that it forms a tie with another actor. Specialty refers to an actor's major responsibility or function in the response.

Dyad-level predictors were used when we hypothesized that a particular characteristic in a dyad affects the probability of observing a tie in the network. For this study, the dyadic attributes are the same activities two actors perform (e.g., both are planned to report a suspected case or send a specimen). We supposed that coordination activities of transferring human resources and/or materials contribute substantially to the network density. Table 3 presents the variables and values assigned to the attributes.

Table 3. Variables

Level	Predictors	Values
Node-level	Scope	0 Local 1 Provincial 2 National
	Government	0 Non-government 1 Government
	Specialty	0 Non-health 1 Health
Dyad-level	Transferring material	0 No 1Yes
	Transferring people	0 No 1 Yes

For each stage in the network, we began by building a null model with the same number of edges and nodes as the planned response network. The null models were used as a baseline to judge the degree to which subsequent models improved. The probability of observing a tie in the estimated networks can be calculated by taking the logistic transformation of the edge parameters added in the subsequent models.

Once the null models were obtained, the simulated models were built by adding node- and dyadic-level predictors to the null models. In particular, dyadic attributes allowed us to test the homophily hypotheses (*H4* and *H5*). We compared these models based on Akaike Information Criterion (AIC) and Goodness of Fit (GoF) values and chose the best fit models to interpret the importance of the configurations of interest.

4. Results

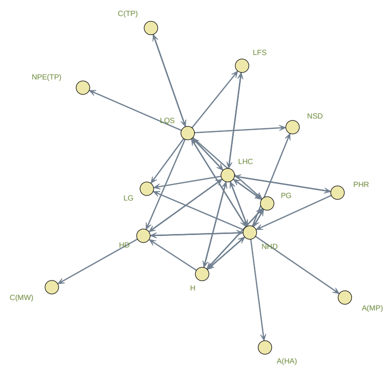
4.1. Network characteristics

Table 4 presents the planned response network's characteristics during the epidemic's different stages observed from the response manuals. Of 16 actors, 15 were planned to coordinate in the manual before the outbreak. The number of connected actors reduced in the subsequent response manuals, such that 13 were found to be connected in the waning stage of the crisis. Each network was fairly dense, and the density increased over stages, which led to the interesting result that as the number of connected actors and the total connections decreased, the network density increased. The average clustering coefficients were between 0.44 and 0.50, indicating that there were some clustering effects in each network.

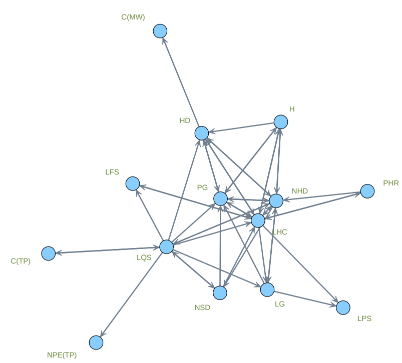
Table 4. Network measures

	Before *(s0)*	**Early** *(s1)*	**Peak** *(s2)*	**Waning** *(s3)*
Nodes	15	15	14	13
Ties	110	118	135	111
Avg. degree	2.67	2.87	3.50	3.08
Density	0.52	0.56	0.73	0.71
Avg. clustering coefficient (cc)	0.45	0.44	0.5	0.5

Figure 1 includes the networks designed before (*s0*) and during the peak (*s*2) of the outbreak for illustration purposes. Before the outbreak, the planners conceived that local actors, such as LHC and LQS together with NHD, would be at the center of the response coordination network (Figure 1(a)). However, as the planners acquired more knowledge of the crisis and the crisis became more severe, LHC remained at the center, but NHD and PG's roles appeared to be enhanced. NHD, PG, and LHC's positions became more apparent at the peak in Figure 1(b). With some changes, the structure and central actors remained somewhat consistent over time.



(a) Planned before the outbreak (*s0*)



(b) Changed at the peak (*s2*)

Figure 1. Response networks

4.2. Coordination networks during different stages

4.2.1. Overall examination of all stages. In Table 6, we examined our hypothesized model by adding node- and dyad-level attributes to the null model (Table 5). The results showed several interesting points. First, the AIC values of the estimated model during each stage decreased considerably compared to the null model, indicating the selected parameters used in our model explained the data during each stage better. Second, given that the parameters' logit transformation was calculated to give the networks' density overall, the Logit values during *s*1-*s*3 increased greatly compared to the null model, except for *s0*. This result indicated that before the outbreak, the planners were less informed of the crisis' nature, and which types of actors or activities to include in the response manual, which resonated with the descriptive results of the actors' number and networks' density in 4.1.

Table 5. Null models

	Before (*s0*)	**Early** (*s1*)	**Peak** (*s2*)	**Waning** (*s3*)
Estimates (SE)	-1.45 (0.18)***	-1.39 (0.17)***	-1.08 (0.17)***	-1.10 (0.18)***
AIC	206.5	212.2	207.8	177.4
Logit	0.19	0.2	0.25	0.25

*** $p<0.01$ ** $p<0.05$ * $p<0.1$

Table 6. Predicting tie formation

	Before (*s0*)	**Early** (*s1*)	**Peak** (*s2*)	**Waning** (*s3*)
Estimates (SE)	-2.85 (1.03)***	-4.03 (1.06)***	-4.13 (0.92)***	-5.33 (1.42)***
Scope				
Provincial	0.10 (0.62)	-1.21 (0.52)**	-1.68 (0.62)***	-1.12 (0.54)**
National	0.12 (0.42)	-0.64 (0.36)*	-1.12 (0.48)**	-0.56 (0.42)
Govt.	-0.12 (0.58)	1.53 (0.44)***	1.60 (0.49)***	1.12 (0.50)**
Health	0.81 (0.41)**	0.75 (0.51)	0.44 (0.49)	2.42 (1.20)**
Material				
Material0	-2.38 (0.89)***	-0.10 (0.64)	0.16 (0.80)	2.08 (1.32)
Material1	1.78 (0.60)***	1.80 (0.62)***	2.78 (0.74)***	0.39 (1.23)
People				
People0	-2.45 (1.16)**	0.37 (0.56)	0.22 (0.55)	0.84 (0.60)
People1	2.97 (0.72)***	1.22 (0.54)**	1.42 (0.53)***	1.37 (0.56)**
AIC	134.5	172.7	163.9	147.3
Logit	0.12	0.42	0.42	0.77

*** $p<0.01$ ** $p<0.05$ * $p<0.1$

In Table 6, the most striking difference was observed in the comparison between *s0* (Before) and *s*1, *s2*, and *s*3 (during the outbreak). We interpret the results in depth below.

4.2.2. Before the outbreak (*s*0). Two node-level attributes, scope and government, did not contribute significantly to the network density during *s*0. Planners did not pay significant attention to the scope of actors' service, and to which sector they belonged when making plans before the crisis. However, health is statistically significant, indicating that planners focused on assigning health-related actors to coordinate in the network. Further, the results indicated that the homophily effects on material and people were mixed. The homophily effects were contributed by two actors, both of which were planned, or neither was planned to transfer material and human resources. These two mechanisms of the homophily effect had different influences on the outcome. The reciprocal relationship between actors that were planned neither to transfer material and/or people decreased the probability of observing a tie in the network significantly. In other words, conducting the supportive activities other than transferring material and/or people decreased the probability of tie formation. In contrast, the two actors, both of which were planned to be involved in transferring materials and/or people, increased the likelihood of observing a tie in the network significantly.

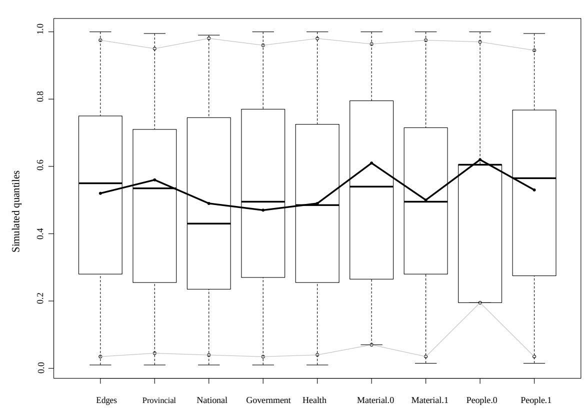
4.2.3. During the outbreak (*s*1-*s*3). The estimates of the scope of service on the provincial and national levels were negative and significant from *s*1 to *s*3, suggesting that national and provincial actors reduced the probability of tie formation significantly compared to local actors. Thus, planners envisioned that assigning tasks to local actors was more likely to enhance tight coordination. Further, government was associated positively and significantly with the probability of tie formation during these stages, indicating that planners began to rely on governmental actors to increase coordination. The estimate of health actors predicted tie formation positively and significantly during *s0*, but not significant during *s*1 and *s*2. The probability that health and non-health actors would form ties did not differ statistically significantly in the early and peak stages, while in the waning stage, health-related actors were planned again to coordinate with other actors, as during *s*0. Unlike during *s*0, the positive and significant results for two dyadic variables during the outbreak (*s*1-*s*3) indicated that two agencies who are both planned to transfer material and human resources had strong homophily effects on predicting the tie formation. In other words, two actors, both of which were planned to exchange materials, contributed to the homophily effect. Two actors that were not planned to be involved in those key activities did not contribute to the tie formation in the network.

4.2.4. Summary of findings. Each of the parameters in Table 6 represents different configurations. An overall comparison of the parameters during each stage revealed some differences. First, the estimates of scope and government were significant during *s*1, *s*2, and *s*3, indicating that local and governmental agencies were planned to play important roles in coordination during the outbreak; thus, *H1* and *H2* were supported in part. Second, the health specialty was associated positively with the probability of tie formation during the Before and Waning stages, but had little influence during the Early and Peak stages, indicating that as the outbreak became severe, the Korean government decided to rely on more supportive agencies to isolate suspected and confirmed cases; thus, *H3* was supported in part. Third, the results that two actors, both of which were planned to transfer physical and/or human resources, were more likely to increase the network density during *s*1-*s*3 shows that planners realized the importance of assigning actors to perform key activities during the outbreak. However, before the outbreak, two actors, neither of which was planned to transfer physical and/or human resources, also contributed to the homophily effect, indicating that the planners did not consider the key activities particularly critical to the response. Thus, *H4* and *H5* were supported in part. Table 7 presents a summary of the results.

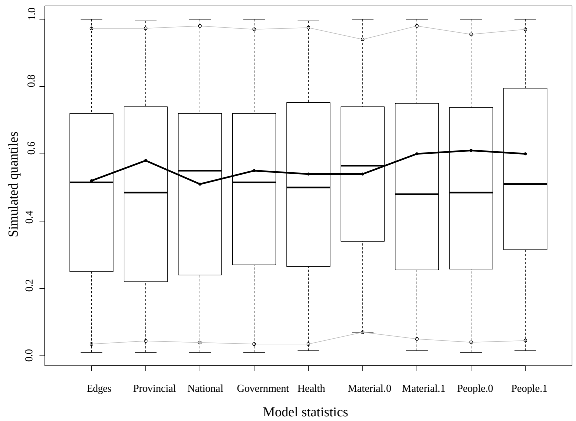
Table 7. ERGM results (summary)

	Before (*s0*)	**Early** (*s1*)	**Peak** (*s2*)	**Waning** (*s3*)
H1	Reject	Accept		
H2	Reject	Accept		
H3	Accept	Reject		Accept
H4	Reject	Accept		
H5	Reject	Accept		

4.2.5. Goodness-of-fit. The goodness-of-fit (GOF) test was performed to ensure that there were no major problems with the convergence [24]. A model fits well when a simulated network is as extreme as the network observed. Our models across the four stages all demonstrated a good fit, with most *p*-values in the GOF test above 0.5 and close to 1. This simple model with eight parameters captured the structural patterns in the planned networks during each stage well. In Figure 2, we presented the diagnostic plots during *s*0 and *s*2 with 95% confidence intervals for illustration purposes. They show that our models fit well with the observed network because there was little variation in each network's statistics across the simulated network.



a. Model Fit Before the Outbreak (*s0*)



b. Model Fit During the Peak (*s*2)

Figure 2. Diagnostic plots

5. Discussion

One step in developing more solid theoretical accounts of response plans for an emergency is to examine what constitutes a useful and realistic plan. In this study, the network arrangements that can affect tie formation between actors were drawn from actor- and dyad-level attributes in the MERS response manuals in South Korea before and during the outbreak. We hypothesized that the probability of tie formation is a function of agencies' scope of service, sector (governmental vs. non-governmental), specialty (health vs. non-health related agency), and the actor's match in activities related to key activities, i.e., transferring material and/or personnel resources.

After examining the network data with ERGM analysis, we found: 1) compared to the response plan prepared before the outbreak, some adjustments were made to enhance the connections between local and governmental actors. While Table 4 shows that the networks became denser over time, Table 6 suggests that the increasing density derived from those local and governmental actors; 2) Health actors' role was unclear during the Early and Peak stages, suggesting that as the outbreak became severe, planners began to emphasize the role of non-health actors, and sought the support from police and fire departments to isolate people suspected to be infected, and 3) The differential homophily effect with respect to the exchange of materials and human resources was observed consistently over time, and proved to be associated positively and significantly with the likelihood of tie formation during all stages. This result also suggested that actors that were planned to transfer human resources, including experts, doctors, nurses and other professionals, were more likely to establish connections with others.

The difference in the response coordination plans between before (*s*0) and during (*s*1-*s*3) the outbreak is worth noting here. Such a discrepancy showed that planners had little idea of the way to plan for an unknown emergency until they experienced it. Their lack of operational experience in planning can be explained from two perspectives. First, before the outbreak, they had little experience on what type of actors and activities to include in the manuals. Therefore, they selected to involve as many actors as possible to eliminate the potential threats to a large extent, regardless of the actors' characteristics. For example, hospitals may play the major role in the response network by treating the patients effectively. It also is likely that non-health actors will play the leading role in identifying and isolating confirmed cases to reduce the infection rate. Second, there was discordance between the planners' perceived threats and the activities that needed to be involved before the outbreak. As the results during *s*0 show, the homophily effect that resulted from transferring material or personnel was attributable simultaneously to two types of actors, one of which was assigned the key activities, while the other was assigned other supportive tasks. Unfortunately, the probability of forming a tie was decreased by the two agencies that were planned to conduct supportive activities, which are irrelevant to key activities like transferring material and/or personnel.

This article provided evidence for the constant revisions in response plans during different epidemic stages. During the revision process, the Korean government chose to continue to involve only key actors rather than including more actors in the response manual. In addition, the government chose to increase the connection among the key actors over time. This tendency to keep core actors in the response plan is consistent with others' observation [28]. In our study, the core actors were composed of those that are local, governmental, and health-related. One drawback of the decision is that the response manual continues to ignore international actors (or perhaps other actors) that were critical in responding to the disease effectively.

We used a small network dataset that consists of 16 core actors that were supposed to prepare for and respond to the epidemic event. At least, we observed certain changes to adapt to the evolving situation by increasing the effort to build connections with other actors on the part of such core actors as local, governmental, and health actors. We cannot judge whether the adjustment was sufficient only by looking at the planned response data. Given the wide recognition that the MERS response was a failed case, the insufficiency in the revisions needs to be examined thoroughly elsewhere. Moreover, emergency response is managed not only by the core actors, but also by emergent actors, which can change the response network's structure, stability, and effectiveness. Our next study will examine the way this planned coordination actually unfolded in the response process, to determine whether the changes the planners made during each stage were meaningful to the actual responders.

6. Conclusion

Societies are unlikely to know in advance when and what type of crisis will occur. However, it is necessary to formulate a plan that assumes such an event will occur, and to ask stakeholders to act on that plan if the presumed event does occur. On the other hand, following the plan as it is designed may not always bring positive or intended results because of unforeseen contingencies. The emergency management literature has recognized well that formal policies and plans are limited inherently in responding to disruptive events [2] [3] [29]. Nonetheless, the gaps between planned and implemented networks may not be identified easily unless the response plans are scrutinized and analyzed thoroughly. This study fills a gap in the emergency management literature by examining the design features and changes in coordination plans among key actors in South Korea's MERS response manual.

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