ISTR INTERNATIONAL SOCIETY FOR THIRD-SECTOR RESEARCH
Voluntas (2017) 28:2145–2175
DOI 10.1007/s11266-017-9887-4
ORIGINAL PAPER

Modeling Resource Network Relationships Between Response Organizations and Affected Neighborhoods After a Technological Disaster

Chih-Hui Lai[1] · **Chen-Chao Tao**[1] · **Yu-Chung Cheng**[2]

Published online: 6 June 2017

Abstract Disaster usually provides a good opportunity to observe the convergence of voluntary organized response efforts. However, the extent to which response organizations and affected neighborhoods go through the relief process similarly or differently is surprisingly less studied. Integrating the framework of community ecology and the concept of community resilience, this study examines the evolutionary process of an emergent disaster response community that consists of the populations of response organizations and affected neighborhoods. Using a technological disaster that occurred in Taiwan in July 2014 as the research context, this study shows that response organizations' resource provision network and affected neighborhoods' resource receipt network exhibited similar structural tendencies over the phases of disaster response and rebuilding. The process of mutual resource mobilization was also observed as response organizations mobilized and provided resources to affected neighborhoods at the same time. Moreover, while affected neighborhoods tended to maintain their resource relationships consistently over time, the changing structural patterns of their resource network reflected individual engagement in resuming normality after the incident. Theoretical and practical implications for emergent post-disaster social and voluntary behavior are discussed through the lens of community ecology and community resilience.

✉ Chih-Hui Lai
chlai@nctu.edu.tw

Chen-Chao Tao
taoc@mail.nctu.edu.tw

Yu-Chung Cheng
colisa@gmail.com

[1] Department of Communication and Technology, National Chiao Tung University, Hsinchu, Taiwan

[2] Department of Mass Communication, Hsuan Chuang University, Hsinchu City, Taiwan

Résumé En général, les désastres procurent d'excellentes occasions d'observer la convergence des initiatives de réponse bénévole organisée. La mesure dans laquelle les organisations et voisinages touchés vivent le processus de secours de façon similaire ou différente est toutefois étonnamment moins étudiée. En intégrant le cadre de l'écologie communautaire et le concept de résilience des communautés, la présente étude se penche sur le processus évolutif d'une communauté de réponse en cas de désastre émergente, qui combine les populations des organisations connexes et des voisinages touchés. En se servant du désastre technologique de Taïwan de juillet 2014 comme contexte de recherche, l'étude démontre que le réseau de prestation des ressources des organisations de réponse et celui de réception des voisinages touchés présentent des tendances structurales semblables au fil des phases de réponse et de reconstruction après désastre. La présence du processus de mobilisation des ressources mutuelles fut aussi observée, alors que les organisations mobilisaient et procuraient simultanément des ressources aux voisinages touchés. Qui plus est, tandis que les voisinages touchés tentaient continuellement de préserver leurs relations avec leurs prestataires de ressources, les modèles structuraux changeants de leur réseau reflétaient un engagement individuel envers la reprise des activités normales après l'incident. Les implications théoriques et pratiques pour les comportements bénévoles et sociaux après désastre émergents sont traitées à la lumière de l'écologie communautaire et de la résilience des communautés.

Zusammenfassung Katastrophensituationen bieten im Allgemeinen eine gute Gelegenheit, um die Konvergenz freiwillig organisierter Hilfsmaßnahmen zu beobachten. Allerdings wird überraschenderweise weniger darauf eingegangen, inwieweit die Katastrophenhilfeorganisationen und die betroffenen Gemeinden auf ähnliche oder unterschiedliche Weise den Hilfeprozess durchlaufen. In dieser Studie werden das Rahmenwerk der Gemeinschaftsökologie und das Konzept der Widerstandsfähigkeit der Gemeinschaft integriert, und man untersucht den evolutionären Prozess einer entstehenden Gemeinschaft zur Katastrophenhilfe, welche sich aus den Katastrophenhilfeorganisationen und den betroffenen Gemeinden zusammensetzt. Forschungskontext der Studie ist eine technologische Katastrophe in Taiwan im Juli 2014. Es wird gezeigt, dass das Netzwerk zur Ressourcenbereitstellung der Hilfsorganisationen und das Netzwerk für den Ressourcenempfang der betroffenen Gemeinden in den Phasen der Katastrophenhilfe und des Wiederaufbaus ähnliche strukturelle Tendenzen zeigten. Der Prozess der beiderseitigen Ressourcenmobilisierung war auch zu beobachten, als die Hilfsorganisationen Ressourcen für die betroffenen Gemeinden zugleich mobilisierten und bereitstellten. Darüber hinaus war zu sehen, dass die betroffenen Gemeinden zwar dazu neigten, ihre Ressourcenbeziehungen im Laufe der Zeit konsequent zu pflegen, die sich ändernden strukturellen Muster ihres Ressourcennetzwerks jedoch ein individuelles Engagement wiederspiegelten, nach dem Vorfall wieder zur Normalität zurückzukehren. Theoretische und praktische Implikationen für das soziale und freiwillige Verhalten nach einer Katastrophe werden aus der Perspektive der Gemeinschaftsökologie und der Widerstandsfähigkeit der Gemeinschaft diskutiert.

Resumen Los desastres normalmente proporcionan una buena oportunidad para observar la convergencia de los esfuerzos de respuesta organizados voluntarios. Sin embargo, la medida en que las organizaciones de respuesta y los vecindarios atraviesan el proceso de alivio de manera similar o diferente sorprendentemente está menos estudiada. Integrando el marco de la ecología comunitaria y el concepto de resiliencia comunitaria, el presente estudio examina el proceso evolutivo de una comunidad emergente de respuesta a un desastre que consiste en las poblaciones de organizaciones de respuesta y vecindarios afectados. Utilizando un desastre tecnológico que se produjo en Taiwán en julio de 2014 como contexto de la investigación, el presente estudio muestra que la red de provisión de recursos de las organizaciones de respuesta y la red de recepción de recursos de los barrios afectados presentaron tendencias estructurales similares a lo largo de las fases de respuesta al desastre y de reconstrucción. También se observó el proceso de movilización mutua de recursos a medida que las organizaciones de respuesta se movilizaban y proporcionaban recursos a los barrios afectados al mismo tiempo. Asimismo, mientras que los barrios afectados tendían a mantener sus relaciones de recursos de manera consistente a lo largo del tiempo, los patrones estructurales cambiantes de su red de recursos reflejaban el compromiso individual en la reanudación de la normalidad después del incidente. Se tratan las implicaciones teóricas y prácticas para el comportamiento voluntario y social post-desastre emergente a través del prisma de la ecología comunitaria y la resiliencia comunitaria.

Keywords Disaster response · Resource network · Community resilience · Ecological and evolutionary perspective · Social network analysis

Human-made and natural disasters, serving as punctuating events, often create a temporary social infrastructure or a new civic coalition that fosters links between otherwise disconnected local corporates and nonprofits (Tilcsik and Marquis 2013). This emergent social response system involves the geographically based neighborhoods affected by the disaster as well as response organizations that provide resource support to the affected neighborhoods. Similar to social movements, disasters usually cause deterioration or loss of resources; hence, aggregation of resources is necessary for collective disaster responses, and the flow of resources may be directed toward and away from the affected neighborhoods as the urgency of response escalates and subsides (McCarthy and Zald 1977). Essentially, the affected neighborhoods following disasters could be considered a collective task environment that influences the resource-dependent relationships between those who supply and those who receive the resources (Benson 1975; Provan et al. 1980). However, the entities involved in such resource relationships are not clear cut because response organizations are not necessarily the resource "suppliers"; depending on the capacities of organizations, they may need additional support (e.g., volunteers, facility) in their resource provision because of the expansion or temporary transformation of their organizational operations (Dynes 2002). In other words, the direction of resource flow might be constantly reversed as certain types of resources (e.g., information about the local need) are available from the affected neighborhoods.

In the existing research on organizational resource relationships, an inherent assumption is the scarcity of resources or the imbalanced allocation of resources, which leads to competition and power relationships between those organizations who control the resources and those who need the resources (McCarthy and Zald 1977; Pfeffer and Salancik 1978; Wry et al. 2013). However, in disaster response, scarcity of resources is less of a challenge than the effective match between those who need the resources and those who can provide them (Moore et al. 2003; Shepherd and Williams 2014). Moreover, even among response organizations, there may be unequal patterns of possessing and delivering resources to the affected neighborhoods. Similarly, the affected neighborhoods may exhibit different patterns of receiving resources such that the resources are delivered to a few neighborhoods more than others. Hence, a set of important research questions (RQs) beg to be answered. Answers to these questions are critical as they help inform a comprehensive understanding about how the human society adapts to environmental hazards.

RQ1: How does the network of resource provision evolve over phases of disaster response?
RQ2: What are the structural patterns of the network of resource provision?
RQ3: How do response organizations engage in resource mobilization in providing resources to the affected neighborhoods?
RQ4a: How does the network of resource receipt evolve over phases of disaster response?
RQ4b: What are the patterns of affected neighborhoods' receipt of different types of resources in different phases of disaster response and rebuilding?
RQ5: What are the structural patterns of the network of resource receipt?

This study employs the framework of community ecology view, coupled with the concept of community resilience, to examine how the emergent disaster response community that consists of response organizations and affected neighborhoods unfolds. As Bryant and Monge (2008) argued, employing a community ecology framework helps uncover not only the patterns of evolution but also the reasons of why the community has evolved as it has. In this study, we examine response organizations' *resource provision network* and affected neighborhoods' *resource receipt network* and through their changing resource relationships will derive a more informed pictured of the evolutionary process of the emergent disaster response community. The case studied is the incident of gas explosions that occurred in Kaohsiung, Taiwan in July 2014. Data were collected through two rounds of survey with the leaders of the affected neighborhoods, and a survey with the response organizations.

This paper first reviews the literature on community ecology, organizational resource relationships, and community resilience and explains the development of hypotheses. Detailed procedures of how to collect and analyze multiple sources of data are provided in the method section. The results of the analyses are presented afterwards, with the aim of enhancing theoretical and societal understandings about the evolving and co-evolving resource relationships in the emergent disaster response community.

An Ecological and Evolutionary Perspective of Resource Networks

The focus of organizational ecology is on the process of how organizations survive and prosper by means of interacting with other members in their communities and populations as well as interacting with their environments (Baum and Shipilov 2006; Hannan and Freeman 1977). Populations comprise of constituent organizations exhibiting similar organizational forms (e.g., providing similar resources), and a community consists of multiple populations of organizations. In particular, an organizational community survives and prospers on a shared resource environment, and encompasses populations, which are defined by distinct functional roles within the community yet develop interdependent relationships with one another (Astley 1985; Monge et al. 2008). Emergence and evolution of an organizational community is then built on the evolution and co-evolution between populations (Baum and Rao 2004). For example, a community of environmental activism is founded and evolves with the establishment, growth, and interaction between and among nonprofit organizations, public agencies, citizen-based groups, and private businesses. They represent different populations based on their distinct functional requirements in fulfilling this common social mission.

In sum, the framework of community ecology considers different forms of resource-dependent relationships between populations of organizations, which becomes the basis for the emergence and evolution of organizational communities (Aldrich 1999). As such, the framework of community ecology provides the theoretical reasoning of why populations and communities originate and dissolve; it also highlights the fluid form of community resulting from interaction between homogeneous organizations *within* populations as well as interaction *between* heterogeneous populations (Astley 1985). However, as far as the framework of community ecology is useful to explain the dynamic interdependence between populations of organizations, an often overlooked aspect is the role of geographically based neighborhoods, which could also be regarded as a population with which different populations of organizations interact and engage in resource relationships. This overlooked aspect is especially salient in the disaster response context as both organizations and affected neighborhoods are involved in intensive resource relationships after a disaster.

In fact, in the existing research in community ecology, organizational behavior is mostly addressed from the standpoint of the organization (Marquis et al. 2007; Tilcsik and Marquis 2013). Hence, there is a lack of theoretical and empirical consideration about resource relationships from both the perspectives of organizations and geographically based neighborhoods. Accordingly, in the disaster context, an important question remains as to how a response community, consisting of populations of response organizations and affected neighborhoods, emerges after a disaster and evolves over time. In the next section, building on community ecology, along with the literature from organizational resource relationships and community resilience, we explain the possible evolutionary and structural mechanisms of resource networks in disaster response.

Evolution of Disaster Response Networks

Disaster can be seen as a radical environmental event that serves as a source of variation contributing to the interaction between social entities and thus the emergence of an organizational community (Hawley 1986; Tushman and Romanelli 1985). After a disaster, resources are needed and response organizations are involved in fulfilling the needs for resource supply; this change in resources in the environment creates the population of resource suppliers (response organizations) and the population of resource recipients (affected neighborhoods). Communication networks figure prominently in community ecology because communication enacted between organizations is integral to the evolution of the population and the community (Monge et al. 2008). In the disaster context, resource exchange is constitutive of communication, and hence, the networks of resource provision and resource receipt represent the enactment of interaction between these two populations. Together, they constitute an emergent disaster response community. Instead of being predefined, the resource space is filled by what the response organizations do in spontaneously creating operating domains. The direction of resource flow between populations can also change dynamically, as the situation demands.

Building on network thinking in community ecology (Bryant and Monge 2008; Lee and Monge 2011; Shumate et al. 2005; Shumate and O'Connor 2010), we consider how the evolution and co-evolution of response organizations' network of resource provision and affected neighborhoods' network of resource receipt together shape the emergence and evolution of the disaster response community. Bryant and Monge (2008) proposed that significant environmental events facilitate initial relationships formed between populations, or the formation of a community. At that point, networks significantly change from one period to the next. When the community moves into the later more self-sufficient and stable stage, the network relationships between populations do not significantly alter. However, in the disaster context, the emergent response community may follow a different evolutionary pattern.

After a disaster, response organizations and affected neighborhoods may take shape as two different populations and develop symbiotic relationships with one another because they have different concerns and needs for resources, which together constitute an emergent disaster response community. After the triage is over, the need for response and rebuilding might change. Populations are likely to transform or dissolve as those temporary response organizations resume their routine operations. In other words, the emergent disaster response community might exhibit intensive communication exchanges early on, followed by a decreased level of interaction between populations. On the side of response organizations, we first develop a hypothesis to examine the evolutionary patterns of the network of resource provision.

H1 The networks of resource provision are more similar in the earlier phase of disaster response than in the later phase.

Organizations' Resources and Capacities

Formation and evolution of multi-organizational response networks has been the focus of disaster research in the past thirty years (e.g., Comfort and Haase 2006; Kapucu 2005; Moore et al. 2003; Nolte and Boenigk 2013; Topper and Carley 1999; Wolbers et al. 2013). A common observation is that after the immediate response stage, several clusters of response organizations emerge, including traditional players, such as emergency response organizations and public agencies, as well as ad hoc citizen-based organizations that are directly involved in responding and providing resources to the affected neighborhoods (Dynes and Quarantelli 1968; Harris and Doerfel 2016). Organizations within the same clusters interact with one another more frequently due to similar tasks or institutional types (Butts et al. 2012). As time evolves, the network of response organizations may become centralized among key coordinators in charge of response operations, and at the same time, become distributed with several clusters of organizations emerging on the periphery in response to new demands and tasks (Topper and Carley 1999).

During the disaster response, the number of clusters, organizations' position within and across clusters, as well as their patterns of interaction with others change over time, depending on the resources, activities, and tasks carried out by response organizations, and the contingencies of the disaster (Butts et al. 2012; Noori et al. 2016). However, in this line of work, the focus is often on coordination and collaboration between response organizations, with less attention to the direct examination of organizations' resources provided to the affected neighborhoods. As a result, little is known about the extent to which activation of organizational response networks reveals different patterns of interaction with affected neighborhoods.

According to the framework of community ecology, organizations or populations of organizations possess varied capacities to procure resources and exploit these resources in the environment ("niche") in order to survive (Freeman and Audia 2006; Hannan and Freeman 1977). In disaster response, it is possible that a few response organizations occupy a wider niche in the environment by consistently providing multiple resources to the affected neighborhoods, in other words, a tendency toward a centralized network structure. For example, Choi and Kim (2007) found that organizations with resources in undertaking certain functions for relief operations were perceived as the central actor in the emergency response networks. The possession of resources may be related to organizations' scale of operations. Moore et al.'s (2003) study found that international non-governmental organizations (NGOs) tended to occupy more central positions in the interorganizational relief network, while local NGOs were relatively peripheral in the relief network. Moreover, a potential clustering structure might be observed as central response organizations also tend to provide popular resources due to the nature of the disaster and the context of the locality (Noori et al. 2016; Topper and Carley 1999). Building on existing research examining disaster response networks and the framework of community ecology, we develop two hypotheses, examining the structural patterns of response organizations' resource provision network.

H2a The network of resource provision will exhibit a structural tendency toward centralization.

H2b The network of resource provision will exhibit a structural tendency toward clustering.

In the disaster context, the network structures of response organizations have implications for resource delivery. If organizations possessing critical resources do not have adequate connections to the other organizations, it poses cracks in the delivery of post-disaster support and services to the affected neighborhoods (Gillespie and Murty 1994). It is known that response organizations tend to connect with their existing contacts for important information necessary for relief operations (Abbasi 2014). Due to the emergent nature of the post-disaster situation, however, response organizations might also receive informational and human resources from individuals or organizations in the affected area, especially those residents or organizations who are less affected by the disaster (Kendra and Wachtendorf 2003a; Shepherd and Williams 2014; Voorhees 2008). In fact, some of the response organizations themselves may be affected by the disaster. Compared with public and for-profit organizations, local community-based and nonprofit organizations are often limited by economic or human resources despite the coveted knowledge about the local circumstances; hence, cross-sector collaboration is inevitable and necessary for those local response organizations to achieve the goal of resource provision (Chikoto et al. 2012; Simo and Bies 2004). Moreover, within the population of response organizations, some organizations are volunteer based and with no pre-disaster existence; they often coalesce to manage resource interdependencies between affected neighborhoods and more established response organizations (Dynes and Quarantelli 1968). Those organizations may be in need of recruiting volunteers, who are either affiliated with established organizations or working in an ad hoc manner, from inside and outside the affected area (Kulik et al. 2016).

Community ecology emphasizes the interdependent relationships between populations of organizations and the social structures in which they are embedded (Freeman and Audia 2006). Extending this conception to disaster response, it is clear that response organizations engage in the process of resource mobilization in their resource provision, and some of these resources may be acquired from other entities within or outside the affected area, and other resources may be originally held by the organizations (McCarthy and Zald 1977). It is thus important to examine how organization mobilizes resources necessary for their relief operations, which in turn influence their resource provision. It is possible that if response organizations receive diverse resources for their relief operations, including those from the affected area and other organizations, they are likely to provide more resources to the affected neighborhoods.

H3a Response organizations receiving resources from diverse entities are likely to provide more resources to the affected neighborhoods than those organizations who did not or receive fewer resources.

The capacity of mobilizing resources may be related to organizations' inherent attributes (e.g., type, size) (Nah and Saxton 2013). In the ecological vocabulary, similarities in organizational attributes such as organizational type can be treated as the structural parameters in defining resource spaces in which organizations occupy (Freeman and Audia 2006). In disaster response, Singer and Kegler's (2004) study found that the intensity and density of collaboration involved in lead position prevention in a Native American community was larger for organizations of similar types. Moore et al. (2003) found that NGOs from outside the affected country tended to have a higher number of beneficiaries for disaster response. Moreover, prior experience with disaster relief may influence the delivery of relief support (Nolte and Boenigk 2013). Less experienced organizations may engage in specialization to avoid competition with large incumbent organizations (Soule and King 2008). It is possible that a group of inexperienced organizations may provide resources that are different from those provided by the more experienced organizations in supporting the affected neighborhoods. Two hypotheses investigate the effects of organizational attributes on response organizations' resource provision.

H3b Organizations of similar types are likely to provide similar types of resources to the affected neighborhoods after a disaster.

H3c Organizations with similar prior experience in disaster relief are likely to provide similar types of resources to the affected neighborhoods after a disaster.

Neighborhoods' Adaptive Resilience

Disaster causes resource mobilization because of deterioration or loss of resources by the affected neighborhoods (Norris et al. 2008). However, while a disaster brings disruption and disorder, it could also stimulate a neighborhood's cooperative spirit and absorptive capacities (Kreps and Bosworth 2007). The concept of resilience refers to the capacities of social units (e.g., organizations, neighborhoods) going through the hazard cycle: to mitigate hazards before they happen, to absorb the effects of hazards when they occur, and to recover with minimal social disruption while mitigating the effects of future hazards (Bruneau et al. 2003; Cutter et al. 2008). These hazards are perceived and dealt with as they fall outside the range of disturbances the social unit can handle (Boin et al. 2010). In Norris et al.'s (2008) model of community resilience, they define community resilience as affected neighborhoods' engagement in adaptation and rebuilding efforts after an environmental disturbance. According to Norris et al. (2008), affected neighborhoods experience loss of resources after disasters; thus, networked capacities represent the affected neighborhoods' ability to mobilize resources and use the resources for adaptation. However, in their work, there is little mention of the temporal requirements of these networked capacities in different phases of the hazard cycle.

More recent conceptualizations of resilience attempt to unpack required capacities by taking into account the temporal characteristics of social infrastructure. As Comfort et al. (2010) pointed out, even during the same disaster event, resilience may embody an enduring and dynamic process of balancing risk against resources and between vulnerability and escalating disasters. According to Tierney (2014), resilience is manifested in the preexisting social arrangements (e.g., emergency planning, residents' community participation) as well as in the post-disaster adaptation (e.g., mobilization of support and resources). The former (inherent resilience) encompasses the inherent conditions, characteristics, and properties of a social entity to cope with disasters, whereas the latter (adaptive resilience) refers to the resourcefulness and the ways a social entity overcomes disruptions induced by disasters (Tierney 2014). In Cretney's (2016) study, a community organization facilitated adaptive capacity by serving as a source for the development of residents' collective social memory and social learning from the current disaster to prepare for future threats. Specifically, this organization fostered the coping and response capacities by serving as a hub to provide social support through reconnecting existing ties and building new ties among residents, as well as an avenue for residents, especially untrained volunteers, to participate in relief assistance after the disaster. Because of the focus on post-disaster resource networks, we follow Tierney's (2014) definition of adaptive resilience in this study.

According to Tierney (2014), inherent and adaptive resilience may evolve differently immediately after the disaster and during the recovery phase. Echoing the conception of evolution from the framework of community ecology, it is thus argued that affected neighborhoods' adaptive resilience may be understood and assessed through the temporal change in their receipt of resources. Differentiating community sport clubs' receipt of resources for short-term and long-term recovery, Wicker et al. (2013) study found that those sport clubs' acquisition of human resources (club members and volunteers), social resources (interorganizational relationships), and access to financial resources (government grants) was positively associated with resilience and recovery, but these resources were used significantly more for short-term recovery. Moreover, instead of passively receiving resources, later on, these sports clubs in turn provided support to other local organizations who helped them during the disaster (Filo et al. 2015). In other words, immediately after the disaster happens, there is an influx of support from individuals and organizations, who attempt to provide support to the affected neighborhoods (Kendra and Wachtendorf 2003b). However, in the later phase of disaster response, the composition of resource contacts and resource types may change because response organizations from outside the area may resume their original operations and leave the site, which will reveal a different pattern of resource provision and resource receipt. Building on the framework of community ecology to theorize how adaptive resilience is manifested across phases of disaster response, we develop a hypothesis, examining the evolutionary patterns of affected neighborhood's network of resource receipt.

H4 The networks of resource receipt are more similar in the earlier phase of disaster response than in the later phase.

In disaster response, it is not uncommon to see the challenges of delivering customized or needed products and services timely for the affected individual and neighborhoods (Moore et al. 2003; Shepherd and Williams 2014). As Tierney (2014) argued, there is an automatic tendency to assess an affected neighborhood's resilience after disasters uniformly on an aggregate level; however, even within an affected area, different boroughs may exhibit different levels of resilience due to severity of disaster damage in different locations, and preexisting vulnerabilities (e.g., socioeconomic status of residents), and the ways post-disaster assistance and recovery progress. For affected neighborhoods, they may develop dependence and power relationships with response organizations due to resource provision, which may be reflected in their network structure of resource receipt. Filo et al. (2015) examined local sport clubs' recovery from the perspective of relationships with resource providers. Specifically, they found that with volunteers and community members and partner organizations (sponsors, local businesses, other sport and community clubs), local sport clubs developed interdependent relationships characterized by mutual power and dependence. However, the relationships with governments (local and state government representatives) were more asymmetrically dependent, for example, dictating the terms of how land rebuilding should proceed.

Compared with research on the network structure of response organizations, there is little theoretical and empirical attention paid to affected neighborhoods' network structure derived from their interaction and relationships with resource providers. It is possible that during a disaster, a few affected neighborhoods may receive more resources than others, that is, a tendency toward a centralized structure. These few neighborhoods may also receive resources from a few popular resource contacts, indicating a tendency toward clustering. Hence, we develop two hypotheses, examining the structural patterns of affected neighborhoods' network of resource receipt.

H5a The network of resource receipt will exhibit a structural tendency toward centralization.

H5b The network of resource receipt will exhibit a structural tendency toward clustering.

Method

Research Context

This study focuses on a technological disaster as the research context to examine response organizations and affected neighborhoods' resource networks. On the evening of July 31, 2014, a series of gas explosions caused by a propene leak happened to Kaohsiung City, a metropolitan city in the southern part of Taiwan, and two districts (covering 23 neighborhoods) were the major affected area (BBC News 2014). The culprit was believed to be the pipelines used for gas delivery to the petrochemical factory owned by LCY Chemical Corp. This incident caused 32 deaths and more than 300 injured people, and severe damages were imposed on the infrastructure such as the roads, the drainage system, and the neighborhood buildings. Some of the deaths were first responders, which probably accounted for the conspicuous mobilization efforts from private and nonprofit sectors or even ad hoc organizations coming to the aid of the affected neighborhoods. At the night of the incident, more than 12,000 people were evacuated to makeshift shelter centers. In addition to nonprofit organizations coming from everywhere around the country, businesses in the city offered temporary lodging, food, or supplies to help the survivors, and volunteers were mobilized locally as well as in the online domain for rescue information identification and fundraising. More than 1000 local shops were affected due to the damaged roads and the reconstruction that followed.

Data Collection

This study draws on a face-to-face survey with the affected neighborhoods at two time points and a survey with the response organizations. The first survey was conducted in November 2014 with twenty-three neighborhood magistrates ("lee chang") representing the affected districts, and 19 of the magistrates were followed up in the second survey, which was conducted in August 2015, a year after the incident. The absence of the four magistrates at the second round of data collection was due to their lack of interest or the excuse of time costs. The neighborhood magistrates are considered most knowledgeable about the resource receipt at the local neighborhood level because they are in charge of neighborhood affairs and resource exchanges usually go through them to deliver to the residents. The first survey included both close-ended and open-ended questions, asking neighborhood magistrates' reactions after the incident in their capacity as the local leader, the channels used for receiving and sharing information, and solicitation and receipt of social support. The second survey focused on the receipt of support from different resource contacts and the situation of rebuilding.

The data from the response organizations were collected through a survey that was administered through both online and mail formats from December 2014 to February 2015. The list of 101 organizations involved in the response actions of this incident was developed from multiple sources, including self-organized Web sites/ Facebook groups that formed after the incident, the first-round survey with the neighborhood magistrates, and the municipal agency in charge of social affairs. Invitations were sent to all of the 101 organizations and 27 organizations responded and completed the survey (response rate = 26.7%). In the invitation letter, we specified to invite the personnel in charge of disaster relief for this particular incident to complete the survey. A non-response bias analysis was conducted, comparing 27 responding and 74 non-responding organizations in terms of organizational type, and no significant difference was found [$\chi^2(6) = 8.00$, $p = .238$].

Measurement

This study uses a two-mode network analysis to analyze response organizations' communication relationships with the affected neighborhoods through resource provision and resource receipt. Here is an example of a two-mode network, which represents 15 members who participate in 10 social clubs. Two approaches can be used to analyze two-mode network data. The first approach is to analyze the rectangular matrix (15×10) directly, examining the relationships between members and the social clubs they attend. This approach can also reveal the network structure among this set of members based on their pattern of participation in certain social clubs, and the network structure among the social clubs based on the pattern of the attending members. The second approach is to conduct analysis on the relationships indirectly by converting the two-mode network data into two one-mode networks (15×15 members, 10×10 clubs), capturing the indirect relationships between members based on their common participation in certain social clubs, and the indirect relationships between social clubs based on the common members they attract. Compared with the second approach, the first approach fits the purpose of this study for theoretical and methodological reasons. In line with the community ecological framework, the direct two-mode network analysis helps inform not only the relationships between organizational populations (i.e., between response organizations and affected neighborhoods), but also the structural pattern within each population (i.e., among response organizations, among affected neighborhoods) based on their interaction with the entities in the other population. The direct two-mode network analysis is also considered a better approach because it can help avoid the potential biased estimations among nodes' contacts that could arise from conducting analysis on transformed one-mode network data (Borgatti and Halgin 2011; Opsahi 2013).

Resource Provision

Existing research has defined different phases of post-disaster response and recovery, and the time points are often determined by the context under study (e.g., Doerfel et al. 2010). In this study, the temporal phases were determined differently for response organizations and affected neighborhoods. Moreover, research on collaboration and coordination between response organizations usually categorizes resource support in terms of functions, such as food, telecommunications, emergency shelter (Kapucu 2011), or in the form of response operations, such as search-and-rescue, medical care, and shelter (Comfort and Haase 2006), or as types of support, such as tangible, emotional, and information support (Finch 2016). Modifying these existing categories to fit the context of this study, which is a technological disaster, in the survey, response organizations were asked whether they provided the following 10 types of resources to the affected neighborhoods immediately ($T1$), the first month ($T2$), and the second month after the incident ($T3$) ($0 =$ no, $1 =$ yes): *materials* (e.g., food), *water and electricity*, *information about volunteers*, *information about the consequences of gas explosions*, *consoling, shelters*, *medicine*, *medical services*, *clean-up services*, and *financial/insurance* *assistance* ($T1$, $M = 2.56$, SD $= 2.04$; $T2$, $M = 1.11$, SD $= 1.72$; $T3$, $M = 0.78$, SD $= 1.34$). For each time period, a rectangular two-mode network matrix (27×10) was created, where the rows represent the 27 response organizations and the columns represent the 10 resource types. In the matrix, a "1" was entered in the cell when the focal organization reported to provide the specific resource type during that period. Three matrices (27×10) were created to examine response organizations' resource provision at three time points. These two-mode network matrices not only examine the pattern of response organizations' resource provision for affected neighborhoods; they could also help identify opportunities for organizations' interaction. If organizations provide multiple types of resources, they are more likely to interact with one another and collaborate for relief operations (Nolte and Boenigk 2013).

Resource Receipt of Response Organizations

In the survey, we asked response organizations to indicate whether they received resources in three phases of their relief support from any of the following nine resource contacts, including: *individuals from the affected area, nonprofit organizations (e.g., faith-based organization) from the affected area , individuals outside the affected area, nonprofit organizations outside the affected area, businesses from the affected area, businesses outside the affected area, local government or public agencies, central government or public agencies,* and *news media* ($0 =$ no, $1 =$ yes). For each time point, the scores were summed from the response to the nine resource contacts. These categories of resource contacts were adapted from existing research (Lai et al. 2015; Doerfel et al. 2010). Three continuous variables were created to represent response organizations' receipt of resources immediately ($T1$, $M = 2.19$, SD $= 2.75$), the first month ($T2$, $M = 1$, SD $= 2.08$), and the second month after the incident ($T3$, $M = 0.86$, SD $= 2.05$).

Attributes of Response Organizations

To analyze type similarity, all of the 27 organizations were classified into the following four categories: $1 =$ nonprofit ($n = 8$), $2 =$ business ($n = 15$), $3 =$ education ($n = 2$), and $4 =$ government agency ($n = 2$). In the survey, organizations were asked whether they had prior experience participating in disaster relief, where $0 =$ no ($n = 12$) and $1 =$ yes ($n = 15$). For categorical estimation, we recoded this variable, where those organizations with no prior experience in disaster relief were coded 1 and others coded 2.

Affected Neighborhoods' Resource Network

In the first survey with the neighborhood magistrates, they were asked whether they received resources within the first month after the incident from the same nine resource contacts used in the survey with the response organizations, plus *self-organized ad hoc groups from or outside the affected area* (e.g., a group of volunteers). The last category was added for the neighborhood survey primarily because of the observation of the prevalence of several volunteer groups on social media in providing support to the affected neighborhoods after the incident (Starbird and Palen 2011). The second round of survey included these 10 resource contacts, but broken into three time points with four months as intervals up to one year after the incident, which paralleled the temporal focus in the media coverage of this incident over time.

To ensure a systematic comparison in analyzing the structure of the resource receipt network, only the responses from those 19 magistrates who completed both rounds of survey were included to calculate the receipt of resources across different time points, including the first month ($T1$) ($M = 1.63$, SD $= 1.26$), the first four months ($T2$) ($M = 4.11$, SD $= 2.47$), the second four months ($T3$) ($M = 2.63$, SD $= 1.67$), and the third four months after the incident ($T4$) ($M = 2.58$, SD $= 1.64$). Compared with the 19 neighborhoods included in the analysis, the average resource ties at $T1$ among the 23 neighborhoods were lower at 1.65 (SD $= 1.37$), but the difference was not significant [$t(40) = 1.319$, $p > .10$].

For each of the four time points, a rectangular two-mode matrix (19×10) was created where the rows represented the affected neighborhoods and the columns represented the 10 types of resource contacts. In the matrix, a "1" was entered in the cell when the focal neighborhood reported to receive resources from the specific resource contact type during that period. In total, four matrices (19×10) were created to examine affected neighborhoods' resource network at four time points. These network matrices examine affected neighborhoods' interaction with resource contacts; they could also help identify whether there is any equal or unequal pattern among affected neighborhoods in terms of the distribution of the number of resource contacts. Additionally, in the second survey, the magistrates were asked to indicate the resource types received from each of the 10 resource contacts, including *human resources*, *information*, *financial resources* (e.g., money), *materials* (e.g., donated supplies, food), *emotional support*, and *other*. These categories were developed based on existing research, which classifies social support into tangible, financial, emotional, and information support (Sherbourne and Stewart 1991; Vaux et al. 1987). We modified these categories to better reflect the context of post-disaster recovery (Wicker et al. 2013). Three matrices (10×6) were created to identify the patterns of co-occurrence among the resource contacts and the resources they provided to the affected neighborhoods at three time points.

Network Data and Analysis Procedures

We used the exponential random graph model (ERGM) method because it permits the examination of both attribute and structural influences on tie formation simultaneously (Shumate and Palazzolo 2010). Tie formation is the equivalent of dependent variables in conventional statistical models. The network ties examined in this study are those formed between response organizations and the resource types they provided, and between affected neighborhoods and the resource contacts that provided resources to them. PNet is a program used for ERGM analysis through Monte Carlo Markov chain likelihood estimation to maximize the probability of generating the network that fits the observed network by producing convergent estimates (Robins et al. 2007). In other words, it is to examine the likelihood of observing hypothesized network configurations in a network. Each hypothesized network configuration is estimated and the parameter estimate more than twice its standard error is considered significantly different from zero (Robins et al. 2007). As with logistic regression, if the parameter of the hypothesized network configuration is positive, this configuration appears more significantly frequently than random chance. Parameter estimates are interpreted in terms of the log-odds of a tie observed between actors.

In a well-fitting model, the convergence *t*-ratio for each estimated parameter should be less than 0.1 in absolute value (Robins et al. 2007). After the model converges (with all *t*-ratios less than 0.1), the goodness-of-fit estimates are then obtained by comparing the observed network to the simulated models using the estimated parameter values (Goodreau 2007). The goodness-of-fit indicates the degree to which the estimated model provides a good explanation for the observed network as well as for additional network dimensions not included in the model. The convergence statistics for the estimated parameters should be less than 0.1. For non-estimated parameters, if the convergence statistic values are between 1 and 2, it indicates a plausible fit, and a good fit if the statistics are less than 1 (Shumate and Palazzolo 2010).

BPNet, an extension of PNet, was used to analyze the two-mode networks investigated in this study because it allows for the examination of the other two-mode networks simultaneously into the model (Wang et al. 2009). In the organizational dataset, the models including both lower and higher order parameters did not converge. Hence, the results relied on the estimates of the higher order parameters. For the similar reason, in the neighborhood dataset, the first model representing the resource receipt network one month after the incident relied on the estimates of the higher order parameters.[1] Higher order parameters involve more than three nodes in network configurations (Robins et al. 2007).

Each of the parameters in the models (Tables 1, 2) represents different configurations in the observed network. Specifically, we examined that, after controlling for the density of ties in the network, how the earlier network, the distribution of central and peripheral actors, the presence of dense clusters, and other attribute factors (in the organizational dataset) influence tie formation between response organizations and the resource types they provided and that between affected neighborhoods and their resource contacts. The density (or edge, in ERGM term) is commonly used as a control variable in two-mode networks (Zhu et al. 2013). Density refers to the state of connections that are actually made relative to the maximum potential number of ties in the network. To test H1 and H4, a significant and positive network prediction (EdgeAB) would suggest that the earlier resource network (resource provision, resource receipt) predicts the formation of the subsequent network (see Fig. 1a). In testing H2a, structural tendency toward centralization in response organizations' resource provision network was examined

[1] For models that could not converge with both higher- and lower-order parameters included, we used the Mahalanobis distance in deciding the inclusion of higher- or lower-order parameters and selecting the best models. In general, the model with a larger Mahalanobis distance provides a poor fit to the data because the observed network is far away from the center of the simulated graph distribution generated by the ERGM analysis (Wang et al. 2009).

Table 1 Results of BPNet estimation for the response organizations' network of resource provision

		*T*1 (immediately after)		*T*2 (1st month after the incident)		*T*3 (2nd month after the incident)	
		Model 1		Model 2		Model 3	
		Estimate/SE	*t*-ratio	Estimate/SE	*t*-ratio	Estimate/SE	*t*-ratio
Density (control)		−5.304 (1.614)*	−0.011	−5.419 (1.429)*	−0.048	−5.560 (1.167)*	0.043
Resource provision at *T*1 (EdgeAB)	H1	–	–	**3.542** (**0.651**)*	**−0.066**	0.916 (0.871)	−0.033
Resource provision at *T*2 (EdgeAB)	H1	–	–	–	–	**3.175** (**0.789**)*	**0.026**
Response org centralization (K-Sa)	H2a	−0.092 (0.591)	0.022	**2.712** (**0.834**)*	**−0.051**	−0.025 (1.088)	0.043
Resource type centralization (K-Sp)	H2a	1.161 (0.854)	−0.017	−0.990 (1.012)	−0.047	1.161 (1.244)	0.021
Response org clustering (K-Ca)	H2b	**0.605** (**0.282**)*	**0.091**	−0.736 (0.467)	0.009	0.263 (0.548)	0.033
Resource type clustering (K-Cp)	H2b	0.116 (0.076)	−0.027	**0.458** (**0.200**)*	**−0.012**	−0.307 (0.586)	0.002
Resource receipt at *T*1[a]	H3a	**0.184** (**0.073**)*	**0.088**	−0.108 (0.069)	−0.039	0.116 (0.123)	−0.022
Resource receipt at *T*2	H3a	–		**0.409** (**0.116**)*	**−0.041**	0.198 (0.166)	0.061
Resource receipt at *T*3	H3a	–		–	–	−0.137 (0.207)	−0.008
Response org-type similarity	H3b	−0.012 (0.130)	0.005	−0.568 (0.370)	−0.010	0.467 (0.462)	−0.025
Response org experience similarity	H3c	**0.196** (**0.080**)*	**0.033**	−0.015 (0.207)	−0.025	−0.302 (0.452)	−0.017

SE standard errors. When including both lower-order and higher-order parameters, models 2–3 did not converge. With only lower-order parameters, model 3 had problems with degree distribution. Hence, the higher-order parameters were estimated for all three models

[a] Resource receipts at three time points were significantly and moderately correlated ($r_{sT1\text{-}T2} = .409$, $p < .05$, $r_{sT2\text{-}T3} = .524$, $p < .01$, $r_{sT1\text{-}T3} = .257$, $p > .10$)

* Parameters in bold were significant ($p < .05$)

Table 2 Results of BPNet estimation for the affected neighborhoods' network of resource receipt

		*T*1 (1st month)		*T*2 (1st four months)		*T*3 (2nd four months)		*T*4 (3rd four months)	
		Model 1[a] Estimate/SE	*t*-ratio	Model 2 Estimate/SE	*t*-ratio	Model 3 Estimate/SE	*t*-ratio	Model 4 Estimate/SE	*t*-ratio
Density (control)		−3.374 (0.759)*	0.031	4.286 (1.698)*	−0.035	−6.456 (1.951)*	−0.064	−7.505 (2.084)*	0.020
Resource network at *T*2[b] (EdgeAB)	H4	–	–	–	–	**2.771 (0.662)***	**−0.031**	**3.497 (1.636)***	**0.034**
Resource network at *T*3[b](EdgeAB)	H4	–	–	–	–	–	–	**5.437 (1.378)***	**−0.050**
Neighborhood centralization (Sa2)	H5a	–	–	**4.175 (1.610)***	**0.023**	0.357 (0.876)	−0.047	−1.552 (1.772)	0.004
Resource contact centralization (Sp2)	H5a	–	–	**2.541 (0.653)***	**−0.047**	**3.017 (1.300)***	**−0.038**	1.126 (1.983)	0.007
Neighborhood centralization (Sa3)	H5a	–	–	**−0.687 (0.324)***	**0.055**	−0.199 (0.360)	−0.040	0.663 (0.374)	−0.006
Resource contact centralization (Sp3)	H5a	–	–	**−0.171 (0.057)***	**−0.040**	−0.061 (0.066)	−0.039	−0.060 (0.228)	−0.017
Neighborhood centralization (K-Sa)	H5a	**1.138 (0.458)***	**−0.008**	**−4.992 (2.422)***	**−0.018**	0.755 (0.970)	−0.049	3.443 (2.149)	0.012
Resource contact centralization (K-Sp)	H5a	0.419 (0.564)	0.001	**−5.839 (1.320)***	**−0.040**	1.009 (1.271)	−0.059	0.708 (2.136)	0.050
Clustering (L3)	H5b	–	–	**−0.115 (0.022)***	**−0.036**	**−0.098 (0.032)***	**−0.054**	−0.121 (0.068)	0.019
Clustering (C4)	H5b	–	–	0.134 (0.097)	−0.043	−0.548 (0.490)	−0.039	0.095 (0.708)	0.024
Neighborhood clustering (K-Ca)	H5b	−0.709 (0.521)	0.025	0.665 (0.523)	0.054	0.957 (1.010)	−0.045	−0.278 (1.530)	−0.020
Resource contact clustering (K-Cp)	H5b	0.187 (0.112)	−0.026	−0.676 (0.420)	−0.019	−2.539 (1.394)	−0.034	−0.686 (1.961)	−0.006

SE standard errors

[a] When including both lower-order and higher-order parameters, model 1 did not converge. Including only lower-order parameters resulted in problems with degree distribution; hence, only the higher-order parameters were estimated

[b] To ensure consistent comparisons between models, the results reported in the table used *T*2 as the baseline for testing the temporal change in the resource network from *T*2 to *T*4

* Parameters in bold were significant ($p < .05$)

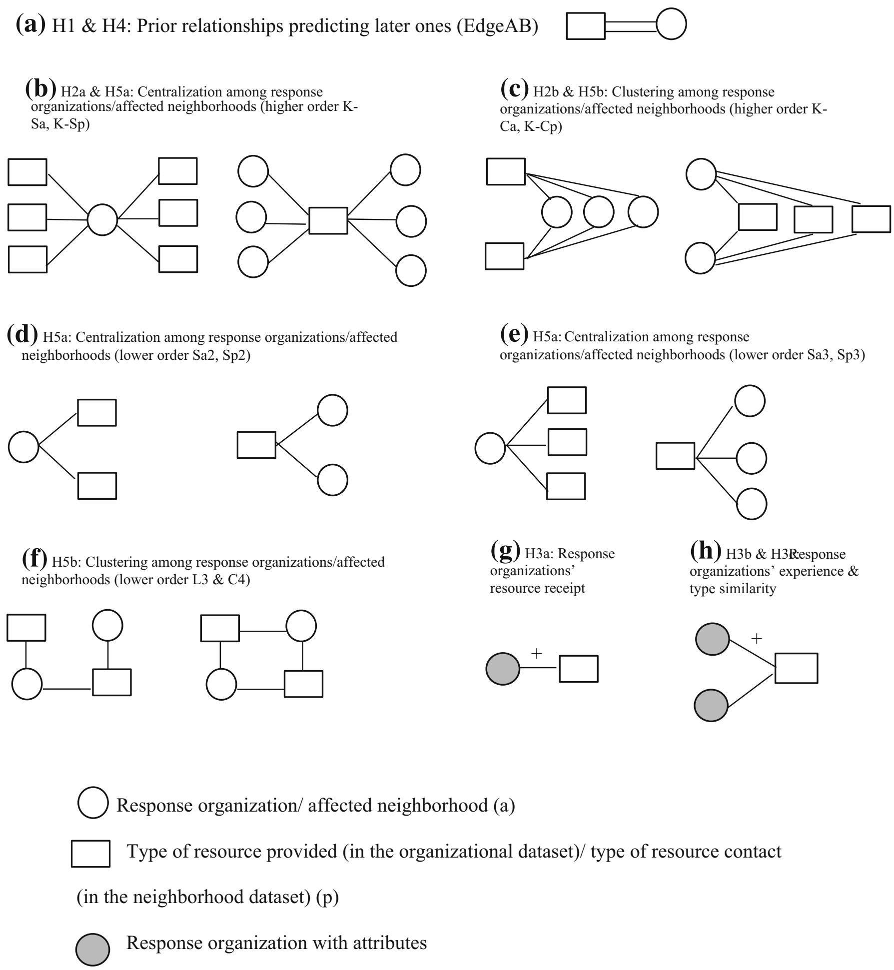

Fig. 1 Summary of network configurations included in the BPNet estimation

through the estimation of higher order alternating stars (K-Sa, K-Sp) (see Fig. 1b). Centralization refers to the situation where the connections among actors are unevenly distributed. A significant and positive K-Sa parameter would suggest the positively skewed degree distribution and the structural tendency toward centralization among a few active response organizations that provide multiple resource types to the affected neighborhoods. A significant and positive K-Sp effect would suggest centralization among a few popular resource types that are provided by multiple response organizations to the affected neighborhoods. H2b tested the clustering tendency in the network of resource provision. Clustering refers to the tendency where a few actors are all connected to one another, forming dense clusters within the network. Note that in the evolving two-mode networks, clustering tendency reflects actors' (e.g., response organizations) adaptation or agreement to connect to the nodes in another set (e.g., resource types) (Opsahi

2013). In this study, clustering was examined through the estimation of higher order two-path parameters (K-Ca, K-Cp) (see Fig. 1c). A significant and positive K-Ca would suggest that pairs of resource types tend to be provided by the same set of response organizations, and a significant and positive K-Cp refers to the situation where pairs of response organizations provide the same resource types to the affected neighborhoods.

The estimation of the following parameters is to test H5a and H5b with regard to the structural tendency in the network of resource receipt. Significant and positive Sa2, Sa3 and K-Sa parameters would suggest a certain level of concentration among a few central neighborhoods receiving resources from multiple resource contacts. Significant and positive Sp2, Sp3, and K-Sp parameters indicate a certain level of concentration among a few resource contacts that support multiple affected neighborhoods (see Fig. 1b, 1d, e). The clustering tendency was examined with the estimation of the three-path (L3), four-cycle (C4), and higher order two-path parameters (K-Ca, K-Cp) (see Fig. 1c, f). Significant and positive L3 and C4 would suggest that a few central neighborhoods are likely to be connected to popular resource contacts. A significant and positive K-Ca would suggest that pairs of resource contacts tend to provide resources to the same set of neighborhoods and a significant and positive K-Cp refers to the situation where pairs of affected neighborhoods share the same resource contacts.

H3a, H3b, and H3c tested the positive effect of response organizations' attributes on their resource provision for affected neighborhoods. These attributes are organizations' receipt of resources, organizational type, and prior relief experience. As illustrated in Fig. 1(g), the significant and positive effect indicates the tendency of response organizations that receive resources from more entities to provide more types of resources to the affected neighborhoods. Effects of similar organizational types and having similar prior relief experience on resource provision were examined as in Fig. 1h. To answer RQ4b, singular value decomposition (SVD) was conducted on the neighborhood data to identify the joint similarity among resource types and resource contacts simultaneously through UCINET (Borgatti et al. 2002). Similar to factor and component analysis, SVD is used to identify the underlying dimensions of the two-mode data by extracting factors (singular values). Due to space limitations, the visualization of the resource provision and resource receipt networks is available upon request.

Results

Resource Provision of the Response Organizations

The BPNet models for response organizations' resource provision network at three time points had a good fit, with the absolute values of the convergence statistics for estimated parameters below 0.1, and for additional parameters less than 1.[2] The

[2] Lower order parameters (for organizational dataset and 1st period of neighborhood dataset), standard deviation and skew degree distribution of both modes of nodes (response org/resource type, neighborhood/resource contact), and global clustering were included in assessing the goodness of fit. The goodness-of-fit results of all the models are available from the authors.

resource provision network at *T*1 significantly predicted the later network at *T*2 (3.542) (see Table 1). That means, the odds of organizations that provided resources at *T*1 also providing resources at *T*2 are 34.54 times (i.e., $e^{3.542}$) higher than for those with no resource provision at *T*1. In the meantime, the resource provision network at *T*3 was significantly predicted by that at *T*2 (3.175), but not *T*1 (0.916) (see model 3 in Table 1). As a result, H1 was supported because the resource provision network evolved in a way that networks at consecutive times significantly predicted one another, but the network at the last point of observation differed from that at the earliest time point.

At *T*2, the resource provision network exhibited the structural tendency toward centralization among a few highly active response organizations, which was shown by the positive and significant K-Sa parameter (2.712) (see model 2 in Table 1). But this centralization pattern was not observed at *T*1 (−0.092) and *T*3 (−0.025). No resource types were particularly popular, as shown by the insignificant K-Sp effects across three time points (1.161, −0.990, 1.161). H2a was thus not supported, suggesting a lack of consistent centralization tendency in the resource provision network. Nonetheless, there was a certain level of clustering in the resource provision network, as indicated by the significant K-Ca and K-Cp parameters at *T*1 (0.605) and *T*2 (0.458), but not for *T*3. In other words, at *T*1, certain popular resource types were commonly provided by response organizations and at *T*2, response organizations tended to cluster together by providing similar resources to the affected neighborhoods. In sum, H2b was partially supported because the results suggested that response organizations tended to provide similar resources to the affected neighborhoods only in the early phases of disaster response, in this case, immediately after and within one month of the incident.

Response organizations' receipt of resources from other entities served an important role immediately after the incident and within one month of the incident. With the increase in one type of resource contact at *T*2, the odds of response organizations providing relief resources at *T*2 is 1.51 times (i.e., $e^{0.409}$) higher than for those who received less support. If the response organizations received more support during a particular period of time, they were likely to provide more types of resource to the affected neighborhoods during that time. However, this influence of resource receipt was not observed at the last point of observation; hence, H3a was partially supported. In terms of organizational attributes, organizations of similar types were not more likely to provide similar resource types to the affected neighborhoods in all phases of disaster response; hence, H3b was not supported. At the same time, organizations with similar prior experience with disaster response were likely to provide similar resource types to the affected neighborhoods immediately after the incident, which was indicated by the significant parameter of 0.196. But this effect disappeared at later times, and H3c was thus partially supported.

Resource Receipt of the Affected Neighborhoods

The BPNet models for the affected neighborhoods' resource network across four time points had a good fit, with the absolute values of the convergence statistics for estimated parameters below 0.1, and for additional parameters less than 1. The significant effects of earlier networks predicting the later ones were observed; the resource networks at *T*3 and *T*4 reflected the networks at *T*2 (2.771) and *T*2 and *T*3 (3.497, 5.437), respectively (models 3–4 in Table 2). That means, H4 was partially supported because the resource receipt network exhibited the evolutionary pattern in ways that the networks at earlier times were similar to the later ones, even including the network at the last point of observation (i.e., one year after the disaster).

The positive and significant K-Sa parameter at *T*1 (1.138) indicates the tendency of centralization among a few central neighborhoods in terms of receiving resources from a diversity of contact types while others receiving resources from a limited set of contacts (see model 1 in Table 2). That means, the odds of observing the tendency where a few affected neighborhoods received support from multiple resource contacts while others only had few resource contacts are 3.12 times higher (i.e., $e^{1.138}$) than by random chance alone. However, moving to the first four months after the incident (*T*2), the combination of the positive Sa2 (4.175) and negative Sa3 (−0.687) effects suggests that affected neighborhoods received resources from multiple resource contacts but not too many contacts. At *T*2, the negative and significant K-Sa effect (−4.992) indicates the relatively equal distribution of resource ties among a few less connected neighborhoods. Later at *T*3 and *T*4, the concentration among a few central neighborhoods receiving support from multiple resource contacts was not observed.

Within the first month of the incident (*T*1), the insignificant K-Sp parameter (0.419) showed that no centralization was observed among a few resource contacts (see model 1 in Table 2). However, at *T*2, the results of the significant positive Sp2 (2.541) and negative Sp3 (−0.171) showed that a few resource contacts provided resources to several affected neighborhoods, but not too many neighborhoods. At *T*2, the significant and negative K-Sp effect (−5.839) presented the evidence of the equal distribution among a few less popular resource contacts. In sum, H5a was partially supported because in affected neighborhoods' resource receipt network, a few neighborhoods received resources from multiple contacts and a few resource contacts provided resources to multiple neighborhoods immediately after and within four months of the incident, but not so much after that. H5b was not supported because the only significant effect of clustering was the negative L3 parameter (*T*2 = −0.115, *T*3 = −0.098), indicating the tendency of a few central affected neighborhoods to not share popular resource contacts with other neighborhoods (see models 2–3 in Table 2).

RQ4b was answered through the SVD analysis and network visualization. Two factors accounted for 70.8%, 81.2%, and 79% of the total variance at *T*2, *T*3, and *T*4, respectively. Figure 2 is adjusted based on the mapping from the SVD analysis, in which nodes clustered together indicate a certain degree of co-occurrence. The network picture in the first four months echoes response organizations' account that we presented earlier where several organizations provided similar resources to the affected neighborhoods in the early phase of the response. As Fig. 2a shows, during the first four months, affected neighborhoods received similar resources—information—from multiple resource contacts. However, they also received material, financial, and human resources from nonprofit organizations and individuals outside

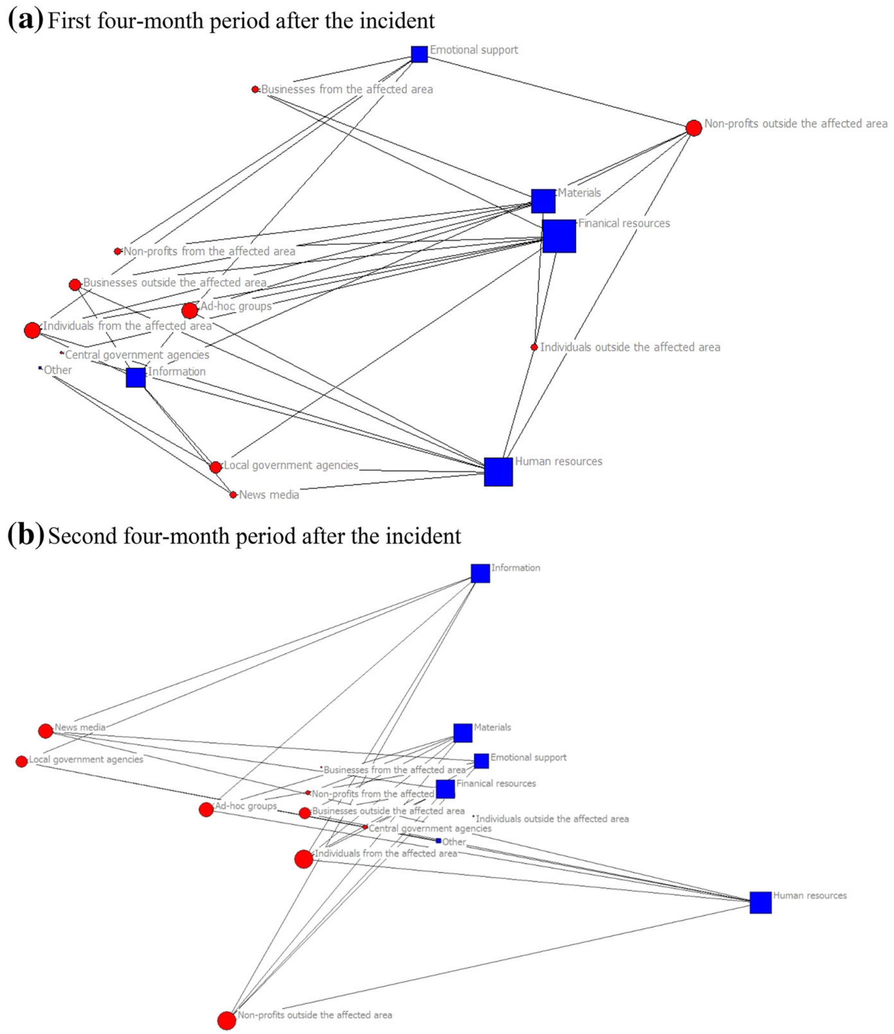

Fig. 2 Receipt of resources as reported by the affected neighborhoods over time. *Blue squares* represent the resource types, and *red circles* refer to the resource contact types. The node size has been adjusted to reflect the degree of centrality of the resource types and contact types (Color figure online)

the affected area. Businesses from the affected area were also mentioned as the major supplier of emotional, material, and financial resources. In fact, several of the response organizations participating in the survey were hotels that provided temporary places for residents to stay after the incident.

Moving on to the next two four-month periods, the types of resources received changed. Emotional support joined the cluster of financial and material resources, which were primarily provided by individuals from the affected area, ad hoc groups (mostly local), and nonprofit organizations from outside the affected area (see

(c) Third four-month period after the incident

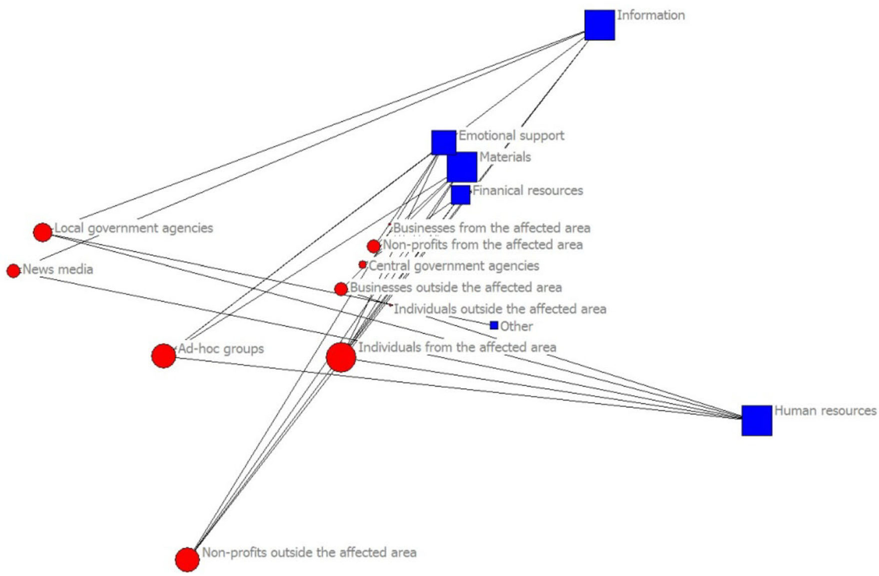

Fig. 2 continued

Fig. 2b, c). In particular, nonprofit organizations outside the affected area were critical in helping the affected neighborhoods in recovering and rebuilding, which may explain their location separated from other resource contact types in the network graph. At the same time, the local government and mass media continued as the main source of information for the affected neighborhoods one year after the incident. Together, these results suggest a different resource picture in the first four months than that in the eight months after the incident. Moreover, different types of resource contacts from the local area consistently played an important role in affected neighborhoods' rebuilding after the incident. It appears that informal volunteerism was enacted by local residents as well as local citizen-based ad hoc groups and for-profit organizations. Such informal volunteerism is considered key to community resilience (Whittaker et al. 2015).

Discussion

The organizational community that has been studied under the community ecology framework is usually of longer terms and with the goal of longevity. However, this study examines an emergent disaster response community that starts with an intensive level of communication and network activity and lasts for a short term. Although its growth and disbanding might be fast-paced, understanding how this emergent response community evolves over time has important implications for the resilience of human social systems.

By integrating the framework of community ecology and the concept of community resilience, our data show how the populations of response organizations and affected neighborhoods evolved and co-evolved through the changing relationships of resource provision and resource receipt. In particular, this study identifies the network mechanisms involved in the emergent response community from both the perspectives of response organizations and affected neighborhoods. It appears that because of the short term and the limited scope of technological disasters like the one investigated in this study, the intense resource-driven network unfolded within the few weeks after the incident, which was evident in both response organizations' resource provision and affected neighborhoods' resource receipt networks. This is the stage where a new population emerged (Astley 1985).

Immediately after the incident, the clustering tendency of certain response organizations providing similar resources to the neighborhoods was observed, which was partly due to their similarity in prior relief experience. After that, a few central response organizations were discerned, who tended to provide a similar set of resources to the affected neighborhoods. The neighborhood data also echo this result concerning the similar pattern of receiving similar resources from different resource contacts. In fact, through the provision and receipt of redundant resources, the local neighborhoods' resource network, alongside the formal emergency response network, can ensure a higher level of redundancy and thus resilience of the affected neighborhood (Harris and Doerfel 2016; Kendra and Wachtendorf 2003a).

Community ecology emphasizes the dynamics of interaction and interdependence between organizational populations (Freeman and Audia 2006). Findings of this study show that the structures of the resource provision network at subsequent time points ($T1 \rightarrow T2$, $T2 \rightarrow T3$) were similar to each other, which suggests that these response organizations might have learned and maintained their ways of providing resources to the affected neighborhoods. Moreover, response organizations' resource receipt from affected neighborhoods and other entities significantly predicted their resource provision immediately and one month after the incident. This demonstrates the enactment of mutual resource mobilization between response organizations and affected neighborhoods. In the meantime, this effect disappeared two months after the incident, which suggests that response organizations might have used their own resources or the accumulated resources received from earlier phases to support the affected neighborhoods. This was the point where the process of mutual resource mobilization became diluted and the temporary response community transformed into a post-disaster state where the transient population (response organizations) and the lasting population (local neighborhoods) resumed their routine operations and the relationships between populations changed accordingly.

The transformation of the emergent disaster response community is further evidenced by the lack of significant centralization or clustering structures in the resource provision network at the last point of observation. Although power issues are not directly examined in this study, this lack of significant network patterns, coupled with the insignificant effect of response organizations' resource receipt on their resource provision at the last point of observation, suggests change in power relationships among response organizations. That is, the unequal distribution of the opportunities to mobilize resources and deliver them to affected neighborhoods becomes less salient in the later phase of disaster response. Moreover, the overall insignificant effects of organizational type and prior relief experience on response organizations' resource provision highlight the importance of theoretically considering the dynamic social structures in which organizational populations are embedded (Freeman and Audia 2006). As response organizations are involved in a new disaster, their resource mobilization activated for the particular disaster in the form of accessing resources from contacts matters more than their pre-disaster attributes.

This study enriches the concept of community resilience through the framework of community resilience to understand affected neighborhoods' evolving resource network. Similar to the resource provision network, affected neighborhoods' resource receipt network exhibited a resource-intensive picture in the first four months after the incident. However, the negative clustering effects after the immediate period, coupled with the disappearance of the existence of a few affected neighborhoods that had more resource contacts after the first four months, show that affected neighborhoods might have engaged in their own rebuilding efforts or resumed normal routines without necessarily tapping into the same popular resource contacts. Together, these results imply that within the evolving population of affected neighborhoods, there exist variations in terms of individual neighborhoods' capacities to adapt and rebuild after the incident. These findings were also echoed by the visualization of the resource receipt network, which showed the change in resources received by affected neighborhoods after the first four months. Practically speaking, these findings suggest that appropriate communication strategies should be developed, considering the timing of mobilizing and deploying certain types of resources to neighborhoods, and the timing to curtail the efforts when affected neighborhoods' needs for resources change.

In the meantime, the significant correlations between resource networks at different time points ($T2 \rightarrow T3$, $T3 \rightarrow T4$, $T2 \rightarrow T4$) indicate that unlike response organizations' resource provision network, affected neighborhoods' receipt of resources tends to be rooted in the earlier interactions with their resource suppliers. On the one hand, this shows that affected neighborhoods tended to maintain their resource relationships consistently over time. However, it also implies that their relational advantages or disadvantages might have been reinforced over phases of disaster response. If neighborhoods did not receive resources from multiple resource contacts early on, they might continue the pattern later. In practice, this points to the importance of paying attention to affected neighborhoods' social foundation prior to and during the disaster in order to identify any potential gaps or disparities in resource allocation.

Note that even after the first four months as the activity of the response community declined and slowed down, this emergent response community did not necessarily disband. In fact, it may have transformed into a latent form of response or preparedness community that can be activated in the future when an emergency happens again. The maintenance of such a latent community is beneficial for the affected neighborhoods' resilience building. Indeed, disaster research has identified the importance of local response organizations' timely demobilization of relief efforts in order to maintain the continuation of their own pre-disaster operations (Donahue and O'Keefe 2007). However, temporally formed ties during disasters can become lasting ties among local stakeholders, which in turn help enhance societal resilience (Busch and Givens 2013). Due to methodological limitations, we did not collect organizations' resource provision data after two months of the incident. The extent to which the newly established ties or latent ties maintained between response organizations influence the resilience of the affected neighborhoods is an important theoretical and empirical inquiry that merits further investigation. As the next step for future research, follow-up in-depth interviews with local residents as well as local community-based organizations both within and across neighborhoods are also necessary to gather more insights into their varied experiences after the disaster. Specifically, data should be gathered with regard to the lessons that residents and local organizations have learned from this technological disaster, which can further identify the mechanisms of inherent and adaptive resilience that can be built by the affected neighborhoods (Tierney 2014).

Conclusion

This study is driven to answer the question of whether and how the emergent disaster response community evolves with distinct populations of resource suppliers and resource recipients. Findings of this study reveal the evolutionary patterns of an emergent disaster response community after a technological disaster through the changing resource relationships between response organizations and affected neighborhoods. These two populations exhibited similar structural tendencies toward centralization in the early phases of the response, yet displayed no clear structural pattern later on. This suggests the timing of the evolution and transformation of the response community into a latent form of community. The process of mutual resource mobilization was also observed because response organizations provided and mobilized resources from affected neighborhoods at the same time. On the neighborhood side, the affected neighborhoods' engagement in rebuilding and resuming normality was reflected in their dynamic change in resource network, from centralization to a lack of centralization among a few neighborhoods after the first four months of the incident. This finding was also corroborated by the change in resources received by the local neighborhoods after four months of the incident.

This study makes contributions to the research in the areas of nonprofit and voluntary organizations in the following ways. First, building on the framework of community ecology and the concept of community resilience, this study addresses both the perspectives of resource providers and resource recipients in disaster response. Analysis of data revealed how the resource networks evolved in different phases of disaster response and how the networks exhibited particular structural patterns in ways that opportunities and gaps for resource allocation can be detected. We also extend existing research on community ecology and community resilience by revealing how affected neighborhoods' evolving resource relationships with response organizations reflect the ways they engage in resilience building after a disaster. In practice, these insights inform appropriate and effective communication strategies that can be implemented in disaster response. Second, borrowing from resource mobilization theory (McCarthy and Zald 1977), this study proposes to consider disaster response actions as a process of mutual resource mobilization enacted by response organizations and affected neighborhoods. Specifically, findings of this study suggest the importance of considering response organizations' capacity of mobilizing resources in different phases of resource provision.

This study has the following limitations. First, it uses small sample sizes for both organizational and neighborhood datasets. However, this limitation authentically reflects the scope of this man-made disaster as the neighborhoods we examined covered the entire area affected by the incident. Second, the data of different time points relied on the response organizations and the local leaders' reconstruction of the resource networks. Documentary analysis (e.g., situation reports) is a common approach used in the assessment of network change in the existing literature on disaster response (e.g., Robinson et al. 2013; Wolbers et al. 2013). Nonetheless, in our case, there was a lack of such records available for analysis. This reason also resulted in the lack of systematic information about organizations involved in the rebuilding phase and consequently the lack of a more parallel organizational dataset extended longer than two months after the incident. Third, this study focuses on one technological disaster as the research context to illustrate the evolutionary patterns of the emergent response community, whose resource networks and interdependent relationships between populations may be manifested differently in disasters of different types and scopes. Lastly, the neighborhood data were gathered from the official local leaders, who had the best knowledge about resource exchange at the local neighborhood level. While this approach suits the purpose of this study, eliciting responses from local residents is critical to understanding community resilience.

Contemporary disasters often cause catastrophic and profound damages to human societies. Human responses to such disasters entail a complex social system of responding and adapting to the disrupted environment. More research on different social systems' adaptive process in the face of different crises is expected to potentially build and enhance our resilience in the changing and unpredictable environment.

Funding This project was partially supported through the first author's 5K Grant from Wee Kim Wee School of Communication and Information, Nanyang Technological University (NTU), Singapore. The first author was affiliated with NTU when the grant award was received. National Chiao Tung University's Research Center for Humanities and Social Sciences also sponsored the process of data collection for this project.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Abbasi, A. (2014). Link formation pattern during emergency response network dynamics. *Natural Hazards, 71*(3), 1957–1969.

Aldrich, H. E. (1999). *Organizations evolving*. Thousand Oaks, CA: Sage.

Astley, W. G. (1985). The two ecologies: Population and community perspectives on organizational evolution. *Administrative Science Quarterly, 30*(2), 224–241.

Baum, J. A. C., & Rao, H. (2004). Evolutionary dynamics of organizational populations and communities. In M. S. Poole & A. H. Van de Ven (Eds.), *Handbook of organizational change and innovation* (pp. 212–258). New York: Oxford University Press.

Baum, J. A. C., & Shipilov, A. V. (2006). Ecological approaches to organizations. In S. R. Clegg, C. Hardy, W. Nord, & T. Lawrence (Eds.), *Sage handbook for organization studies* (pp. 55–110). London: Sage Publications.

BBC News. (2014, August 1). *Taiwan gas blasts in Kaohsiung kill at least 25*. Retrieved from http://www.bbc.com/news/world-asia-28594693.

Benson, J. K. (1975). The interorganizational network as a political economy. *Administrative Science Quarterly, 20*(12), 229–249.

Boin, A., Comfort, L. K., & Demchak, C. C. (2010). The rise of resilience. In L. K. Comfort, A. Boin, & C. C. Demchak (Eds.), *Designing resilience: Preparing for extreme events* (pp. 1–12). Pittsburgh, PA: University of Pittsburgh Press.

Borgatti, S. P., Everett, M. G., & Freeman, L. C. (2002). *UCINET for Windows: Software for social network analysis*. Harvard, MA: Analytic Technologies.

Borgatti, S. P., & Halgin, D. S. (2011). Analyzing affiliation networks. In J. Scott & P. J. Carrington (Eds.), *The Sage handbook of social network analysis* (pp. 417–433). London: SAGE Publications.

Bruneau, M., Chang, S. E., Eguchi, R. T., Lee, G. C., O'Rourke, T. D., Reinhorn, A. M., et al. (2003). A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthquake Spectra, 19*(4), 733–752.

Bryant, J. A., & Monge, P. R. (2008). The evolution of the children's television community, 1953–2003. *International Journal of Communication, 2,* 160–192.

Busch, N. E., & Givens, A. D. (2013). Achieving resilience in disaster management: The role of public-private partnerships. *Journal of Strategic Security, 6*(2), 1–19.

Butts, C. T., Acton, R. M., & Marcum, C. (2012). Interorganizational collaboration in the Hurricane Katrina response. *Journal of Social Structure, 13*(1), 1–36.

Chikoto, G. L., Sadiq, A., & Fordyce, E. (2012). Disaster mitigation and preparedness: Comparison of nonprofit, public, and private organizations. *Nonprofit and Voluntary Sector Quarterly, 42*(2), 391–410.

Choi, S. O., & Kim, B. T. (2007). Power and cognitive accuracy in local emergency management networks. *Public Administration Review, 67*(s1), 198–209.

Comfort, L. K., Boin, A., & Demchak, C. C. (2010). Resilience revisited: An action agenda for managing extreme events. In L. K. Comfort, A. Boin, & C. C. Demchak (Eds.), *Designing resilience: Preparing for extreme events* (pp. 272–284). Pittsburgh, PA: University of Pittsburgh Press.

Comfort, L. K., & Haase, T. W. (2006). Communication, coherence, and collective action the impact of hurricane katrina on communications infrastructure. *Public Works Management & Policy, 10*(4), 328–343.

Cretney, R. M. (2016). Local responses to disaster: The value of community led post disaster response action in a resilience framework. *Disaster Prevention and Management, 25*(1), 27–40.

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., et al. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change, 18,* 598–606.

Doerfel, M. L., Lai, C.-H., & Chewning, L. V. (2010). The evolutionary role of interorganizational communication: Modeling social capital in disaster contexts. *Human Communication Research, 36,* 125–162.

Donahue, A. K., & O'Keefe, S. (2007). Universal lessons from unique events: Perspectives from Columbia and Katrina. *Public Administration Review, 67*(S1), 77–81.

Dynes, R. R. (2002). *The importance of social capital in disaster response*. University of Delaware, Disaster Research Center. Preliminary Paper # 327.

Dynes, R. R., & Quarantelli, E. L. (1968). Redefinition of property norms in community emergencies. *International Journal of Legal Research, 3,* 100–112.

Filo, K., Cuskelly, G., & Wicker, P. (2015). Resource utilisation and power relations of community sport clubs in the aftermath of natural disasters. *Sport Management Review, 18*(4), 555–569.

Finch, B. (2016). Boston sport organizations and community disaster recovery. *Disaster Prevention and Management, 25*(1), 91–103.

Freeman, J., & Audia, P. G. (2006). Community ecology and the sociology of organizations. *Annual Review of Sociology, 32,* 145–169.

Gillespie, D. F., & Murty, S. A. (1994). Cracks in a post disaster service delivery network. *American Journal of Community Psychology, 22*(5), 639–660.

Goodreau, S. (2007). Applying advances in exponential random graph (p*) models to a large social network. *Social Networks, 29*(2), 231–248.

Hannan, M. T., & Freeman, J. H. (1977). The population ecology of organizations. *American Journal of Sociology, 82,* 929–964.

Harris, X., & Doerfel, M. L. (2016). Interorganizational resilience: Networked collaboration in communities after disasters. In E. C. Jones & A. J. Fass (Eds.), *Social network analysis of disaster response, recovery, and adaptation* (pp. 75–92). London: Elsevier.

Hawley, A. H. (1986). *Human ecology: A theoretical essay*. Chicago: University of Chicago Press.

Kapucu, N. (2005). Interorganizational coordination in dynamic context: Networks in emergency response management. *Connections, 26*(2), 33–48.

Kapucu, N. (2011). Collaborative governance in international disasters: Nargis Cyclone in Myanmar and Sichuan Earthquake in China cases. *International Journal of Emergency Management, 8*(1), 1–25.

Kendra, J. M., & Wachtendorf, T. (2003a). Elements of resilience after the World Trade Center disaster: Reconstituting New York City's emergency operations center. *Disasters, 27*(1), 37–53.

Kendra, J. M., & Wachtendorf, T. (2003b). Reconsidering convergence and converger legitimacy in response to the World Trade Center disaster. In *Terrorism and disaster: New threats, new ideas* (pp. 97–122). Emerald Group Publishing Limited.

Kreps, G. A., & Bosworth, S. L. (2007). Organizational adaptation to disaster. In H. Rodriguez, E. L. Quarantelli, & R. R. Dynes (Eds.), *Handbook of disaster research* (pp. 297–315). New York: Springer.

Kulik, L., Arnon, L., & Dolev, A. (2016). Explaining satisfaction with volunteering in emergencies: Comparison between organized and spontaneous volunteers in operation protective edge. *VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations, 27*(3), 1280–1303.

Lai, C.-H., She, B., & Ye, X. (2015). Unpacking the network processes and outcomes of online and offline humanitarian collaboration. *Communication Research*. doi:10.1177/0093650215616862.

Lee, S., & Monge, P. (2011). The coevolution of multiplex communication networks in organizational communities. *Journal of Communication, 61*(4), 758–779.

Marquis, C., Glynn, M. A., & Davis, G. F. (2007). Community isomorphism and corporate social action. *Academy of Management Review, 32*(3), 925–945.

McCarthy, J. D., & Zald, M. N. (1977). Resource mobilization and social movements: A partial theory. *American Journal of Sociology, 82*(6), 1212–1241.

Monge, P. R., Heise, B. R., & Margolin, D. (2008). Communication network evolution in organizational communities. *Communication Theory, 18,* 449–477.

Moore, S., Eng, E., & Daniel, M. (2003). International NGOs and the role of network centrality in humanitarian aid operations: A case study of coordination during the 2000 Mozambique floods. *Disasters, 27*(4), 305–318.

Nah, S., & Saxton, G. D. (2013). Modeling the adoption and use of social media by nonprofit organizations. *New Media & Society, 15*(2), 294–313.

Nolte, I. M., & Boenigk, S. (2013). A study of ad hoc network performance in disaster response. *Nonprofit and Voluntary Sector Quarterly, 42*(1), 148–173.

Noori, N. S., Wolbers, J., Boersma, K., & Cardona, X. V. (2016). A dynamic perspective of emerging coordination clusters in crisis response networks. In *Proceedings of the ISCRAM 2016 Conference*—Rio de Janeiro, Brazil, pp. 1–9.

Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., & Pfefferbaum, R. L. (2008). Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American Journal of Community Psychology, 41*(1), 127–150.

Opsahi, T. (2013). Triadic closure in two-mode networks: Redefining the global and local clustering coefficients. *Social Networks, 35*(2), 159–167.

Pfeffer, J., & Salancik, G. R. (1978). *The external control of organizations*. New York: Harper & Row.
Provan, K. G., Beyer, J. M., & Kruytbosch, C. (1980). Environmental linkages and power in resource-dependence relations between organizations. *Administrative Science Quarterly, 25*(2), 200–225.
Robins, G., Snijders, T., Wang, P., Handcock, M., & Pattison, P. (2007). Recent developments in exponential random graph (p*) models for social networks. *Social Networks, 29*(2), 192–215.
Robinson, S. E., Eller, W. S., Gall, M., & Gerber, B. J. (2013). The core and periphery of emergency management networks. *Public Management Review, 15*(3), 344–362.
Shepherd, D. A., & Williams, T. A. (2014). Local venturing as compassion organizing in the aftermath of a natural disaster: The role of localness and community in reducing suffering. *Journal of Management Studies, 51*(6), 952–994.
Sherbourne, C. D., & Stewart, A. L. (1991). The MOS social support survey. *Social Science and Medicine, 32*(6), 705–714.
Shumate, M., Fulk, J., & Monge, P. (2005). Predictors of the international HIV/AIDS INGO network over time. *Human Communication Research, 31*(4), 482–510.
Shumate, M., & O'Connor, A. (2010). The symbiotic sustainability model: Conceptualizing NGO–corporate alliance communication. *Journal of Communication, 60*(3), 577–609.
Shumate, M., & Palazzolo, E. (2010). Exponential random graph (p*) models as a method for social network analysis in *communication* research. *Communication Methods and Measures, 4*(4), 341–371.
Simo, G., & Bies, A. L. (2004). The role of nonprofits in disaster response: An expanded model of cross-sector collaboration. *Public Admiration Review, 67*(s1), 125–142.
Singer, H. H., & Kegler, M. C. (2004). Assessing interorganizational networks as a dimension of community capacity: Illustrations from a community intervention to prevent lead poisoning. *Health Education & Behavior, 31*(6), 808–821.
Soule, S. A., & King, B. G. (2008). Competition and resource partitioning in three social movement industries. *American Journal of Sociology, 113*(6), 1568–1610.
Starbird, K., & Palen, L. (2011). Voluntweeters: Self-organizing by digital volunteers in times of crisis. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1071–1080). ACM.
Tierney, K. (2014). *The social roots of risk: Producing disasters, promoting resilience*. Stanford, California: Stanford University Press.
Tilcsik, A., & Marquis, C. (2013). Punctuated generosity how mega-events and natural disasters affect corporate philanthropy in US communities. *Administrative Science Quarterly, 58*(1), 111–148.
Topper, C. M., & Carley, K. M. (1999). A structural perspective on the emergence of network organizations. *Journal of Mathematical Sociology, 24*(1), 67–96.
Tushman, M. L., & Romanelli, E. (1985). Organizational evolution: A metamorphosis model of convergence and reorientation. *Research in Organizational Behavior, 7,* 171–222.
Vaux, A., Riedel, S., & Stewart, D. (1987). Modes of social support: The Social Support Behaviors (SS-B) Scale. *American Journal of Community Psychology, 15*(2), 209–232.
Voorhees, W. R. (2008). New Yorkers respond to the world trade center attack: An anatomy of an emergent volunteer organization. *Journal of Contingencies and Crisis Management, 16*(1), 3–13.
Wang, P., Sharpe, K., Robins, G. L., & Pattison, P. E. (2009). Exponential random graph (p*) models for affiliation networks. *Social Networks, 31*(1), 12–25.
Whittaker, J., McLennan, B., & Handmer, J. (2015). A review of informal volunteerism in emergencies and disasters: Definition, opportunities and challenges. *International journal of disaster risk reduction, 13,* 358–368.
Wicker, P., Filo, K., & Cuskelly, G. (2013). Organizational resilience of community sport clubs impacted by natural disasters. *Journal of Sport Management, 27*(6), 510–525.
Wolbers, J., Groenewegen, P., Mollee, J., & Bím, J. (2013). Incorporating time dynamics in the analysis of social networks in emergency management. *Journal of Homeland Security and Emergency Management, 10*(2), 555–585.
Wry, T., Cobb, J. A., & Aldrich, H. E. (2013). More than a metaphor: Assessing the historical legacy of resource dependence and its contemporary promise as a theory of environmental complexity. *The Academy of Management Annals, 7*(1), 441–488.
Zhu, M., Huang, Y., & Contractor, N. S. (2013). Motivations for self-assembling into project teams. *Social Networks, 35*(2), 251–264.