Quick Response Report

COMMUNITY RESILIENCY AND EMERGENCY MANAGEMENT NETWORKS: FOLLOWING THE 2012 KOREAN TYPHOONS

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SUMMARY

This research aims to examine the evolution of interorganizational networks emerged from the Southeastern region of Korean Peninsula, which consists of Busan and Ulsan Metropolitan Cities, and the South Kyeongsang Province, following the 2012 pacific typhoon. The quick response research was conducted at the organization level to explain how the typhoons affected joint coordination efforts contributing to community resiliency. Particularly, this research utilizes four community resiliency indicators: robustness, rapidity, resourcefulness, and redundancy. The research tests two general hypotheses: bonding and bridging effects. While the former illustrates the importance of trust and information redundancy to coordinate and align emergency preparedness and response, the latter captures the tendency for local actors to seek dominant partners in order to bridge crucial information across the region. During the first stage of the field work, 30 semi-structured interviews were conducted in December 2012 among local and provincial officials including police, EMS, and fire chiefs and directors of non-governmental organizations to gauge barriers and success in preexisting response plans. A structured survey instrument was administered to 159 organizations in the second stage of the field work, January 2013, in order to capture interorganizational networks that emerged after the disasters. A network evolution analysis using SIENA employs two-time-points data, which was collected in July 2012 before the typhoons and in January 2013 after the typhoons. The analysis results provide two general implications to understand the evolution of interorganizational EM networks. First, interorganizational collaboration for enhancing community resiliency proposes the importance of bilateral aids rather than unilateral. Sine interdependency offers the potential benefits to reduce conflicts among local organizations as well as across the sector, self-organizing EM networks are more likely to consist of reciprocal collaboration that enhance community resiliency. Second, direct collaborative ties with other organizations generate structural benefits derived from close-knit EM networks. Formulating a clustered structure in efforts to enhance community resiliency not only provides associational benefits such as reputation, knowledge, and institutional norms. The findings provide theoretical insights into interorganizational coordination that accounts for the network evolution in terms of community resiliency, particularly disparities between actual response and preexisting disaster plans.

INTRODUCTION

Building community resiliency is a complex and dynamic process playing out over multiple scales of public, private, and nonprofit organizations. While much of growing research has highlighted the importance of interorganizational emergency management networks (Waugh 2003; Waugh & Streib 2006; Kapucu 2006; Choi & Brower 2006; Andrew & Carr 2012), few research has identified how patterns of social relations established by diverse local organizations is modified by a disaster.

The transformation of interorganizational ties in order to enhance community resiliency is timely and an important topic for the fields of emergency management (Kapucu *et al.* 2012). Given the limitations of resource and fragmented regional governance, previous literature has argued that emergency networks encompassing federal, state, and local governments played an important role in promoting successful adaptation to adversity (Kapucu et al. 2010; Andrew 2009; 2010). Helping to build regional resilience – characterized by a community's ability and capacity to respond and recover damages from disasters – has also received much attention by regional, state, and national policymakers (Norris *et al.* 2008; Chandra *et al.* 2010; Sherrieb *et al.* 2010).

This research aims to determine the patterns of interorganizational relations and how planned joint coordination efforts changed to meet unexpected local demands and thus contributing to community resiliency. The term "community resiliency" is generally conceptualized as the capability of a community to bounce- back from an adverse situation (National Research Council 2010; Cox & Perry 2011). The concept has gained wide interest after the adoption of the Hyogo Framework for Action 2005-2015, calling for the need of national and community resiliency to disasters (Manyena 2006). Community resiliency is operationalized as the capability of interconnected networks of local organizations to foster the following resiliency dimensions: robustness, rapidity, resourcefulness, and redundancy.

This research is intentionally designed to test two general hypotheses: bonding and bridging effects. While the former illustrates the importance of trust and information redundancy to coordinate and align emergency preparedness and response, the latter captures the tendency for local actors to seek dominant partners in order to bridge crucial information across the region (see Andrew 2009; 2010; Andrew & Carr 2012). The relationship between interorganizational ties and community resiliency is timely and an important topic for the fields of urban and emergency management (Kapucu *et al.* 2012). Scholars have argued that emergency networks encompassing national, regional, and local governments as well as private and non-governmental organizations play an important role in promoting adaptation to adversity and establishing meaningful emergency planning processes (Kapucu *et al.* 2010; Andrew 2009; 2010).

The dimensions of resiliency proposed by Bruneau and Reinhorn (2006) are used as indicators of community resiliency. The dimensional approach not only describes situational assessment, rapid response, and effective recovery strategies, but also captures strategies adopted by local organizations that can reduce the risks of coordination failure and thus minimizing disruptions and shortening the time of recovery. While the dimensions to build community resilience has received much attention by policymakers (Norris *et al.* 2008; Chandra *et al.* 2010; Sherrieb *et al.* 2010), disaster scholars generally limited their analysis to using secondary data at the meso or macro level (Cutter *et al.* 2010; Kapucu 2011). Moreover, in the realm of emergency management, whether planned or not, scholars have argued that self-organizing governance will emerge in one form or another (Dynes, Quarantelli, & Kreps 1972; Kreps 1991; Dynes 1994). Although this stream of work provides insight into the different types of emergence groups during disasters, it tends to focus on the normative issues rather than investigating factors explaining the process of interorganizational coordination.

This is an innovative approach in that it focuses our attention on how a diverse set of organizations are transforming their resources and devising alternative means to overcome unexpected challenges, thereby building community resiliency. Social network analysis allows us to identify the role of diverse organizations and patterns that they collaborate with others by capturing a form of their ties (e.g., reciprocal or one-sided relationship). For example, Kapucu (2006) argues that by using social network analysis, we cannot only identify organizations playing a role of boundary spanner in interagency communication network, but also examine how the boundary spanner can contribute to coordinating various agencies' resources and information. Based on the network evolution approach of social network analysis, this research focuses on changes of interorganizational emergency management network by using two-time-points data collected before and after the extreme event.

THE 2012 KOREAN TYPHOONS

On 28 August 2012, Typhoon Bolaven devastated the Korean peninsula, resulting in 25deathsand causing severe destruction in infrastructure and livelihood in the Southeastern Economic Region. The economic lost was estimated at $374.3 million in South Jeonna and South Kyeongsang provinces. Unlikely previous years, between August 28 and September 18, 2012, the recent disaster was caused by three successive typhoons: Bolaven, Tembin, and Sanva, (*see* Table 1). The National Emergency Management Agency (NEMA) (2012) reported that, the region experienced maximum wind speed of 130 and 175 mph, which led to overflows of water along the southern coastlines and a heavy runoff from the Nakdong river basins. Over 1.9 million households in the southwestern provinces experienced total blackout for more than a week. Approximately 20,000 hectares of agricultural lands were damaged. Samsung, Hyundai, and Kia factories located in the Southeastern regions were also affected, especially in Ulsan

Metropolitan area. With an estimated $730 million in economic losses, the Korean national government officially designated 45 cities as “special disaster zones”.

Table 1. Characteristics and Impacts of Three Typhoons in South Korea, 2012

	Bolaven	Tembin	Sanva
Category (SSHS*)	Category 4 typhoon	Category 4 typhoon	Category 5 super typhoon
Maximum winds	145 mph	130mph	175 mph
Date of impacts	28 - 30 August 2012	31 August -2 September 2012	16 - 18 September 2012
Fatality	25	2	2
Total damage	USD 374.3 million	USD 8.25 million	USD 347.5 million

*The Saffir–Simpson Hurricane Scale (SSHS) is the classification of hurricanes from 1 to 5 categories distinguished by the intensities of continual winds. A typhoon with maximum sustained winds of at least 74 mph is classified as Category 1. The highest classification in the scale, Category 5, is earmarked for the typhoon with winds exceeding 156 mph (National Hurricane Center 2012).
** Source: The National Typhoon Center in South Korea (2012)

DATA AND METHODS

Scope of Study and Site Selection

This research focuses on the role of interorganizational coordination in the recovery phase of the Southeastern region, which consists of Busan Metropolitan City, Ulsan Metropolitan City, and South Kyeongsang Province. The unit of analysis is at the organization level (e.g., local and provincial agencies, fire and police stations, and non-governmental organizations). On 16-28 July 2012, I collected data in the region related to emergency planning (before the typhoons strike). A structured survey was conducted to examine community resiliency and I employed the social network analysis to examine interorganizational coordination. My preliminary findings, based on 130 respondents, show that interorganizational coordination relies on national agencies before a disaster strikes. Although the findings are insightful in showing the nature of interorganizational coordination before a disaster strikes, it is uncertain as to how interorganizational relations have changed to accommodate local resident needs and affected community resiliency. By comparing patterns of interorganizational relations, this research identify the notion that how planned joint coordination efforts are modified to meet unexpected local demands and thus contributing to community resiliency.

Data Collection and Survey Instruments

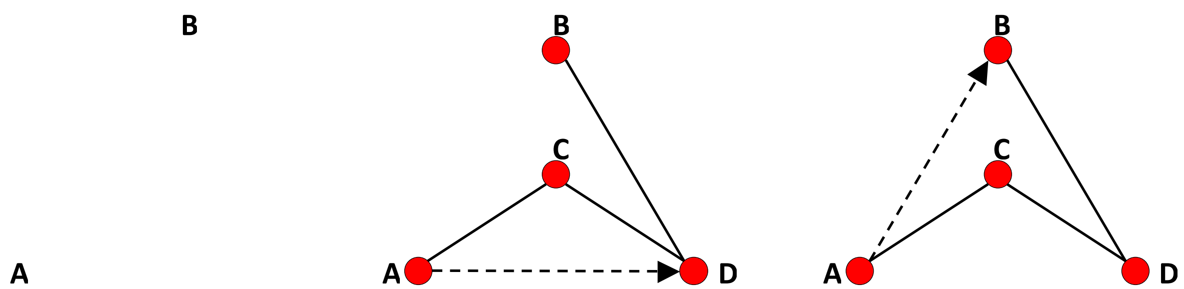
The data collection involves a two steps process. In the first wave of data collection, I used a semi-structured interview technique and interviewed 30 key informants who had direct responsibility for processing and/or providing services on behalf of their organizations in the affected communities. A semi-structured interview guideline was developed around the following three research questions:

1. With whom local organizations/agencies coordinate their efforts to provide emergency services in the affected areas? What are the key issues surrounding their coordination planning and the modification they made in order to meet local demand for services during the response?

2. Given the nature of the disaster, what types of resources being deployed and utilized to ensure local community are able to bounce back from the disasters? What alternative services are being provided immediately after the first, second, and third typhoons?

In the second wave of data collection, I administered a survey[1] on 7-12 January 2013 with the same organizations (i.e., 170 organizations) that responded to my initial field work in July 2012. Again, in order to determine whether interorganizational networks changed during the transitional stage of the disaster, this research utilized two-time-points data collected before and after the typhoons. Two types of interorganizational emergency management networks are represented as an*170* x *170* matrix reporting all ties among all 170 actors. I employed a specialized software program called SIENA (Simulation Investigation for Empirical Network Analysis) to analyze the network data at two time periods (Snijders *et al.* 2010). The method is appropriate to test the bonding and bridging effect hypotheses stated above.

Figure 1. Hypothetical Interorganizational Networks



Note: Each of hypotheses is shown as a dotted line on this figure.
*Adopted to Snijders et al. (2010)

Data Analysis

Using the simulation investigation network analysis (SIENA) approach, this research answers the question: how the observed ties that formed emergency management networks are evolved by natural disaster. The SIENA estimates models of network evolution based on the "actor-oriented model" (Snijders 2005; Snijders *et al.* 2010), indicating that given a particular configuration of a tie that links actor *i* and *j*, each of actors *i* and *j* can consider whether to establish or terminate the tie. This decision of actor *i* and *j* may rely on the rate that each of them has the opportunity to change the tie (Snijders 2005). Based on a continuous-time Markov Chain Monte Carlo (MCMC) simulation, where the algorithm computes the maximum likelihood estimates. (Snijders 2005; Snijders *et al.* 2010), the SIENA employs a three-phase stochastic approximation algorithm to estimate the pattern of relationships (Snijders *et al.* 2010). Those methods allow SIENA to conduct a check for convergence of each variable. If the convergence diagnostic statistics for the algorithm is less than 0.2 in absolute value, the parameter estimate is considered to have good convergence and excellent when they are less than 0.1 (Snijders *et al.* 2010). The convergence diagnostic, covariance, and derivative matrices were based on 1,000 iterations, and the t-value provides a significance test of the estimated parameters.

[1] Human Subject Application No. 12567 approved by Institutional Review Board in University of North Texas

FORMULATING COMMUNITY RESILIENCY AND NETWORK EVOLUTION

Community Resiliency

The level of community resiliency perceived by organizations is represented by a collapsed index developed from their responses to the survey questions based on four dimensions of resiliency: robustness, rapidity, resourcefulness, and redundancy (Bruneau *et al.* 2003; Kendra & Wachtendorf 2003; Bruneau & Reinhorn 2006). In accordance with four dimensions of the concept resiliency, the respondents are asked the following questions:

> 1. Robustness: "Do you agree that your organization has the CAPABILITY to immediately help disaster victims and local communities rebound (or return to normalcy)?"
> 2. Rapidity: "How would you rank the RAPIDITY of providing assistant to disaster victims with resources that you have?"
> 3. Resourcefulness: "Do you agree that your organization is RESOURCEFUL in order to meet the needs of disaster victims and local communities?"
> 4. Redundancy: "Do you agree that your organization has the ABILITY to carry out routine tasks and, at the same time, help victims and local communities to cope with disasters?"

The community resiliency index (CRI) is based on the following procedures. The respondents were directed to indicate their perception of community resiliency's dimensions in terms of five scales: 0 (strongly disagree) to 4 (strongly agree). For each organization, the four answers were summed to create a single response ranging from 0 to 8. The summed scores were then divided by 8 and then multiplied by 100 to create a highly reliable index of regional resiliency, the scope from 0 to 100. Higher scored index indicates greater resiliency in the region where the responded local government is located.

Table 2. Differences of Means Test: Community Resiliency Index by Types of Organizations

	Before the typhoons		After the typhoons			
Organizational Type	Mean	Std. D.	Mean	Std. D.	*Mean Diff.*	*t*
Local Government	79.65	11.57	79.02	13.97	.627	.223٩
Fire Station	78.97	12.59	78.4	19.26	.562	.132^
Police Station	75.39	13.12	69.47	15.63	5.921	1.421٩
Nongovernmental Org.	78.26	11.04	76.59	13.19	1.667	.461٩
Total	78.08	12.18	76.65	15.56	1.445	.811^

Notes: ٩ denotes equal variance assumed; ^ denotes equal variance not assumed.
*p<.10; **p<.05; ***p<.01

Community Resiliency Index

The level of community resiliency perceived by organizations is collapsed into an index based on four dimensions of resiliency. Table 2 shows all means of the community resiliency index (CRI) by types of organizations. Overall, the CRI of all types of organizations was slightly decreased by 1.43 point from before (i.e., 78.08) to after the 2012 Korean typhoons (i.e., 76.65).

Specifically, the CRI of local governments is higher than all other types of organizations (i.e., 79. 65 before the typhoon and 79.02 after the typhoons), while police stations indicates the lowest CRI before and after the typhoon.

In order to determine whether the CRI perceived by organizations is significantly different (Table 3 in the Results Section), the difference of mean *t*-tests between two temporal points was conducted. The analysis is important because the results determine whether the CRI provided by different types of organizations was changed by the disaster. The analysis results shows that the mean differences between the CRI before and after the typhoon are not significantly different in terms of all types of organizations (i.e., local governments, fire and police stations, and nongovernmental organizations). Although the finding suggests that there is no statistical evidence of the mean differences, this research anticipates that these differences between two time points are resulted from the catastrophic event.

Interorganizational Collaboration

This research measures interorganizational collaboration before and after the typhoon based on a question in the survey instrument:

> "Consider the full range of organizational types including national government agencies, grassroots organization, interest groups, NGOs, and local agencies. Please list the organizations that you have collaborated with during emergency response and recovery in order to enhance assistances for disaster victims and their communities."

The question was originally written in English, and then translated to Korean through the Research & Research as the professional survey institute before the survey was administered. It was purposely designed to capture with whom local governments established collaboration before and after the disaster in terms of community resiliency.

To determine the nature of interorganizational collaboration in emergency management practices, a sociomatrix 170 by 170 were used to systematically manage data sets. The reason is that respondents in the first survey indicate five national agencies (i.e., National Emergency Management Agency, Ministry of Public Administration and Safety, Ministry of National Defense, Ministry of Load, Infrastructure, and Transportation, and Ministry of Environment) and six regional agencies (i.e., Busan and Ulsan Metropolitan Government, the South Kyeongsang Provincial Government, and three Regional Military Corps). Interorganizational emergency management network structures before and after the typhoons are presented in Figure 2 and 3.

Network Evolution

Three network effects, reciprocity, bonding, and bridging effects, are used to explain the evolution of interorganizational emergency management networks in the Southeastern Economic Region. The function of network evolution for actor *i* is formally defined as:

$$f^{net}(x) = \sum_k \beta_k^{net} s_{ik}^{net}(x)$$

Here, β_k^{net} is a parameter that the actor *i* can change a set of ties from networks t_1 to t_2, and $s_{ik}^{net}(x)$ are effects resulted from the change of the actor *i*. According to Snijders *et al.* (2010), the network evolution function proposes the notion that decisions of actors who establish new ties or terminate existing ties (i.e., the internal effect parameters) result in the network evolution (i.e., the dynamics of the external effect parameters).

Reciprocal Effect: The reciprocal effect was measured by the "reciprocity effects" as a mutual relationship. It is formally defined by:

$$s_{i1}^{net}(x) = \sum_j x_{ij} x_{ji}$$

The formula accounts for the total number of reciprocal relations between actor *i* and *j* (Snijders 2005; Toivonen *et al.* 2009; Snijders *et al.* 2010). As shown in the left of Figure 1, for instance, if actor *i* and *j* jointly seek information and/or resources from each other, the tie can be operationalized as indicating the existence of a mutual tie between actor *i* and *j*.

Bonding Effect: The bonding effect was measured by the "transitive triplets effects", which captures the propensity to form a direct link to other critical actors and highly clustered network structures (Andrew 2009; Snijders *et al.* 2010). The bonding effect is illustrated on the center of Figure 1. The structure can be formally written as:

$$S_{i2}^{net}(x) = \sum x_{ij} x_{ih} x_{jh}$$

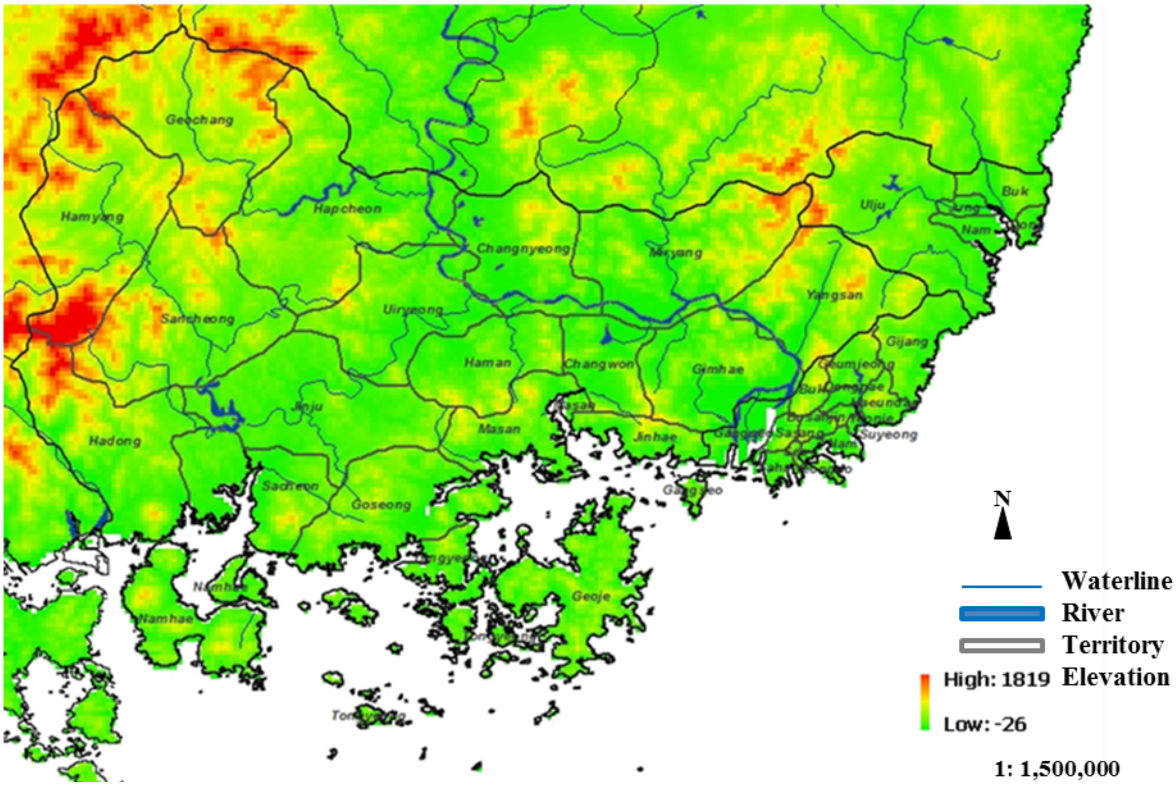
The transitive effects are the number of transitive patterns that all of three actors forming a triad are tied to each other. A positive parameter suggests a tendency for actors in the network to establish relations toward a set of triads or a reasonably high number of a closely-knit structure (Snijders 2005; Snijders *et al.* 2010).

Bridging effect: The bridging effect was measured by the "the number of distances two effects", which suggests the preference to alternatively forge an indirect tie through intermediary actors (Andrew 2009; Robins *et al.* 2009; Snijders *et al.* 2010). The bridging effect can be formally defined by:

$$s_{i3}^{net}(x) = \#\{j\, x_{ij} = 0, \max_h (x_{ih} x_{hj}) > 0\}$$

The formula explains the number of the actor *i*' ties that are indirectly linked with the actor j through at least one intermediary actor h at sociomatric distance two. While a positive parameter implies a propensity for actors in the given network to utilize the actors who play a bridging role in transmitting information, a negative one proposes that the actors are less likely to share the bridging actors in the network evolution from t_1 to t_2.

Figure 2. The Southeastern Economic Region in South Korea



Node: The range of elevation is from -26 (i.e., green) to 1,819 (i.e., red) meters, and the blue line across the region is major rivers and water courses.
*Visualized by the Arc Geographical Information System 10.1.

Covariate Effects: Three covariate effects as control variables are included in the model: (1) the metropolitan status, in which an organization located in the metropolitan area is coded as 1 otherwise 0, (2) the coastal status, which is indicated by an organization located beside the coastal area (i.e., coded as 1, otherwise 0), and (3) the riverside status that if an organization is located beside a riverbank, coded as 1 otherwise 0. The covariate effect is represented by the statistic, where are the value of covariate *v* and the degree of the actor *i*. For the covariate effects, a positive parameter implies that the attributes have an impact on the probabilities of actors to seek others in the network for information and resources regarding emergency management issues. A negative parameter suggests the influence of personal characteristics is improbable (Snijders *et al.* 2010).

Homophily Effects: This research also tests for the homophily effect, which is represented by whether local governments establish ties with similar others rather than other types of organizations such as fire and police stations and nongovernmental organizations (Feiock *et al.* 2010; Andrew 2009). This hypothesis evaluates the homophily effects among local governments playing a critical role in emergency management. The indicator function is 1 if an organization is local government, otherwise 0.For the homophily effect, a positive parameter implies that actors prefer ties to others with similar preferences, while a negative parameter suggests the actors' preferences for similar actors are less likely to drive actors to establish ties with them.

RESULTS

Total of 159 organizations were contacted in the region, and 112 organizations agreed to complete the surveys (i.e., 70.4 percent respond rate). The organizations responded to the phone survey included senior public officials from municipal governments, assistant chief of fire and police stations, and non-governmental organizations. Table 3 provides the distribution of the responded organizations in both July 2012 and January 2013, indicating that 43 local governments and 25 nongovernmental organizations responded both surveys while only 24 fire and 20 police stations less than the first survey answered the second survey.

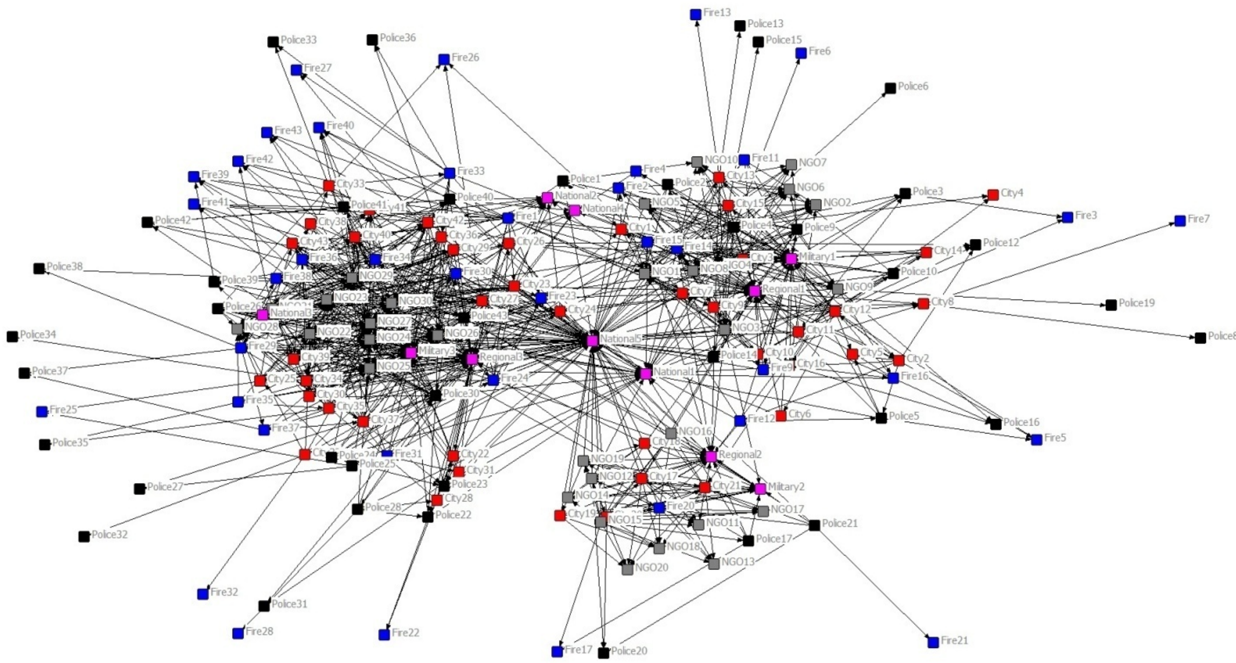
Table 3. Respondents by Types of Organizations

	Before the typhoons		After the typhoons	
Organizational Type	Frequency	Percent	Frequency	Percent
Local Government	43	33.1	43	38.4
Fire Station	34	26.2	24	21.4
Police Station	28	21.5	20	17.9
Nongovernmental Org.	25	19.2	25	22.3
Total	130		112	

Interorganizational EM Networks before and after the 2012 Korean Typhoons

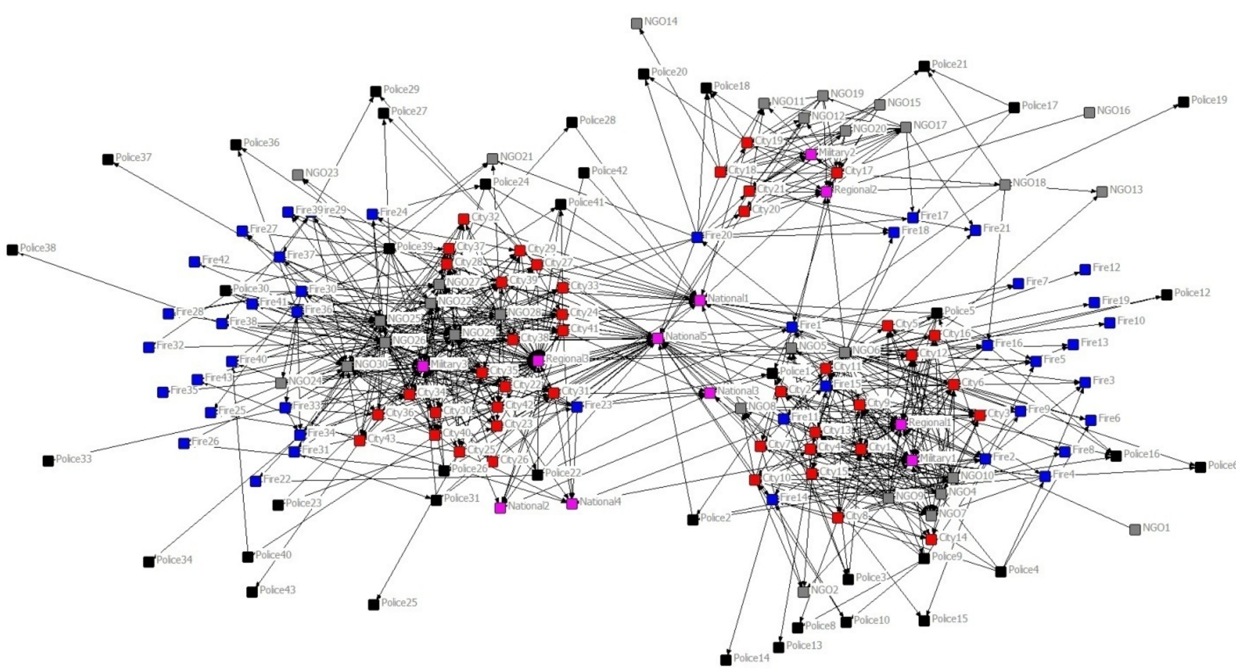
The interorganizational emergency management (EM) networks organized by 170 organizations are presented in Figure 2 and 3. The figures illustrate that almost organizations interacted in before and after the typhoons, and isolators in both EM networks decreased from 8 (4 fire and 4 police stations) to 5 organizations (4 police stations and one nongovernmental organization). There are apparent patterns that national agencies (i.e., NEMA and Ministry of Public Administration and Safety) and metropolitan and provincial governments play a significant role in coordinating emergency management resources. In addition, noteworthy from the networks is that local governments are placed in a central position of local emergency management compared to other types of organizations. On the contrary, fire and police stations are not well coordinated in both networks. Lastly, nongovernmental organizations shown in the networks are evidence for different interaction patterns in accordance with their status such as regionalized and localized branches (e.g., Busan and Ulsan branch of Korean Medical Association and municipal branches of Korean Marine Veteran Association).

Figure 3. Interorganizational Emergency Management Networks before the typhoons



Note: Red nodes are local governments; blue nodes are fire stations; black nodes are police stations, gray nodes are nongovernmental organizations; and purple nodes are national and provincial agencies.

Figure 4. Interorganizational Emergency Management Networks after the typhoons



The descriptive analysis in Table 4 presents specific network statistics of two interorganizational EM networks. In the overall networks, mutual dyads increased from 54 to 68 while asymmetric dyads decreased from 1,159 to 832. As a result of that, the network density decreased from 0.039 to 0.028. In columns 2 through 6 of Table 4, I categorize the samples into five groups by a type of organizations. In terms of the relationships among same organizational type (i.e., local government, fire and police stations, and organizations in the nongovernmental sector), the network density of the nongovernmental sector (.054) is only greater than the overall density (.039) in the network before the typhoon, while there is no group that is greater than the overall density (.028) in the network after the typhoon. Despite that, the density of the fire station group increased from .012 to .014 through the disaster. Although the density of relationships across sectors decreased from .038 to .029, its density in the network after the typhoon is greater than any other types of organizations, indicating that approximate 89.7 percent of mutual and 91.9 percent of asymmetric dyads are established across sectors.

Table 4. Networks Statistics

	Overall Network	Among Governments Gov ↔ Gov	Among Fire Stations FS ↔ FS	Among Police Stations PS ↔ PS	Among Nongovernmental Organizations NGO ↔ NGO	Across Sector
Before the typhoons						
Mutual	54	4	2	2	1	45
Asymmetric	1159	22	19	15	45	1058
Null	16352	879	882	886	389	13316
Density	.039	.014	.012	.009	.054	.038
Average Degree	6.351	.605	.488	.395	1.567	6.937
After the typhoons						
Mutual	68	1	2	1	3	61
Asymmetric	832	24	21	8	14	765
Null	19753	878	880	894	418	16683
Density	.028	.014	.014	.005	.023	.029
Average Degree	4.741	.605	.581	.209	.667	5.194

Table 5 shows the changes in interorganizational ties between subsequent observations. The changes of ties indicate that through the catastrophic event, organizations participating in the EM network maintained 1,183 ties while established 487 new ties and terminated 696 previous ties. While Andrew (2009) and Steglich *et al.* (2006) argue that the changes of ties may not examine dynamics of the network evolution due to limited methods of data collection based on documents and contents, this research proposes that at least the changes of ties show dynamic impacts of the catastrophic event when the data collection procedures based on the peer-to-peer survey covered a full range of organizations in both networks. Again, the changes of ties account for the notion that organizations do maintain existing ties, establish new ties, or terminate previous ties by learning the significance of certain interorganizational collaboration from natural disaster.

Table 5. Tie Changes between Subsequent EM Networks

	No Tie	New Tie	Broken Tie	Maintained Tie
	$0 \rightarrow 0$	$0 \rightarrow 1$	$1 \rightarrow 0$	$1 \rightarrow 1$
$t_1 - t_2$	27228	487	696	1183

Evolution of EM Network: Reciprocity, Bonding, and Bridging Effects

The final results of estimation are presented in Table 6. The rate parameter (rho) is positive and significant. It means that the formation of collaborative ties generated a global dynamic through a reasonable number of small changes under the current model specification. All *t*-ratios (i.e., average divided by standard deviation) for the diagnosis are less than 0.1 in absolute value, indicating that the convergence is excellent (Snijders *et al.* 2010). The convergence diagnosis is important because a *t*-ratio for the analysis is closely concerned with the deviations between simulated ties of the statistics and their observed ties. Model 1 shows the results of the baseline model with network effects, and Model 2 incorporates covariate and homophily effects. Since Model 2 reflects similar results of Model 1 with network effects, the rest of this section reports the results of Model 2 by interpreting the effects of network structures followed by the covariate and homophily effects. The results show the estimated parameter values (*E*) and standard errors, and the statistical significance of the effects is based on the ratio between the parameter value and the corresponding standard error (i.e., *t*-statistics).

In Model 2, the parameter estimated for the reciprocity effect is positive and statistically significant ($E = .748$, $p < .01$). The results indicate that by responding to a catastrophic disaster and recovering damages, a mutual relationship will emerge under the presence of uncertainty and complexity of interorganizational collaboration. Again, it implies that the change of ties induces the reciprocal collaboration of organizations rather than an asymmetric relationship. The formation of collaborative ties for building community resiliency has a positive parameter estimate for the bonding effect ($E = .124$, $p < .01$) and a negative parameter estimate for the bridging effect ($E = -.154$, $p < .01$). Both parameter estimates are statistically significant. The analysis results of the network evolution show that a close-knit network will emerge from interorganizational EM collaboration through a disaster, while a sparse network will not be anticipated. The results also present strong evidence supporting the bonding effect that local organizations are more likely to directly link with those who are densely clustered for joint activities.

For instance, the coefficient for the reciprocity effect is positive and significant, which reflects the costs of establishing and sustaining a mutual tie after the typhoon ($E = .748$). Despite that, building the mutual relationship between two organizations does not provide any structural benefits derived from regional EM networks. Given the basic costs of the mutual collaboration, the strategic formation of interorganizational collaboration across the sector may maximize structural benefits as well as reduce uncertainty and complexity of collaboration that dramatically increase after the disaster. In this point of view, both the positive bonding effect ($E = .124$) and the negative bridging effect ($E = -.154$) imply that Actor A in Figure 1 are more likely to directly forge a new tie with Actor D, rather than bridging through Actor B, in order to offset the basic costs of the mutual collaboration.

Moreover, the covariate effects in Model II of Table 6 test the probability that organizations under a certain environmental condition such as the metropolitan, coastal, and riverbank area are more likely to collaborate with other organizations after a disaster. The results report that organizations located on the metropolitan area (E = 1.264; p <.01) and the coastline (E = .098; p <.05) are more likely to create interorganizational ties after the typhoon. Both results may support the notion that organizations collaborating with other organizations are influenced by environmental vulnerability (Villa & McLeod 2002). It implies that by enhancing collaborative activities for hazard mitigation, organizations under geographical disadvantages may actively try to secure critical resources and information from a highly dense EM networks to cope with shared hazards (Randolph 2012).

The homophily effect of local government is positive and significant (E = 0.096; p <.1), indicating the propensity that interorganizational ties are more likely to be established among local governments. The finding is consistent with the argument presented by Feiock *et al.* (2010) and Andrew (2009), illustrating that in order to reduce the administrative costs, local governments tend to establish ties with other local governments under regional EM coordination enforced by metropolitan and provincial governments.

Table 6. Parameter Estimates and Standard Errors

		Model 1		Model 2	
		Estimates	Std. Err.	Estimates	Std. Err.
Rate Parameter (rho) $t_{1\text{-}2}$		10.718***	.214	24.435***	1.426
Network Effects	Reciprocity	2.34***	.307	.748***	.108
	Bonding	.506***	.052	.124***	.008
	Bridging	-.255***	.028	-.154***	.034
Covariate Effects	Metropolitan Area	-	-	1.264***	.102
	Coastal Area	-	-	-.023	.052
	Riverbank Area	-	-	.098**	.051
Homophily Effects	Local Governments	-	-	.096*	.057

Note: All coefficients are resulted from the SIENA (3.12) with directed network matrixes
All statistics converged with a t-statistic <0.1 with a minimum of 1,000 iterations
*p<.10, **p<.05, ***p<.01

DISCUSSION AND CONCLUSION

Interorganizational collaboration for building resilient community comes in many forms, and thus it is critical to understand the change of its formation before and after a catastrophic event. Given uncertainty and complexity of building community resiliency (National Research Council 2010), the dilemmas of local organizations are: (1) the decision whether to forge a tie as interorganizational collaboration or not and (2) the choice with whom to create collaborative ties. Through much trial and error in the dilemmas, interorganizational EM networks have evolved over the years (Feiock & Scholz 2010; Kapucu *et al.* 2012). The network evolution in terms of natural disaster is predicted on the success of previous collaboration, the significance of current partners, and the expectation of subsequent collaboration that ultimately enhance community resiliency. By perceiving, experiencing, and learning the significance of collaborative ties through the disaster, consequently, organizations optimize the costs to establish new ties, terminate previous ties, and maintain existing ties as procedures of the network evolution.

The findings based on the field work supported by the quick response research provide two general implications to understand the evolution of interorganizational EM networks. First, interorganizational collaboration for enhancing community resiliency proposes the importance of bilateral aids rather than unilateral. Since interdependency offers the potential benefits to reduce conflicts among local organizations as well as across the sector (Feiock & Scholz 2010), self-organizing EM networks are more likely to consist of reciprocal collaboration that enhance community resiliency. In terms of the importance of bilateral aids, particularly, the interview results highlight that the three typhoons hold up a true mirror to the existing limit of the unilateral aids provided by other organizations. According to the principal administrator in the City of Changnyeong, Kwon Heeduck, the requests for emergency aids relying on the unilateral agreement was easily overlooked during the disaster. The director of regional fire administration headquarter in the South Kyeongsang province, Jung Dongcheol, also pointed out that successive catastrophic events such as continuative three typhoons shelved almost of the unilateral requests and aids until at least passing the typhoons while a committed bilateral aids between organizations intensified the resource mobilization during the disaster in order to support those who are located on the affected area.

Second, direct collaborative ties with other organizations generate structural benefits through close-knit EM networks. Formulating a clustered structure in efforts to enhance community resiliency not only provides associational benefits such as reputation, knowledge, and institutional norms, but also offer practical advantages such as sharing technical resources and coordinating joint activities based on consensus reflecting organizational preferences (Randolph 2012). For example, local governments and agencies located on the riverbank (i.e., Nakdong River across the Southeastern Economic Region) established the committee for hazard mitigation planning and implementation in 2011 and have developed the resource mobilization framework that activates during the disaster. Given the institutional committee, local organizations can enhance community resiliency through formal and informal communication and availability of shared resources (Andrew 2009; Kapucu *et al.* 2012). The manager of Fire Station in the City of Changwon, Park Changho, emphasized the importance of a close-knit EM network in the local level, arguing that direct collaborative ties forging a dense network structure allow local organizations to secure their own communication channel to increase community resiliency. Those findings imply that separate communication channels of organizations such as local governments, police, and fire stations have impeded effective information and resource mobilization in emergency responsiveness as well as recovery procedures.

While scholars in the field of emergency management have speculated for years on the importance of networks, they have fallen short in predicting the change of structures that are likely to emerge after natural disaster (Waugh & Streib 2006; Kapucu 2006; Kapucu *et al.* 2010; 2012; Andrew & Kendra 2011). The findings in this report are consistent with the argument provided by the assistant director of National Urban Disaster Management Research Center, Dr. Lee Byoungjae. In the interview, he underlined that because current interorganizational collaboration tends to heavily rely on emergency planning and paper-based system, a sparse network based on one-way relationships are more likely to fail to secure resources and critical information that local organizations need during a catastrophic disaster. Given the nature of natural disaster and community resiliency, this report provides evidence that local organizations related to emergency management transform from the unilateral into bilateral relationships as well as from indirect into direct collaboration with other organizations through natural disaster.

Consequently, interorganizational EM networks based on diverse types of organizations have evolved to enhance community resiliency.

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