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Formal and social structures as organizing mechanisms of disaster response: A longitudinal social network analysis

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Abstract

Organizations in disaster-prone areas generally have formalized plans that will help them recover after environmental disasters. However, these formal mechanisms are usually adapted "on the fly" because disasters don't unfold according to plans. This paper examines how a cross-sector network of community organizations used both formal structures (planned/bureaucratic relationships within and among organizations) and informal structures (emergent/social networks) that interacted to support organized response work in response to both anticipated and chaotic events during and following Hurricane Harvey. Results showed that formal reporting relationships that included preestablished network relationships predicted organizing structures on the days when volatility was highest, while emergent networks were crucial in guiding recovery actions during periods of crisis. The findings extend phase models of crisis with a more granular and longitudinal analysis of these organizing processes, advancing organizational theory that often frames bureaucratic structures and social networks as dichotomous rather than as symbiotic.

Keywords

Longitudinal recovery, disaster response, social networks, nonprofit organizations, interorganizational communication

Climate change is increasing the frequency and intensity of major weather events that can bring entire countries to a halt. Planning for disaster remediation is a standard operating practice for businesses and nonprofits alike; these plans are often coordinated with local governments and agencies to assure the safety of citizens and continuation of vital services. Formal plans are particularly salient for organizations working in the public sector, where nonprofit organizations often deliver human services in collaboration with government agencies (Milward and Provan 2000; Milward et al. 2009; Mintzberg and Waters 1985). Disaster plans are often part of strategic planning, a form of formal communication where professionals develop protocols that detail the tasks, roles, and responsibilities that their organizations deem necessary to assure minimal disruption of services to vulnerable clients. Informal organizing (unplanned, spontaneous work coordinated through emergent networks) also surfaces as workers and volunteers mobilize coordinated response efforts as they assess and reassess conditions on the ground (Kim and Williams 2022).

The actions people perform and the nature of the disasters, themselves, are time-sensitive, changing hour by hour and day by day (Doerfel et al. 2022). They change because response efforts and solutions in the moment impact the nature of the problem itself, generating a dynamic, adaptive context. Yet how the formal, planned actions and the informal, spontaneous work complement, supplement, contradict, or work in parallel ways is less understood than the research that oftentimes criticizes the way plans fall short. Similarly, existing literature often views emergent communication as a counterpoint to planning, highlighting aspects of informal organizing as spontaneous—not planned—action in the aftermath of disasters (Doerfel 2016; Kendra and Wachtendorf 2003). Understanding how formal and informal organizing support response efforts is especially important for nonprofit organizations (NPOs) that serve vulnerable clients (e.g., the elderly, homeless, and people with disabilities). NPOs rely on formal organizing structures because they often work in partnership with and are funded by federal and local government programs that require structured planning. Local

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governments also develop and rely on formal plans to serve particularly vulnerable citizens. Yet disasters generate turbulent context where informal processes, often simultaneously with planned ones, are vital in the organizations' ability to work through volatile situations.

This paper examines the relationship between formal and informal response efforts by examining the ways NPO workers and cross-sector interorganizational partners worked within or around formal structures to return to their mission-driven work during disruption. It examines and compares bureaucratic functions, as reflective of formality and communication networks to represent informality at different points during the time when Hurricane Harvey impacted Houston, Texas in August of 2017. We present the ways in which bureaucratic and informal organizing worked in tandem during the hurricane and its immediate aftermath as the need for urgency to ensure the safety of others compressed and expanded time. Data are based on matrices created by examining the social networks constituted by emails exchanged before, during, and after the storm. They were sent by workers and organizations that were affiliated with a system comprised of government, nonprofit, and faith-based organizations.

This paper proceeds by (1) reviewing research about disaster response with a lens informed by formal and informal organizing structures; (2) describing the methods used to construct matrices of bureaucratic structures and informal networks inside a focal organization and with its interorganizational relationships (IORs) using documents, informant-sourced site information, and archived emails; and (3) analyzing the interplay of bureaucracy and emergent networks and its impact on disaster response and recovery. Findings reveal how bureaucratic and informal processes intersect over time. Broader impacts for policymakers show that previously established social networks and formal structures predict the evolution of emergency response networks at precise times during the disaster.

Crisis communication, interorganizational relationships, and social networks

Social network theories show the ways NPOs and government agencies work collaboratively to support their vulnerable constituents (c.f., Milward et al. 2009; Shumate and O'Connor 2010). For organizations that serve surrounding communities, their work during crisis events mitigates disruptions for both themselves and their communities (Aldrich 2012). In such contexts, organizations draw on networked relationships that enable uninterrupted communication and operation (Williams et al. 2017). Research shows that relationships established prior to crisis events can mitigate the disruptions to organizations and communities (Barbour et al. 2020; Doerfel, Chewning, and Lai 2013; Ulmer, Sellnow, and Seeger 2007). For instance, Local Emergency Planning Committees (LEPCs), which are designed to engage multiple stakeholders in decision-making and designing crisis plans (Barbour et al. 2020; Heath, Bradshaw, and Lee 2002), often take the lead in coordinating disaster planning. These partnerships range from formal, legally binding agreements to informal relationships such as coalitions that engage emergent collaboration. Barbour et al. (2020) showed that when LEPC plans include stakeholders, they shared a sense of risk and saw risk as relevant to their own response. Their findings suggest that formal and informal networks between government agencies and local stakeholders benefit not only these groups, but the community at large as well (Rank 2008). Arguably, formal and informal processes are critical assets to crisis management and planning.

Bureaucratic and informal processes of organizations

Organizations rely on a combination of formal and informal organizing structures to accomplish their goals (Teece 1996). Formal structures in organizations are planned and previously agreed upon relationships such as legalized partnerships or exchange-based agreements (Kim et al. 2021). These bureaucratic relationships often reflect cooperative ties "that have been intentionally created to safeguard economic processes" (Rank 2008, 147). For example, to receive funding from the Veterans Administration, an NPO that serves this population will have a formal relationship that outlines responsibilities and programs. Within an organization, bureaucratic structures can also be hierarchical and marked by communicative relationships between management and staff based on their positions in the organization. These same formal structures are observed across organizations, for example, when organizations form coalitions to solve community-wide problems or seek relationships to access resources. The defining factor of formal structures is the deliberate nature of their formation; roles and positions are clearly defined (Diefenbach and Sillince 2011), and communication generally originates at the top of the hierarchy and filters downward (Askim, Christensen, and Lægreid 2015). Table 1 compares bureaucratic and informal structures based on their emergence from either established relationships or workarounds that enable work to be accomplished in nonroutine situations.

Informal networks, by contrast, are unplanned and emergent. Informal relationships are mostly "voluntary, cooperative relationships" (Rank 2008, 147) that do not arise through an organization's formal structure. In other words, rather than a Weberian bureaucratic approach that designs rules and accountability-based relationships to maximize organizational success and goal accomplishments, informal networks arise unexpectedly or emerge as needed when crisis situations unfold. For instance, an informal network emerges when individuals and teams share information and resources laterally and rules develop through the activities of members rather than by formal policy established by management (Diefenbach and Sillince 2011). Kim et al. (2021) found that during Hurricane Harvey, NPOs serving socially vulnerable communities

Table 1. Formal and informal organizing functions.

Functions	Formal (bureaucratic) structures	Informal structures
Relationships and communication flows	Through hierarchies	Through social networks
Accountability and decision-making	Assigned based on role (e.g., manager; accounting clerk)	Shared through coordinated actions
Actions	Protocol based; designed in advance	Situated; spontaneous and responsive in the moment
Power and control	Nested in positions (e.g., management)	Networked (e.g., brokers and hubs)
Knowledge	Explicit; defined in policies and rules	Implicit; tacit and embedded in narratives/organizational cultures (Dailey and Browning 2014)

had to handle a rapidly changing crisis but lacked resources to do so. In addition to their existing bureaucratic relationships, emergent networks based on existing community relationships arose that enhanced operational recovery. As such, informal networks can coincide with bureaucratic organizations, as when groups of employees come together to find workarounds during disasters.

Bureaucracies and informal structures are organized into multi-level networks when individuals, teams, organizations, and their interorganizational networks navigate bureaucratic and informal communication (Kim and Williams 2022). These relationships are predicated on trust, improvisation, and interdependence (Doerfel, 2018; Vangen and Huxham 2003). Such formal and informal organizing can be seen in postdisaster recovery efforts as well. Bureaucratic control is evident at interorganizational levels when funders may require NPOs to form interorganizational partnerships to receive program grants for crisis recovery (Doerfel, Atouba, and Harris 2017; Doerfel 2016). On the other hand, informal arrangements within and across organizational boundaries emerge relative to the scope of work and therefore involve relationships that become stronger over time (Doerfel et al., 2010).

In crisis, hyper-local disaster response networks emerge as informal networks. They include citizen groups, and local organizations centralized around first responder organizations like fire, police, and the mayor's office (Harris and Doerfel 2017; Majchrzak, Jarvenpaa, and Bagherzadeh 2015; Majchrzak, Jarvenpaa, and Hollingshead 2007). Zooming out to a regional perspective, various hyper-local groups make up subnetworks within a decentralized system. The activated organizations need multiple sources of information and resources to survive and mobilize (Lengnick-Hall and Beck 2005, 2009; Williams et al. 2017). By virtue of being decentralized, the networks have moderate levels of network density, facilitating information flows (Doerfel 2016).

Although disruptive events do not always unfold predictably, plans improve response processes (Salkin 2014). However, the enactment of planned strategies during an event are both formal (planned) and informal (improvised) (Kendra and Wachtendorf 2003; Mendonça and Wallace 2007, 2015). Individuals involved in citizen response groups may be employed by organizations that are both impacted by and play a role in response and recovery. Response and recovery encompass both the individuals and the affiliated organizations, and thus formal approaches coexist with network processes (Doerfel et al. 2022; Kim et al. 2021). For example, although emergent groups were vital along the New Jersey coastline after Superstorm Sandy, the formally structured Office of Emergency Management was also actively engaged in recovery efforts with community members (Harris and Doerfel 2016).

Implementation of formal disaster plans can be enabled by emergent organizing that facilitates workarounds. Yet, despite the ways bureaucratic and informal structures are different and arguably complementary, to the best of our knowledge, existing research that examines their intersections is scarce with two known qualitative studies (Doerfel et al. 2022; Kim et al. 2021). Indeed, the dynamics between bureaucratic and informal networks are still predominantly treated as being dichotomously opposed and independently (dis)functioning even though underlying assumptions in the existing literature alludes to their interdependence. We therefore ask:

RQ1: In what ways do formal structures and informal networks function together and apart during postdisaster organizing?

Given the dynamic nature of crisis, we turn next to stage models of crisis as an approach to understanding the dynamics of disaster recovery.

Crisis unfolds over time

Crises, and in particular environmental crises like hurricanes, are not isolated events; they unfold over time (Ndela 2019) and in stages (Williams et al. 2017). Crisis management and crisis communication are described as occurring in sequential phases labeled precrisis, crisis, and postcrisis (Coombs 2006, 2012; Seeger, Reynolds and Day 2020; Williams et al. 2017). These stages clarify activities that occur in preparation, during, and after crisis occurs. For example, researchers conceptualize that organizations become aware of potential crises (signal detection), and prepare and try to prevent them during

the precrisis phase (Coombs 2010b; Tokakis, Polychroniou, and Boustras 2019). Formal crisis management plans are particularly important in this phase (Coombs 2006). The actual event, whether a corporate misdeed or an environmental disaster, moves the organization into the crisis phase (Tokakis, Polychroniou and Boustras 2019). At this point, the organization's efforts are directed toward responding to and containing the crisis while attempting to minimize damage and disruption to routine operations. Once the emergency is over, the organization refocuses on recovery and learning from the event attempting to revive any disruption. Ulmer, Seeger, and Sellnow (2007) adds renewal to the postcrisis segment, arguing that following disasters organizations engage in renewal discourses in order to "rebuild and move beyond the crisis" (131). Each stage involves tasks that evolve in a predetermined series, for example, signal detection; preparation or prevention, containment or damage control, recovery, and learning (Williams et al. 2017).

While helpful for understanding the overall cycle of crisis, there is little to add to our understanding of when to employ different strategies. For example, Coombs (2010a) describes effective processes and content for responding to crises, suggesting that organizations appoint appropriate spokespeople and get their messages out quickly and accurately to limit reputational damage during corporate crises. Sellnow et al. (2012) advocate using targeted instructional messages during crises as a means of motivating behavioral responses. We could find no studies other than Doerfel et al. (2022) that used time as a linear variable to understand how organizations shape their work processes during disasters and recovery and within the general phases. They found that time had clear implications for the way that work is structured during these periods. We add to Doerfel and colleagues' work by adding granularity to the stage models by focusing on how the type of communication affected organizational ability to get work done during particular crisis stages. Thus, we ask

RQ2: How does communication change during time-delineated crisis periods to enable effective organizing?

Methods

To answer our research questions, we used a mixed method approach. We employed quantitative social network analysis and archival analysis to establish the hierarchical structure. We used content analysis to code disaster-related email provided by NPO-12-S (with IRB approval) to create matrices that represent the crisis and noncrisis networks. News reports and National Weather Service data were used to track and describe the context and storm's impact on work. We then used quantitative social network analysis to ascertain the relationship between these networks to better understand how communication changes day by day as disaster unfolds.

Procedures and data

Research context. This study focuses on the processes used by several nonprofit social service networks serving socially and economically vulnerable communities (e.g., the elderly and homeless) to respond to Hurricane Harvey. The focal organization, NPO-12-S, is a multi-faith coalition that includes subsidiary organizations that serve the elderly, indigent and otherwise underserved residents in Harris County and its surrounding region and part of a robust interorganizational system that serves the greater Houston-area. NPO-12-S had an extensive plan in place to deal with environmental disruptions like hurricanes, which occur frequently in Houston. Harvey caused unprecedented destruction and disruption throughout Harris County, yet NPO-12-S was able to continue serving vulnerable clients with minimal interruptions. This study investigated how emergent social networks interacted with bureaucratic structures to augment formal plans and allow the agency to get back to its mission-driven work.

Operationalizing bureaucratic structures and emergent networks. Data for this study came from a larger corpus that was part of a field study of organizations impacted by Hurricane Harvey. Data for the field study included documents, field notes, and interviews with informants who represented organizations that experienced significant disruption during and after the hurricane. Additionally, news reports and National Weather Service data were used to track and describe the context and storm's impact on work processes as Harvey unfolded.

We gained access to the emails flagged as disaster-related by the organization that were sent and received by NPO-12-S (a member of the internal management team and a liaison across organizations) from April 6 to November 14, 2017. NPO-12-S's role meant that they were copied on all emails having to do with disaster management plans, which included emails sent among the cross-sector service network in which NPO-12-S, as an organization, played an active role. Email was shared in PDF form with sender/receiver information, cc names, and time stamps dated between April 6 and November 14, 2017 (708 pages total). We used the emails to identify the organizations that were active in the system ($n = 234$). All identifying information in the data was anonymized according to human subjects research protocols.

To operationalize NPO-12-S's formal structure, we used NPO-12-S's organizational chart, information from leaders about formality between organizations, and information from web documents such as archived reports and meeting minutes, to capture the formal, bureaucratic relationships within the organization and at the interorganizational level (see Figure 1 for a representation of NPO-12-S's formal relationships). We entered the data into a 234-node square matrix in UCINET, a network analysis software (Borgatti, Everett and Freeman 2002), where the relationship between

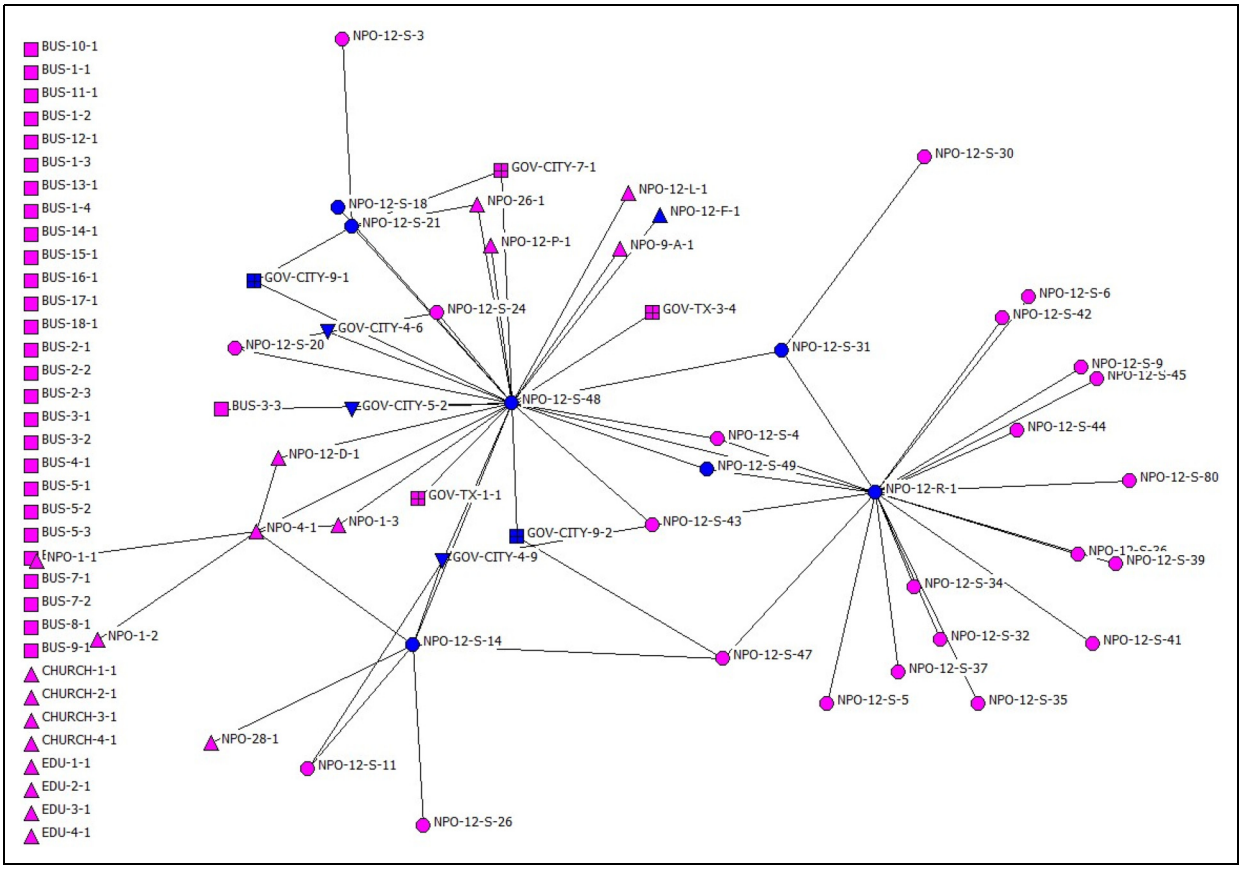

Figure 1. Formal reporting structure of NPO-12-S and its interorganizational system.

two organizations *i* and *j* was assigned a 1 if there was a formally defined directly accountable relationship between the two organizations. A zero indicated that there was not a direct and formally defined relationship (explained in more detail below). NPO-12-S had multiple formal relationships to other organizations and agencies; for example, they had formal ties to their parent organization at the state level, the City of Houston's Health and Human Services Department, and a veterans' group that required certain protocols as a condition for using their funds. Likewise, we coded ties as formal between state agencies that oversee other aspects of senior services organizations in the region. Because the formal structure is stable as a prescribed and defined reporting structure, this map was used as the formal structure for each point in time.

To construct the informal network and establish time-based information, we used the archived emails related to the disaster since emails reflect spontaneous communication flows among people and the organizations they represent. We first used messages shared among key partners such as nonprofit, government, and private entities to construct a matrix of the crisis network as it emerged by following actual communication flows (as opposed to perception-based networks constructed from self-reports) (Marsden 1990). Thus, this matrix reflects the actual communication flows among individuals that occupy different ranks and positions within the 234 node network rather than the presence or absence of formal ties.

Variables. *Communication*. Communication during these 2 weeks focused on (1) internal and external coordination of activities; (2) decision-making; (3) planning; and (4) and execution of existing and emerging plans across multiple stakeholders. More specifically, we operationalized communication content into three categories: *tasks*, *processes*, and *interpersonal*. *Tasks* included work accomplishments that individuals took up as part of their responsibilities. Tasks did not require interdependent coordination but rather straightforward reporting of accomplishments and information sharing, reflective of the independence some aspects of work involve. *Processes* reflected *inter*dependent coordination such as problem-solving or critical decision-making, which reflect innovative aspects of work (e.g., collective decision-making and creating solutions to an unfamiliar emergency). *Interpersonal* referred to emails pertaining to personal situations (e.g., member safety checks and appreciation of one another). Intercoder reliability checks confirmed that after a second round of testing coders found complete agreement in assigning these categories. Using these codes, we constructed social network matrices where a 1 (interpersonal), 2 (task), or 3 (processes) indicated that the sender and receiver were linked based on a specific category for each day from August 25 to September 9. The matrices became the basis of social network analyses discussed below. Thus, in total, we constructed five matrices representing (1) the bureaucratic structure of NPO-12-S (which is a stable structure regardless of crisis), (2) the

overall crisis network on each day where two nodes were connected if they exchanged emails regardless of topic, and (3) three networks that illustrated who communicated with whom about interpersonal, task, or process topics.

Time and temporality. We treated time as a linear variable upon which we were able to map activities (Ancona, Okhyusen, and Perlow 2001). We operationalized time in two ways: based on the crisis phases and calendar dates. Email dates were used to track changes in networks prior to, during, and after the 9-day course of the hurricane and flooding based on storm-related events (hitting landfall and when Houston opened their levees) as well as within those time periods. Precrisis refers to the time leading up to the actual disaster event. During-crisis means the ongoing volatility of the disaster, and postcrisis is the immediate aftermath of the storm. In the context of Hurricane Harvey, precrisis refers to points leading up to August 25, when Harvey made landfall in Houston. The crisis phase lasted from August 25–September 2. At that point, NPO-12-S entered a postcrisis phase, but a second crisis engulfed its partner organization in Beaumont. By September 3, flood waters were receding from Harris and Jefferson County, and organizations and government agencies began post-Harvey cleanup. Table 2 indicates how we defined crisis phases by calendar dates.

Analysis

Based on the operationalized structures described above, we analyzed the email data to understand the communication flow, and NPO-12-S's interorganizational networks that emerged throughout the crisis periods.

Email coding. In order to identify the content of communication throughout the different crisis stages, we first engaged in email coding of 6,113 storm-related emails sent and received by NPO-12-S from April 6 to November 14, 2017, using the above-described categories of content (task, process, and interpersonal links). We used quantitative content analysis in which features of textual data are systemically categorized and recorded for analysis (Coe and Scacco 2017). The unit of analysis was each whole email. To comply with IRB guidelines, email senders and receivers were identified through their organizations. For example, the 48 staff members of NPO-12-S were categorized as NPO-12-S-1 through NPO-12-48.

We coded the emails based on the sender, receiver(s), sent date, sent time, and general content of each email. As described above, emails were coded into one of three general and discrete categories: interpersonal, task, and process. We did not code for threads of replies to avoid duplicate codes. To ensure intercoder reliability, all four authors first conducted three rounds of practice coding on a random sample of emails and discussed our differences in depth. Intercoder reliability checks confirmed that after a third round of testing, coders found complete agreement.

Network analysis. To answer RQ1, we used UCINET to conduct network analysis comparing the formal (bureaucratic) structure and informal (network) relationships that emerged. At the interorganizational level, various entities have formal control over NPO-12-S as discussed above. A total of 37 nodes in the network were identified as holding a formal position of authority. As described above, we used a crisis network for each date from August 25 to September

Table 2. Storm timeline: precrisis, crisis, and postcrisis phases in Houston.

Date	Hurricane-related activities
Precrisis (observed noncrisis network)	
Aug 22	Prehurricane
Aug 23	Prehurricane
Aug 24	Prehurricane
Crisis	
Aug 25	Harvey makes landfall near Corpus Christi; category 4 hurricane
Aug 26	Harvey makes 2nd landfall on Copano Bay
Aug 27	Storm moves toward Houston
Aug 28	Hurricane Harvey floods Houston
Aug 29	Levee breached near Houston causes additional flooding
Aug 30	Rainfall throughout area; flooding in Jefferson County, where an NPO-12-S partner organization is located
Aug 31	Harvey continues flooding in Jefferson County; hurricane storm watch discontinued
Sep 1	Tropical Storm Harvey moves into Louisiana
Sep 2	Harvey dissipates
Postcrisis	
Sep 3	Flood waters recede in Harris and Jefferson counties
Sep 4	Post-Harvey cleanup
Sep 5	Post-Harvey cleanup
Sep 6	Post-Harvey cleanup
Sep 7	Post-Harvey cleanup
Sep 8	Post-Harvey cleanup
Sep 9	Post-Harvey cleanup

9, 2017. These nine matrices depict communication inside NPO-12-S and among its partner organizations during the crisis period of the hurricane, flooding, and immediate aftermath. Using UCINET, we examined the overall networked structure of the system for each day, allowing us to dissect changes in the network over time. We identified brokers, those people who could make connections between previously unconnected parts of the network, thus enabling the flow of crucial resources and information, using UCINET's betweenness centrality analysis measures.

We also analyzed how interorganizational networks transformed over time relative to formal reporting structures and the noncrisis social networks. UCINET enables network level correlations and centrality analysis to examine the dynamic network structures of the interorganizational system. The network analysis counterpart for computing correlation and regression analyses can be found in the UCINET program's Quadratic Assignment Procedure (QAP) and Multiple Regression QAP (MRQAP) options with the Double-Dekker MRQAP being robust under multi-collinearity (Dekker, Krackhardt, and Snijders 2003). QAP is a nonparametric statistic that allows for conducting Pearson's r correlations between two matrices of equal size without violating the assumptions that traditional statistical modeling requires. To assess network level activity over time, each crisis day's network was examined to evaluate the level of interactive communication and organizing during crisis-mode organizing. The crisis-mode networks were also correlated using QAP against the noncrisis social network to identify the degree to which the crisis-mode communication system was similar to the social structure during normal operations. Similarly, the formal network was correlated using QAP with each crisis day's social network to identify the degree to which the crisis-mode communication system was similar to formal lines of authority in the system. A baseline correlation between the noncrisis network and the formal structure showed that during normal times, they had a moderate correlation ($R^2 = .03$ ($p < .001$). Node-level betweenness centrality analysis in UCINET enabled us to track the degree to which brokers were in formal positions of power.

Noncrisis social network. To test the impact of social networks during the crisis, we constructed a noncrisis network based on the email networks that occurred between April and November minus the 9 days of crisis. This noncrisis social network enabled an estimate of what the system's social structure looks like during "normal" times as opposed to when the system was in "crisis mode." As with the task, process, and interpersonal networks, we used this information to generate a noncrisis matrix for use when conducting social network analysis.

To answer RQ2, we conducted a qualitative content analysis of 2,571 emails sent and received from August 28 through September 9, the period beginning when Hurricane Harvey made landfall near Corpus Christi as a Category 4 hurricane and ending 6 days into the post-Harvey recovery period. These emails were coded for interpersonal, task, and process-related communication as described above, and divided by day to capture within-phase activities. We averaged each of the three types of communication that flowed through the network on each day to understand how interpersonal, task, and process-oriented changed during each crisis period.

Results

RQ1: The intersection of bureaucratic structures and emergent networks during and environmental disaster.

To answer this question, we looked at communication over a 16-day period beginning prior to Hurricane Harvey's landfall. We examined three different communication structures: the bureaucratic communication structure; the noncrisis network, or the pattern of communication among staff members as they normally do their work; and the crisis network, or how staff communicated during the days when Hurricane Harvey most impacted the organization. Our results indicate that when disasters unfold as planners assume they will (in other words, as they are written about in disaster plans), bureaucracies and informal networks show low but significant correlations as both leaders and staff have complementary but different responsibilities. However, during periods of crisis, when conditions on the ground require new ideas and solutions, the degree of association between these formal and networked structures increase, indicating capacity for improvision as leaders and staffed communicate across task domains and geographic boundaries. Additionally, network changes over the course of 9 days, starting 3 days before the storm, revealed the ways in which leaders brokered information and resources between the organization and its cross-sector partners.

Bureaucratic structures and social networks during disaster organizing

We first compared the noncrisis network with the formal bureaucratic structure to create a baseline comparison point of communication during "normal" periods. Social network analyses revealed that during noncrisis times, there is a generally low but significant relationship between the bureaucratic structure and noncrisis social network, $r = .29$, $p < .001$. This is to be expected, as leaders communicate through their subordinates and staff communicate with one another to complete their daily tasks. Figure 2 shows this correlation (dotted line) as a point for comparing the correlations (summarized on Table 3). The dotted line in Figure 2 stays the same over time because it represents this correlation as a point of comparison to the other correlations that changed from day-to-day during the crisis. The other lines on Figure 2 show each observed network on each day of the crisis and its correlation with the formal structure (line denoted with triangles) versus its correlation with the noncrisis network structure (line denoted with circles). The crisis network was most active during two periods, between

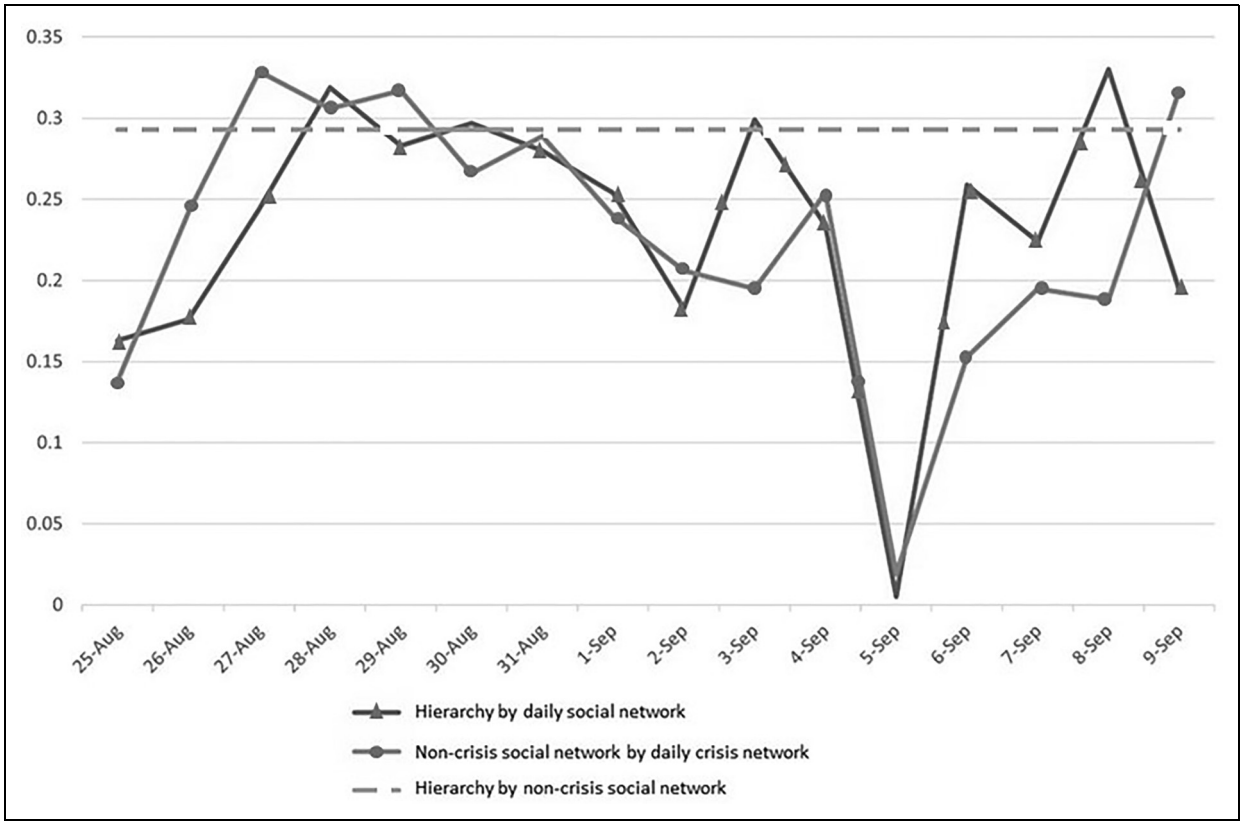

Figure 2. QAP Pearson's *r* correlation results. Figure depicts the degree to which the hierarchical structure and crisis social network matrices correlate to the default, noncrisis network matrix. The noncrisis matrix (horizontal line) represents the correlation between the hierarchy and the noncrisis informal structure during "normal" times ($r = .29$, $p < .000$) and thus does not change during the period from August 25 to September 9. The noncrisis matrix serves as a comparison point for the daily correlations with the hierarchical structure (line denoted with triangles) and informal structure (line denoted with circles). All values are significant, $p < .001$.

Table 3. Pearson's QAP correlations between formal structures and noncrisis social networks by observed networks on each date from August 25–September 9.

Date	Formal structure by daily social network	Noncrisis social network structure by daily social network
Aug 25	.163*	.138*
Aug 26	.176*	.242*
Aug 27	.244*	.329*
Aug 28	.319*	.306*
Aug 29	.283*	.317*
Aug 30	.297*	.266*
Aug 31	.28*	.289*
Sep 1	.254*	.24*
Sep 2	.183*	.206*
Sep 3	.299*	.195*
Sep 4	.234*	.254*
Sep 5	.005*	.019*
Sep 6	.259*	.153*
Sep 7	.224*	.195*
Sep 08	.33*	.188*
Sep 9	.194*	.317*

*$p < .001$ for all correlations reported.

August 25 and September 2 in Houston and September 3 through September 9 in Beaumont. The first period correlates to the flooding and its aftermath in Houston, where NP-12-S is headquartered. Beaumont was far more devasted by the storm and sought help from their Houston colleagues at a later stage. Results show that the August 27 the crisis network's correlation with the noncrisis network spiked, indicating greater communication among staff, then dropped below the August

28 correlation between the crisis network and the formal structure. On August 28, there was a significant correlation between the formal structure and the crisis network, $r = .32$, $p < .001$. On September 2, a relatively low correlation ($r = .18$, $p < .001$), shows the degree of interdependence between bureaucratic and informal structures fell below normal levels of association. The results show that during crisis periods, informal networks became more active as staff organized to assess the well-being of staff and resume necessary services.

Given the moderate and significant correlations, we conducted an MRQAP to test the degree to which observed networks could be predicted by the formal structures and noncrisis networks. QAP is a method used "to evaluate the statistical significance of a correlation between two whole matrices" (Borgatti et al. 2022, 287). In this case, we wanted to see whether there was a statistically significant association between crisis and noncrisis networks. There were four dates when the formal and noncrisis networks explain a sizable proportion of the variance relative to other dates: August 29, $R^2 = .29$; August 30, $R^2 = .23$; August 31, $R^2 = .26$; and September 2, $R^2 = .22$ (see Table 3 for all MRQAPs; all based on 2,000 permutations and 27,261 observations). These dates correspond to the days of most severe flooding and recovery in Houston, indicating more emergent and improvisational organizing occurred during the crisis period relative to noncrisis days (see Table 2). Figure 2 shows a dip in the correlation on September 5, which was simply due to no storm-related emails being sent or received that day. Figure 2 also shows that on September 9, the correlation between the daily network and noncrisis social network rose back to levels consistent with noncrisis times, reflecting how Beaumont's needs reactivated the system.

Using the beginning and end of the data collection period as our baseline for noncrisis communication, we then employed an independent-samples *t*-test to assess whether people in authority-based positions acted as brokers more often during crisis periods than in normal, noncrisis times (see Appendix in the online supplemental materials for a summary). Scores differed significantly between those holding authority positions ($M = .14$, $SD = .41$) and those in non-authority positions ($M = .01$, $SD = .04$) during normal, noncrisis times; $t(232) = 4.209$, $p < .001$. In other words, people in positions of power facilitated the transfer of resources and information through unconnected parts of the network. There were significant differences in the scores especially when the storm was at its peak and following thereafter. The results suggest that during a heightened crisis, those in bureaucratic positions of authority serve as brokers more than those that do not hold authority-based positions, suggesting their formal role is enacted in activity that is normally viewed as informal and networked. (The bolded figures in Table 4 indicate the days when this occured.) This could be because departmental and agency leaders often have relationships with peers in other agencies, regulatory or government bodies, and social relationships through fraternal bodies like Chambers of Commerce. Thus, they know of resources that can help their agencies during crises. Tables 4 and 5 report the findings from the independent *t*-tests.

In summary, we found that routine communication during noncrisis periods involves a lower (but still significant) relationship between bureaucracies and informal social networks that enables the work of organizations to continue, crisis situations cause breaks in this pattern. The informal social networks became more active as staff assessed the situation on the ground and developed processes to deal with disruptions. At the same time, people within the bureaucratic structure use their formal positions to reach out to otherwise unconnected parts of the wider network to access resources and information.

Communication and networks

Analysis revealed changes in internal and external communication during the 16 days studied. As opposed to the precrisis period, the system experienced heightened urgency during the crisis period on August 27 when rain triggered dangerous and overwhelming flooding across the region. Leaders mobilized within and across the NPO-12-S system to initiate inquiries and mobilize networks to account for employee and partners' safety (see Appendix in the online supplemental materials for visualizations for each date). On 3 particular days, August 27 and September 1 and 6, the greatest number of emails was exchanged across the greatest number of external partnerships as key brokers emerged across the city and state. At the network level, August 27's structure was most correlated with the noncrisis network, reflecting that IORs were mobilizing. For example, members of NPO-12-S were central communication senders and receivers across the network, while City 5 and City 4 brokered efforts via emails, connecting NPO-12-S and their partners across the network. On August 30, formal ties (between agencies with reporting relationships) were mobilizing through the brokering work of City 5 and City 4. These findings demonstrate the speed in which formal partnerships were able to resume work to benefit both the agencies and their various constituencies.

On September 6, Houston was already in the postcrisis period. Flood waters had receded, and organizations were involved with cleanup and return to services. Leaders activated work tasks related to returning to service delivery; once again, the bureaucracy was a stronger predictor of who communicated with whom than the noncrisis network structure (see Table 6). For example, organizations that had formal ties with NPO-12-S brokered resources by asking community NPOs, faith-based groups, and corporate partners to come to help out in the recovery process. Leaders were also concerned with assessing client needs, securing the supply chain, completing repairs, etc. They were also trying to assess the personal needs of NPO-12-S staff and their families to assure that NPO-12-S had the internal capacity necessary to provide client services. Formal leaders in the system (at the organizational level and in partnership with both NPO-12-S and ServiceNet leaders) were actively coordinating a "storm meeting" to assess internal and external needs and mobilize for community

Table 4. Group statistics of independent *t*-test comparing people/their organizations holding authority positions versus those who are not in positions of authority during noncrisis and from August 25–September 9.

	Point of authority	*N*	*M*	*SD*
Noncrisis	Authority	37	**.1347**	.41208
	No authority	197	.0089	.04157
Aug 25	Authority	37	.0028	.01710
	No authority	197	.0000	.00000
Aug 26	Authority	37	.0019	.00646
	No authority	197	.0001	.00114
Aug 27	Authority	37	**.1722**	.53819
	No authority	197	.0047	.01985
Aug 28	Authority	37	.1056	.44766
	No authority	197	.0135	.08399
Aug 29	Authority	37	.0045	.02695
	No authority	197	.0048	.05934
Aug 30	Authority	37	.0928	.30664
	No authority	197	.0003	.00323
Aug 31	Authority	37	.0198	.08431
	No authority	197	.0000	.00000
Sep 1	Authority	37	**.1707**	.69690
	No authority	197	.0285	.23848
Sep 2	Authority	37	.0257	.08893
	No authority	197	.0010	.00864
Sep 3	Authority	37	.0013	.00789
	No authority	197	.0002	.00181
Sep 4	Authority	37	.0275	.16719
	No authority	197	.0004	.00606
Sep 5	Authority	37	.0014	.00855
	No authority	197	.0000	.00000
Sep 6	Authority	37	.0028	.01710
	No authority	197	.0000	.00000
Sep 7	Authority	37	.0091	.05540
	No authority	197	.0000	.00000
Sep 8	Authority	37	.0022	.00989
	No authority	197	.0000	.00000
Sep 9	Authority	37	.0239	.09239
	No authority	197	.0000	.00000

recovery. In short, multi-level organizing within NPO-12-S (among employees) and in coordination with its formally prescribed partners (leveraged by the NPO-12-S senior staff as brokers in interorganizational networks) changed daily, both in structure and content.

On days when there was relatively less email activity, centralized communication from key service network headquarters dominated (See Table 4). Analysis of the network visualizations corroborate the quantitative results reported above and validated the importance of formal roles. For example, on August 25 (Figure 3) and 26, SO1 (i.e., senior officer 1) was at the center of the email networks. Internal communication was prevalent during those days as the organization prepared for disruption. August 28, 29, and 31 show similar patterns. These visualizations help interpret QAP (Figure 2) and MRQAP values: while the quantity of communication dropped within the network, it was guided by preestablished IORs and formal structures. These days were more chaotic given the storm's conditions. These days did not appear to be a time of spontaneity or improvisation.

Data revealed active cross-sector networks between nonprofits and government entities like the city and county officials. Over the course of 16 days, the central service provider organization NPO-12-S and its key leader, SO1, mobilized partnerships with government actors and other nonprofit organizations to initiate recovery efforts and secure resources. Interestingly, while they had formal partnerships with several business sectors (except for August 27, when there was the most heightened communication activity, see Figure 4), the business networks remained inactive, not participating in the main communication network via email. In large part, the network transformation was dependent on *what* they communicated about.

In summary, our analysis reveals the extent to which leaders in the NPO-12-S system used their formal ties to benefit the wider network and assure that services would continue to their vulnerable clients. Their ability to access resources and share information enhanced system-wide recovery while simultaneously attending to the safety of NPO-12-S staff members and assuring that operations experienced minimal disruption.

RQ2: How communication changes in the pre-, during-, and postcrisis periods.

Table 5. Timeline of exogenous factors and content of emails.

Date	Storm phase (total emails sent)	Interorganizational communication	Communication type (% of daily emails)		
			Interpersonal	Task	Process
Aug 25	Harvey makes landfall near Corpus Christi; category 4 hurricane ($n = 9$)	NPO-12-S in contact with other networked organizations, including centers that report to NPO-12-S and those to whom NPO-12-S offers assistance when needed.	0	100	0
Aug 26	Harvey makes 2nd landfall on Copano Bay ($n = 37$)	Spike in networked communication as NPO-12-S offices discuss preparations.	100	0	0
Aug 27	Storm moves toward Houston ($n = 1,377$)	Networked communication at its highest among NPO-12-S, city agencies, and other NPOs.	76	21	3
Aug 28	Hurricane Harvey floods Houston ($n = 292$)	Level of formal and networked communication is high; formal structures predominate. NPO-12-S reaches out to staff to ascertain well-being.	21	64	15
Aug 29	Levee breached near Houston causes additional flooding ($n = 196$)	NPO-12-S gauges damage to smaller nutrition centers and Harris County agencies, faith-based agencies, and other NPOs coordinate resources.	10	90	
Aug 30	Rainfall throughout area; flooding in Jefferson County, where an NPO-12-S partner organization is located ($n = 91$)	Formal structures prominent as NPO-12-S continues task-related objectives and interorganizational collaboration continues apace.	9	91	
Aug 31	Harvey continues flooding in Jefferson County; hurricane storm watch discontinued ($n = 57$)	NPO-12-S staff continue to coordinate workarounds to serve clients; interorganizational, process-oriented communication at reduced pace.	49	49	2
Sep 1	Tropical Storm Harvey moves into Louisiana ($n = 206$)	NPO-12-S determines needs and provides resources for networked organization in Jefferson County.	0	100	1
Sep 2	Harvey dissipates ($n = 48$)	NPO-12-S departments return to client-driven, task-related work; report to senior management.	13	87	
Sep 3	Flood waters recede in Harris and Jefferson counties ($n = 57$)	NPO-12-S departments return to client-driven, task-related work and reports to senior management.	0	100	0
Sep 4	Post-Harvey cleanup ($n = 38$)	NPO-12-S departments return to client-driven, task-related work and reports to senior management.	0	100	0
Sep 5	Post-Harvey cleanup ($n = 7$)	Few Harvey-related emails are exchanged; most are between an NPO-12-S partner and NPO-12-S staff.	86	14	0
Sep 6	Post-Harvey cleanup ($n = 8$)	NPO-12-S departments return to client-driven, task-related work and reports to senior management.	0	100	0
Sep 7	Post-Harvey cleanup ($n = 35$)	NPO-12-S departments return to client-driven, task-related work; NPO-12-S CEO and senior staff engage in post-Harvey reflection and planning.	0	83	17
Sep 8	Post-Harvey cleanup ($n = 15$)	NPO-12-S partner continues to interact with NPO-S staff; NPO-12-S CEO coordinates activities with senior staff.	54	46	0
Sep 9	Post-Harvey cleanup ($n = 98$)	NPO-12-S departments return to client-driven, task-related work; NPO-12-S CEO and senior staff engage in post-Harvey reflection and planning.	0	91	9

Table 6. Regression analysis (using Double-Dekker MRQAP in UCINET) of noncrisis networks versus formal structures to predict observed social networks for each date.

Date	R^2	Adjusted R^2	Formal standardized coefficient	Social standardized coefficient
Aug 25, 17	.04	.04	.1	.13
Aug 26, 17	.07	.07	.11	.21
Aug 27, 17	.13	.13	.16	.28
Aug 28, 17	.19	.19	.23	.31
Aug 29, 17	.29	.29	.14	.48
Aug 30, 17	.23	.23	.18	.4
Aug 31, 17	.26	.26	.14	.45
Sep 1, 17	.16	.16	.16	.33
Sep 2, 17	.22	.22	.05	.45
Sep 3, 17	.06	.06	.17	.15
Sep 4, 17	.08	.08	.14	.22
Sep 5, 17	–	–	–	–
Sep 6, 17	.04	.04	.14	.11
Sep 7, 17	.05	.05	.11	.16
Sep 8, 17	.08	.08	.23	.13
Sep 9, 17	.14	.14	.21	.26

Note. MRQAP was run for each date. All dates models are significant. $p < .001$: all based on 2,000 permutations: observations $n = 27{,}261$.

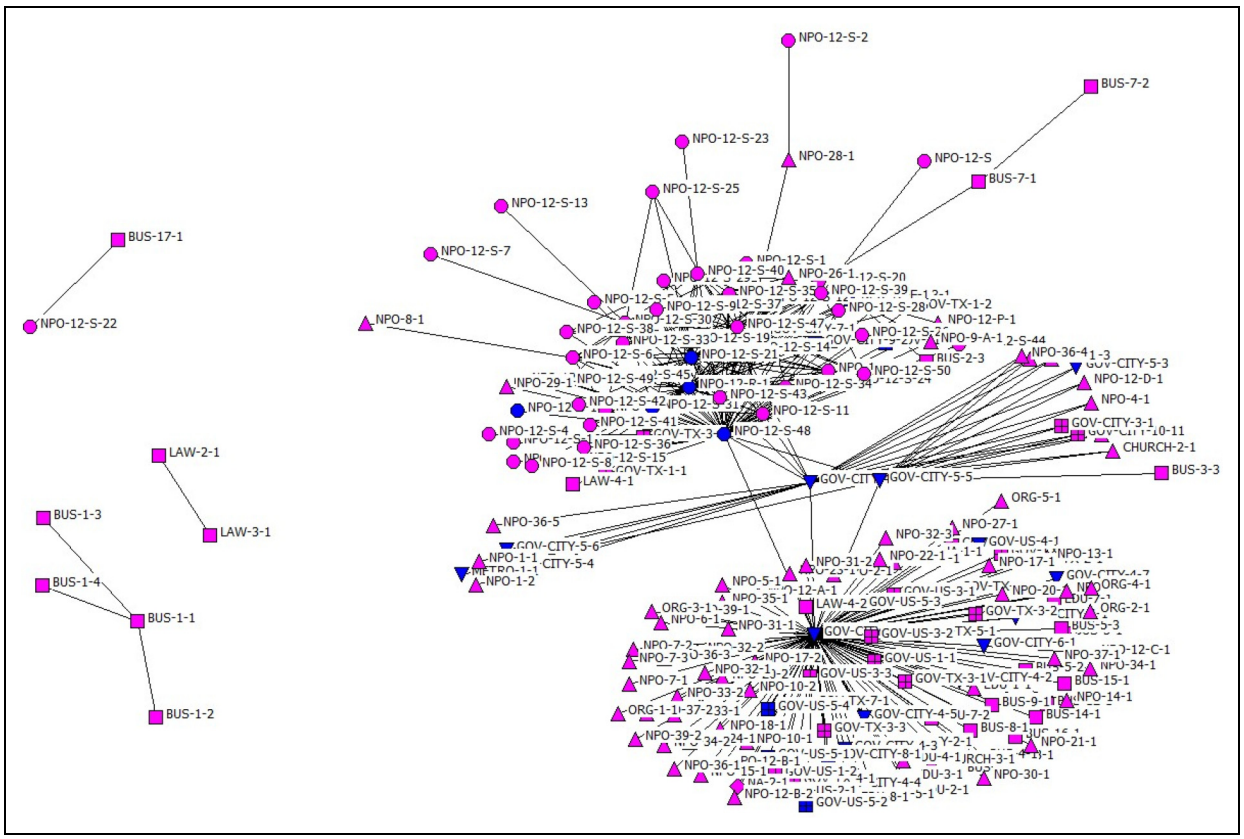

Figure 3. NPO-12-S observed interorganizational communication, August 25.

Our second research question asked how actual messages change during periods of heightened crisis: how does the type of message allow people in the bureaucratic and informal structures to adapt and return to normal as disaster unfolds. To answer it, we used both social network analysis and systematic content analysis to ascertain both changes in the correlation among networks and the type of communication during crisis periods. The results showed that leaders and staff focused on interpersonal, task-related, and reflexive communication at different times during the disaster. The ability to organize to serve vulnerable clients was dependent on utilizing these three strategies at the appropriate times. Table 5 shows how the content and focus of communication shifted during each phase of the storm among three key themes—task, interpersonal, and process.

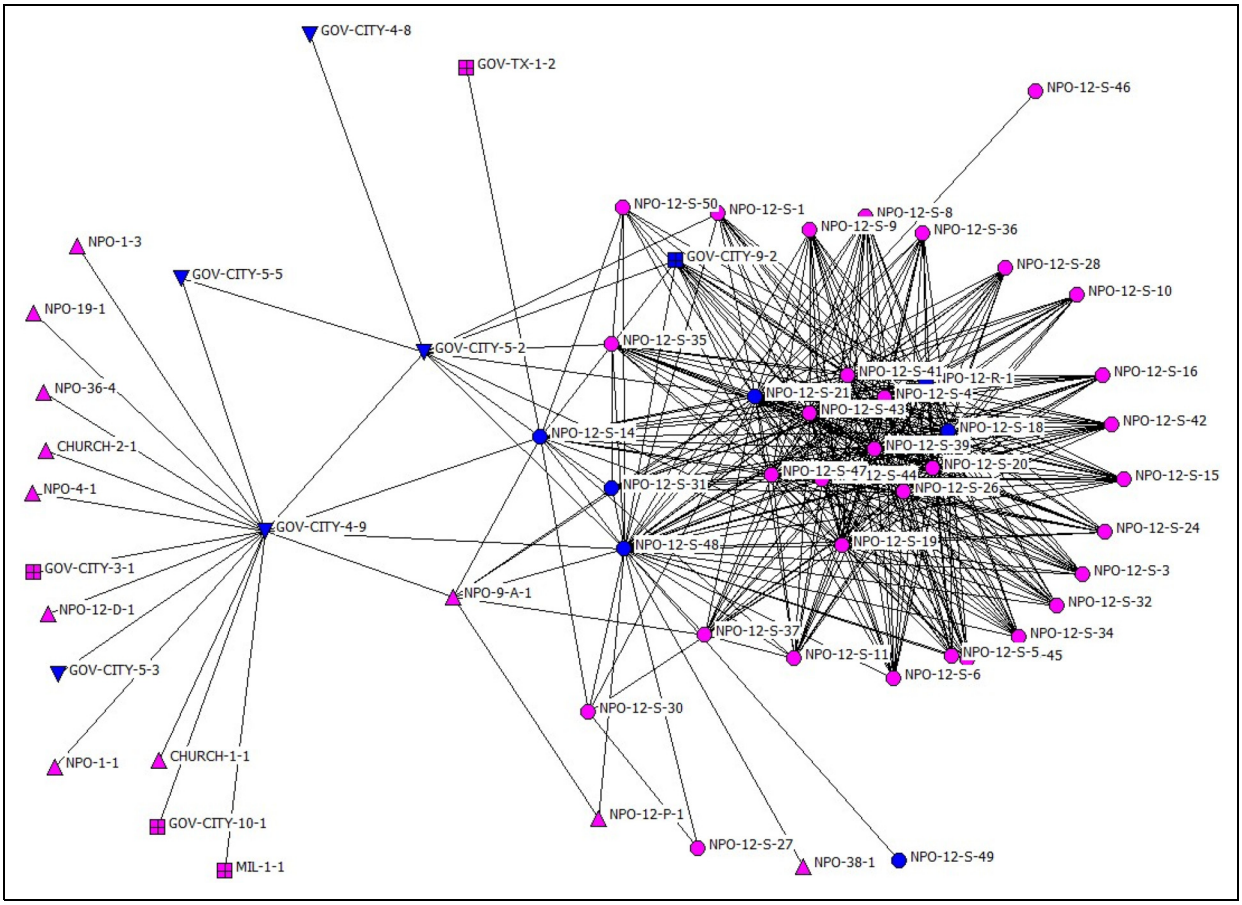

Figure 4. NPO-12-S interorganizational communication, August 27.

On August 25, during the precrisis period, one of the senior staff managers of NPO-12-S initiated a preparatory communication in advance of the storm. Email data revealed that he was coordinating according to the organization's disaster plan, for example, updating client contact information and planning alternate meal deliveries. One hundred percent of email sent and received that day was task-related. As the event shifted into the crisis phase, communication changed as well. During the heavy rainfalls between August 26 and 27, the communication shifted from task-related to interpersonal as the president of NPO-12-S asked members to check-in to ensure that all staff were safe and to reassure workers emotionally (100% on August 26, and 76% on August 27, when 1,377 emails were sent and received). He reached out to the entire organization through a group email, and staff members used "reply all" to share their status ("I'm safe," "We're ok," "How's everyone"). Only on August 28 (the fourth day), did communication content shift from personal well-being checks to one-way reporting about task completion (21% interpersonal/64% task-related/15% process) (Figure 4). At that point, an employee of the local city department, acting in his official capacity, also checked in and shared information to assure that NPO-12-S would begin serving clients again.

By August 29, communication returned to task-related interactions as NPO-12-S's staff devised continued wellness checks with clients and agencies in the network, and suggested ways to deliver services to vulnerable clients. Correlations between formal and informal networks declined, suggesting more spontaneous communication was taking place within the network. By the next day, communication, still mostly task-oriented and process driven, centered around collective decision-making and brainstorming. Although environmental conditions were still chaotic on August 30, with rain still falling and flooding in Jefferson County, where an NPO-12-S partner is located, there was a significant shift to external task-related communication as the Houston Health Department interfaced with its agencies and partners (HHD; Figure 5). Internal task-related and process-driven communication also continued as staff engaged in wellness checks and assessed options for meal delivery (which resumed August 31). By September 6, Harris County was in postcrisis mode, as cleanup had begun 3 days earlier. Although the water had subsided in large part, there were multiple tasks being handled by staff and interorganizational partners. Since the meal delivery and other community services resumed, they were also actively communicating with other service assistance providers like volunteers and drivers.

Our analysis demonstrated that the focus of communication shifted as leaders and staff members responded to a rapidly unfolding crisis. While naturally attentive to their work-related responsibilities, during the height of the storm these

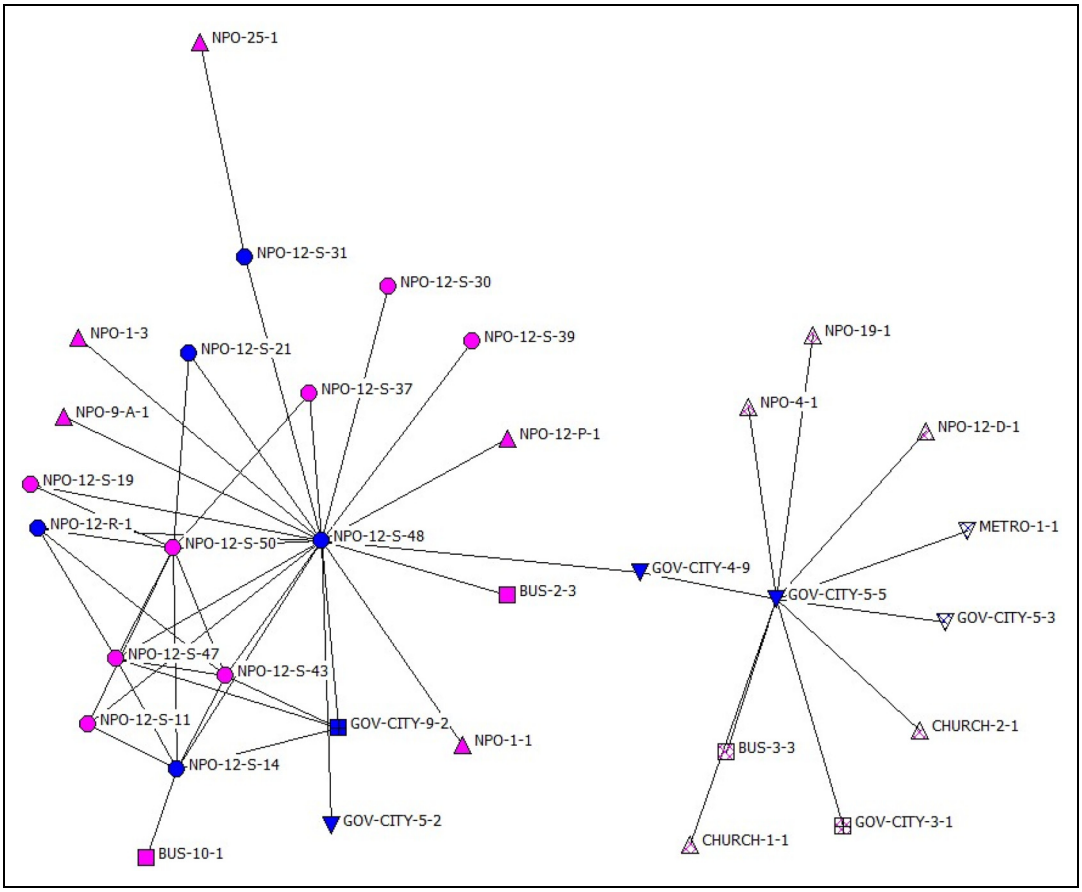

Figure 5. NPO-12-S interorganizational communication, August 30.

obligations temporarily took a back seat to reassuring that all were safe. They then were able to tackle both task-related and reflexive activities, communicating internally and externally to serve vulnerable clients.

Discussion

While disasters may last a relatively short time, the impact on organizations can last for days, weeks, or even months as the organization struggles to get back to business. This research was driven by questions of how formal and informal communication structures intersect over that liminal period between the actual disaster and the point when organizational activity returns to a base line of communicative functioning. We viewed this question through the structure of formal (bureaucratic) structures and informal networks because organizations today utilize both traditional top/down leadership and bottom/up networks (e.g., teams working across departments or geographic locations) to complete tasks, often blurring the distinctions between formal leadership structures and informal networked communication. Indeed, this study demonstrates the symbiotic relationship between the two and shows that effective organizing during disasters appears to involve the emergence of a robust crisis network that includes bureaucracies and preexisting social networks, as well as emergent networks. Additionally, our focus on the type of communication that occurs day-by-day allows us to understand what happens within the pre-, during-, and postphases of a crisis.

The ebbs and flows of organizing

Monge and Contractor (2003) assert that distinctions between informal and formal processes "may become increasingly irrelevant in coming decades" (10). Our findings suggest otherwise. There is a nuanced dynamic relationship between formal and networked structures. In the cross-sector system examined here, preplanned structures were still present and were a necessary condition for coordinating work in the aftermath of disaster. Such findings reflect what Kim et al. (2021) identified in that formal structures provide foundations for flexible and emergent connections to become an asset for disaster recovery. However, what existing research fails to recognize is the fact that there are also defined periods of time when improvisation drives the organization forward. This research underscores the critical temporality within crisis networks. We observed that daily changes in NPO-12-S's crisis network allowed the organization to serve its vulnerable population, first by assuring that staff had the ability to work, then by focusing on tasks and reflexivity. Formal structures and

emergent networks became co-occurring organizing mechanisms for NPO-12-S, allowing NPO-12-S to navigate the crisis in advance, during, and after the storm. In fact, NPO-12-S's flexibility may have enhanced these capacities: our findings show that the organization returned to its mission-driven work even before flood waters receded.[1] NPO-12-S's capacity to return to work by embracing the crisis network can be a model of recovery for other NPOs.

Time and uncertainty

Doerfel et al. (2022) proposed that organizations can successfully adapt work processes during disasters by shifting between formal and informal processes. In the case of NPOs like NPO-12-S, the interplay between formality and networked forms were necessary for serving clients. However, this study demonstrates the degree to which time itself matters as leaders and staff attempt to process personal and work-related challenges and serve vulnerable clients. The crisis network was most active during periods of great uncertainty for both the organization and its staff. However, formal structures guided the organizations as NPO-12-S's leader-initiated communication that reinforced both the networked conversation around well-being and the task- and process-related segments of operations. His leadership further empowered staff flexibility. As communication moved from interpersonal check-ins to task-related functions, leaders were able to focus on extra-organizational and interorganizational relationships that could direct resources and information through the wider network. Thus, NP-12-S was able to resume to preplanned activities, for example, interfacing with the City of Houston and reporting to its Board of Directors. When it comes to understanding disaster response, unlike research that has argued for looser network structures (Boersma et al. 2014; Doerfel, Chewning, and Lai 2013; Kendra and Wachtendorf 2003), these findings suggest that those looser structures are both enabled by formality and facilitate a return to it depending on the timeline of the event.

Communication matters

Buzzanel (2010) argues that communication is necessary to "bounce back" (1) following crises. It is through interpersonal communication that people impart their experiences and work together to craft a narrative of hope and shared identity that allows them to return to work. One of the roles of formal structures within organizations is to allow and encourage informal, networked communication to emerge during crises. We found that all three types of messages, personal, task-related and process-related communication among internal and external partners—facilitated the crucial work of disaster response and recovery. NPO-12-S's focus on its workers during the first days of the crisis facilitated their return to the task of finding ways to serve the vulnerable. The 2 days of highest email activity in the 2 weeks studied were the days following the "check-in day," and it is at this point that email switched from interpersonal to ask related. Indeed, the shift from personal to task-related communication was dramatic, occurring literally overnight from August 28 to August 29.

Implications

Environmental disasters produce uncertainty at all levels as government agencies, organizations, and individuals worry about short- and long-term survival while also concerned with the ability to meet personal and societal needs. Organizations, particularly nonprofits serving vulnerable populations, must be mindful about whether their facilities are operational, staff will be able to work, and how work will continue during and after the crisis. This research underscores the importance of communication at all levels as part of recovery and long-term resilience to uncertainty. Organizations would benefit from acknowledging the importance of promoting more flexible, decentralized systems that empower staff to be more autonomous during crisis periods, adapting formalized plans to conditions on the ground. At the same time, people in positions of authority in a cross-sector network are also vital to facilitating disaster response. They can leverage formal organizational positions to act as brokers of information and resources across the system, enabling organizations to coordinate activities and serve clients. Finally, while this study did not focus on leadership, the decision of NPO-12-S's leader to prioritize the well-being of his staff by encouraging interpersonal check-ins at the beginning of the crisis facilitated the ability of staff to concentrate on the organization's mission and tasks even as the Houston was experiencing record-breaking rain and flooding. While in the midst of crisis, organizations that safeguard their human resources may be best situated to recover from disaster.

Limitations and future research

These data enabled our ability to examine (1) the dynamic intersection of formal and informal networks; and (2) types of communication flows during defined time periods rather than temporal stages. There are limitations, however, worth noting. By focusing on email archived by one organization, data only represent the reporting features email provides. Other activities like phone calls, texting, and meetings were certainly happening during this time, too. This approach fails to capture the complexity of organizational communication when individuals work through multiple different channels (Doerfel and Haseki 2015). Additionally, the data were sourced by one organization. Emails that were exchanged

between other organizations in the network without copying the focal organization are another part of the overall case but not included. Despite these issues, these data are behavioral and longitudinal, giving substantial access into actual communication dynamics among a large social network of actors compared with the more common self-report data that brings its own biases and meaning (Bernard et al. 1984). Finally, this research amplifies the importance of having preexisting networks and built-in accountability through formal leadership positions both within organizations and across a cross-sector network. The system was nimble and indicated that improvisation through emergent networking was present, but during the most volatile times, formal structures and already existing informal relationships were mobilized to support information needs and coordination of services.

Conclusion

In this research, we explored how already established social network relationships and formal work structures affect the social structure of organizing in the aftermath of disaster. In short, both are important, especially on the most chaotic days of the crisis, then as conditions stabilize, social networks ebb and flow more organically, suggesting improvisation follows critical early organizing. This study shows how formal, centralized communication with flexible boundaries can set up conditions for transformative communication and how networks take shape during and after the most tumultuous periods of crises. Additionally, we demonstrated that effective organizing requires shifting the type of messages communicated at different points of a prolonged environmental disaster. In short, mitigating initial chaos in the aftermath of a disaster requires both formal structures and established social networked relationships that are tuned in to the human element of response.[2]

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Supplemental Material

Supplemental material for this article is available online.

Notes

1. Interview data from the greater corpus confirmed that NPO-12-S's leader was able to leverage interorganizational contacts to deliver fresh water to vulnerable clients while major roads were still flooded.
2. The correlations between the matrices are based on 234 nodes, or 27,261 observations that QAP makes to compute the correlations, making high correlations between formal and informal structure more mathematically challenging.

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