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Social Network Methodology in the Study of Disasters: Issues and Insights Prompted by Post-Katrina Research

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Abstract Dynamic social networks, a key concept in modern social science research, are beginning to play a major role in understanding the ways in which individuals and communities respond to disasters. The authors of this paper review the relevant theory and research regarding how crises cause change in social networks, and how those changes may or may not facilitate recovery, as a function of the kinds of changes that occur. It applies the In/Out/Seeker/Provider (IOSP) framework to identify categories in which we might study disasters and the impact both *on* the networks and the impacts *to* the networks. This paper details options for applying social network analysis to research of both pre- and post-disaster settings and concludes by framing a research agenda for the future study of the dynamics of network change following a disaster.

Keywords Social networks · In/Out Seeker/Providers (IOSP) · Social network analysis · Disaster research · Katrina

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Introduction

For decades, network theorists have explored the importance of social interactions and network structures. Most network studies have focused on small networks in very routine situations. We now have a better understanding of how to access resources by increasing diversity in our networks (Granovetter 1973), how community networks form and grow (Prell 2003), how network governance influences policy (Hajer and Wagenaar 2003), how to most effectively and efficiently shape a network to reap its competitive benefits (Burt 1997), and even how to fragment a terrorist network to ensure a safer nation (Krebs 2002). But these traditional frameworks in studying and identifying social networks are not fully adequate for research in non-routine situations, such as post-disaster recovery.

When a disaster affects a community, dissipated (and ad-hoc) social infrastructures can result, leading to new questions about how to identify and study social networks. These networks arise on different scales, from the individual (Quarantelli and Dynes 1977; Drabek and Key 1984; Solomon 1985; Drabek 1986) to the community level (Tierney 1985; Solomon 1986; Kapucu and Van Wart 2006), so a range of methodology is needed.

The recent Hurricane Katrina disaster provides a setting by which we can further explore these kinds of questions. Hurricane Katrina by most measures was the greatest natural disaster in American history. The spread of the disaster stretched 90,000 square miles, roughly the size of Great Britain. At least 1,836 people lost their lives, and hundreds of thousands of Gulf Coast residents lost their homes and jobs. One authoritative source estimates economic losses at $81.2 billion (and growing), nearly double the costs associated with the next most costly disaster, Hurricane Andrew (Department of Commerce, 2006). The occurrence of such a loss of a social infrastructure, the emergence of new networks, and the activation of multiple network ties in various dimensions was conspicuous in the aftermath of Hurricane Katrina in September 2005, leading to a new wave of research on social networks in disaster contexts.

This paper reviews the relevant theory and research regarding how crises cause change in social networks, and how those changes may or may not facilitate recovery, as a function of the kinds of changes that occur. It applies the In/Out/Seeker/Provider (IOSP) framework that is a means of identifying the categories in which we might study disasters and the impact both *on* the networks and the impacts *to* the networks. After drawing on past research as guidance, we highlight current social network research from interdisciplinary teams working to define, understand, and analyze social networks in multiple aspects of the post-disaster context in the wake of Hurricane Katrina.

The Network Paradigm in a Disaster Context

Before introducing the framework, we review past research to answer the question: Why are social networks important in assessing disaster recovery and relief at the individual and organizational levels? Researchers have found that in the short-term recovery phase of Hurricane Andrew, individuals who received more social support experienced better physical health and lower levels of depression than individuals who received less support (Haines et al. 1999; Haines et al. 2002). Haines et al. (1996) reported that networks in which a high proportion of members have strong ties to similar individuals play a central role in the provision of informal social support, which, in turn, contributes to better health outcomes. Regarding Hurricane Katrina, Hurlbert et al. (2005) built on their own and other's research (Hurlbert et al. 2000) to argue that the urban poor are less likely than their more affluent counterparts to have participated in optimal networks prior to the disaster, and that they may also be less likely to maintain their pre-Katrina network structures.

At the organizational level, interorganizational networks in emergencies have been found to play important roles in facilitating the flow of information across organizational boundaries (Kapucu 2005a, b) through the development of trust (Coleman 1990), providing support to engage in overall higher levels of risk taking (Fukuyama 1995), rapidly disseminating information (Kapucu 2005a, b), improving social capital (Burt 1992), and allowing members to collectively solve problems (Fulk et al. 1996; Monge et al. 1998).

To explore the impact of a disaster on social networks at all levels requires innovative research designs and methodological tools that account for the unique social structures and their accompanying dynamics. Quarantelli and Dynes (1977) identify the response to social crisis and disaster as a dimension of social structure that includes the "basic substantive and structural trends from the literature that either implicitly or explicitly assume that a disaster is primarily a social phenomenon and is thus identifiable in social terms (p. 24)." Disasters have the ability to shake up an entire social infrastructure, turning what we know about the way people relate, the way organizations behave, and the system of social and resource support into new questions that, if understood, could greatly impact an entire society's ability to deal with the consequences of disasters.

Social network theory is flexible and applies to many kinds of networks. The networks can be egocentric or whole networks at the individual, community, and organizational levels, they can involve different kinds of link relationships, and they can have fixed or variable sets of actors. There are, however, particular features that distinguish their application in disaster contexts. These features include the atypical structure of networks after the disaster, the need for new types of links (e.g., collaboration and resource sharing) that are specific to disaster response and recovery, and the difficulty in identifying members and measuring network relations in the fluid uncertainties of a refugee population.

A Framework for Disaster Research on Social Networks

Below we introduce the In/Out/Seeker/Provider (IOSP) framework that attempts to capture the various dimensions of social networks for multiple levels of investigation, analysis, and understanding. This framework is a means of identifying the categories in which we might study disasters and the impact both *on* the networks and the impacts *to* the networks. Providing operational measures for these actors is a critical next step in conducting social network analysis both pre- and post-disaster, and these measures can frame a research agenda for the future study of the dynamics of network change following a disaster.

Applied to a disaster setting, the framework allows researchers to address questions that are relevant to disaster mitigation, relief, and recovery. For instance, do social networks determine why some individuals are better able than others to overcome the physical, psychological and economic problems in the immediate aftermath of major disasters? Does the economic, educational, racial or experiential (previous catastrophic event experiences) status of an individual largely determine their perceptions of relief and recovery? Which groups are most likely to be central to providing and coordinating relief within post-disaster social networks? How might communications be enhanced within these networks?

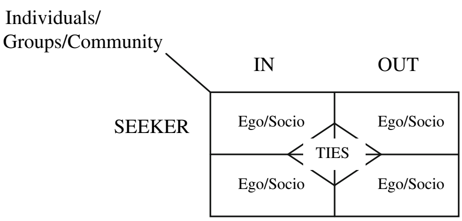
These questions require a framework for identifying and measuring social network relations after disasters. Figure 1 provides a descriptive model summarizing the various roles and attributes of actors in a pre- and post-disaster setting. These actors may be conceived as individuals, groups, or communities within the social network. The vertical axis relates to the roles played by different actors in a pre- and post-disaster setting. Actors may be conceived as either service-seekers or service-providers (although it is possible for the same actor to serve in both roles, depending upon the persons with whom they interact). The horizontal axis communicates the spatial location of the actor, either "in" or "out" of the disaster area. But since a disaster may have amorphous boundaries, and since actors can move into and out of the affected area, once again the same person can appear in two ways. For both of the role and spatial axes, social networks can be studied at either the egocentric or sociocentric levels with many types of relationships (ties) connecting the network members.

As noted, this simplifying framework does not capture the multiple roles and locations that actors can take. But it is a useful categorization for a network at a single time point, and a reasonable approximation over short periods of time. It also does not capture the degree and nature of service needs or provisions. The strength of the framework is in its ability to categorize members of a network, by drawing on the easily measured attribute characteristics of the network members.

Examples of network actors that might fall into each quadrant are as follows:

Quadrant 1: In/Seekers: Network members who are in the disaster area, seeking something from others in the network. For example, this may include disaster victims seeking post-disaster resource assistance.

Fig. 1 Social network actors in a post-disaster setting [specifically, their attributes]. In/Out/Seekers/Providers (IOSP) framework



Quadrant 2: Out/Seekers: Network members who are out of the disaster area, seeking something from the network. For example, this could include organizations that are seeking assistance to provide resources for disaster evacuees.

Quadrant 3: In/Providers: Network members who are in the disaster area, providing something to other network members. For example, this could include rescue workers who are located in the disaster zone, trying to provide modes of transportation to victims to leave the area.

Quadrant 4: Out/Providers: Network members who are out of the disaster area, providing something to other network members. For example, hospitals that are treating disaster victims once they leave the disaster zone.

Operationalization of social networks in a disaster context should take into account the IOSP framework, applying the various dimensions to identify networks at the individual, group, or community level. First, the framework can be used to identify network boundaries. Second, the unit and level of analysis can be identified to meet the needs of the research question. Ties between the network members are then identified to fit the disaster context. These steps can then guide the framing of research questions, instrument development, and data gathering. Once these steps have taken place, the networks must be measured and analyzed.

The methodological approach commonly used to explore social network theory is social network analysis (SNA). SNA is the study of the structural relationships among interacting network members—individuals, organizations, etc.—and of how those relationships produce varying effects. The fundamental property of network analysis is the ability to determine, through mathematical algorithms, whether network members are connected—and to what degree—to one another in terms of a variety of relationships like communication, resource sharing, or knowledge exchanges. Network analysis provides a mathematical approach to measure the number, the paths, and the strength of those connections. In addition, visual representations of the network can be created as graphs. Furthermore, network analytic techniques can quantify the emergence of networks and their dynamic processes (Monge and Contractor 2003).

Table 1 illustrates the typical patterns and measures that we apply to the study of social networks.

The following sections discuss the various dimensions of this framework including the unit and level of analysis, the types of ties of interest to disaster researchers, and methods to operationalize these category distinctions using techniques of social network analysis, particularly in a dynamic nature.

Unit of Analysis: Individuals, Groups, and Community

We begin discussion of the framework by discussing the unit of analysis which can include individuals or groups, each embedded in a larger community (see Fig. 2). The inclusion of individuals as a unit of analysis involves identifying single actors,

Table 1 Operationalizing social networks: patterns and measures

Typical patterns we look for among ties	Measures of individual actors	Measure to describe networks
Characteristics		
Indirect links	Degree	Size
Frequency	In-degree	Inclusiveness
Stability	Out-degree	Component
Multiplexity	Range (diversity)	Connectivity
Strength	Closeness	Connectedness
Direction	Betweeness	Cohesion
Symmetry (reciprocity)	Centrality	Density
	Prestige	Centralization
	Brokerage	Symmetry
		Transitivity

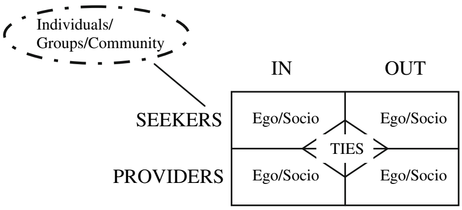


Fig. 2 Unit of analysis in IOSP framework

independent of the group to which they belong, and asking questions about how individuals activate their social networks or play a role within a social network. This unit of analysis can be used to answer such questions as: Who seeks social support in an emergency? Who provides the support? How do patterns of support in a crisis compare to those in everyday life for people involved in disasters (both seekers and providers)? (Shavit et al. 1994).

Much of the social network disaster research to date that looks at the individual seeks to identify their typical social networks, the mobilization and activation of their social ties, and the impact of the various social support configurations in a disaster context. Findings reported on the individual include: social support improves morale as well as providing practical aid in disasters (Solomon 1985; Figley 1986; Solomon 1986); people overwhelmingly turn to kin in a crisis for shelter and to non-kinship ties for talking/advice (Shavit et al. 1994); and mobilization of personal networks helps explain in great measure why mental illness is an atypical outcome of community disasters (Quarantelli and Dynes 1977).

At the group level, the most common type of study includes organizations as the unit of analysis (e.g., church groups or the Red Cross or federal relief agencies). The increasing focus of organizational research in disaster contexts is the call for organizations to better coordinate and communicate both pre- and post-disaster. The efficacy of interorganizational efforts to communicate during and after a disaster has been studied in various contexts including emergency medical preparedness and response (Tierney 1985), organizing to reduce vulnerabilities of complexity (Perrow

1999), cross-agency coordination in dynamic contexts (Kapucu 2005a, b; Robinson et al. 2006), boundary spanners in multi-agency coordination (Kapucu 2005a, b), and the importance of well-designed communications and information infrastructure in managing the complex, dynamic operations that evolve in disaster environments (Comfort and Haase 2006).

Usually, the main focus has been on the emergence of interorganizational networks after the disaster. But such studies are difficult for three reasons:

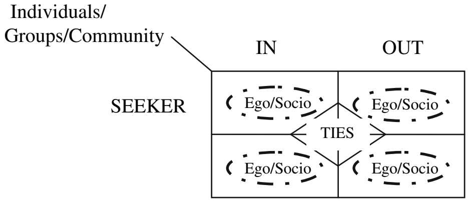
1. Organizations that typically respond to a disaster transcend multiple organizational types and do not necessarily have classic structural dimensions of formal organizations (Quarantelli and Dynes 1977; Stallings and Quarantelli 1985), making it difficult to apply systematic organizational theory principles.
2. Many organizations that respond to disasters are small in size and therefore lack formal divisions of labor, complex communication technologies, and hierarchies that are needed in a disaster setting.
3. "Disaster situations tend to be peopled by emergent groups, entities that had no existence prior to the crisis; these often have only transitory existence, but their functioning may be crucial to the whole trans- and post-disaster response (Quarantelli and Dynes 1977, p. 31)."

Not only is it important to characterize individuals and groups in their community context, but the community context itself can become a third unit of analysis. For example, Stallings and Quarantelli (1985) studied informal emergent citizen groups, i.e., private citizens working together in pursuit of collective goals relevant to actual or potential disasters without a formal organizational identity. This community response was documented and identified in three types: damage assessment, operations, and coordinating groups. Each collectively plays a role in the overall emergent community of local citizens that react post-disaster.

Level of Analysis

The next dimension of the IOSP framework includes analytic levels of analysis that we might consider including the egocentric and sociocentric levels. The *egocentric level* is focused at the individual level. The *sociocentric level* is focused at the dyadic (any two network members), triadic (any three network members), subgroup, and global levels (see Fig. 3). Describing networks at each of these levels provides different ways to answer questions posed by disaster researchers; it allows one to gain understanding and test hypotheses to further empirical social network research

Fig. 3 Level of analysis in IOSP framework



in a disaster context. Below we will discuss these levels and pose examples of research questions that relate to disaster research at each level.

The first level looks at egocentric networks. The “individual” in this level need not be a single person, but could also represent single organizations, agencies, and other aggregated nodes that are a unit of analysis with specific structural characteristics. Each of these types of nodes (individuals, organizations, and agencies) can be analyzed by their particular network connections with each other (people as well as organizations and agencies with which they link). Egocentric network data, sometimes known as personal network data, consists of information on the local social environment surrounding the ego and is often used to predict the consequences of a specific network structure (e.g., if an egocentric network is densely connected, then communication may be more efficient).

Egocentric data are gathered by asking the ego to list a certain number of alters to whom they relate in specified ways. Then a number of questions are asked about the alters in order to categorize both the ties and the network structure surrounding the ego. Egocentric measures may also be constructed from complete network data. That is, if a researcher has gathered data about a whole set of network members and their network ties, analyses can be applied that measure characteristics of each network member aside from the connection they have with the whole network. Most egocentric approaches pose research questions that ask how the network within which the ego is embedded affects certain outcomes. Egocentric analysis allows one to sample individuals from the population in order to draw conclusions about patterns of social support and behavior. Examples of questions that disaster research asks of egocentric data include:

Q1: What kinds of routine networks allocate resources in nonroutine situations (Hurlbert et al. 2000)?

Q2: What is the size of informal helper networks mobilized during a serious personal crisis (Chatters et al. 1989)?

Q3: How do people use their social networks during a mortal threat (Shavit et al. 1994)?

This leads to the next level of analysis a disaster researcher might consider: *sociocentric analysis*. What distinguishes a sociocentric approach from an egocentric approach is that the latter includes an interest in the relation between two network members. It focuses on the characterization and likelihood of their ties, thereby explaining the emergence of whole networks. Example of sociometric analysis include mutuality (the reciprocal exchange within a relationship), distance (how many steps it takes to reach others in the network), and structural equivalence (based on the similarity of interaction patterns between two nodes). This level is distinguished from egocentric measures of a whole network because we are no longer concerned with the characteristics of a network member within the greater system; we are instead concerned with the characteristics of two network members and their relationship in the greater social structure. Another level of sociometric analysis is triadic; this studies any three nodes and the relationship between them. At this level, one examines transitivity (the level of information flow within a network based on the connections between any three members). Beyond this are subgroup and global analyses. At the subgroup level, one evaluates the connectedness of the various subgroups based on components and cliques. At the global level, one evaluates characteristics such as network centralization (the overall measure of how "equal" the members are based on their structural positioning) and density (the presence of relationships in relation to all possible relations). Examples of questions disaster researchers might ask from a sociocentric perspective include:

Q4: Can central actors in the network serve as a means for increased information dissemination (Kapucu 2005a, b)?

Q5: Can redundancy in network ties be reduced to produce a more efficient means of communicating timely information (Comfort and Haase 2006)?

Q6: Are emergent networks lasting and how do they evolve over time? Do these networks formalize and continue to function post-recovery?

Q7: How important is reciprocity in a coordination and communication emergency network? Does information need only disseminate, or is a response necessary?

Q8: Does the level of centralization within a decision-making network relate to the ability of the network members to make timely decisions?

Q9: Do network members that are structurally equivalent have similar communication patterns pre- and post-disaster?

At the highest level of analysis, a combination of the various units and levels of analyses are combined to examine important theoretical questions through hypothesis testing. For example, the MTML framework posits that multiple theories operating at multiple levels explain the emergence of networks. Each theory is associated with a distinct structural "signature" or configuration that is more likely to occur in the observed network than one would expect by chance. Since the emergence of networks arise from multiple theoretical motivations, multiple structural configurations are overlayed in any observed networks and are in general not easy to discern based on visual inspection. Yet, recently developed statistical techniques (called p* or Exponential Random Graph Models) enable us to detect the extent to which distinct multiple structural configurations (and by extension, distinct theoretical mechanisms) are driving the emergence of a particular network (Contractor et al. 2006). Preliminary results using the MTML framework suggest compelling evidence that multiple theories operating at multiple levels offer much higher levels of explanatory power for the emergence of networks than single theories (Contractor and Monge 2002). An example question that examines networks at these various levels is: How do characteristics of providers, their personal networks, and the community contexts in which they live facilitate or impede their ability to provide support (Haines et al. 1996)?

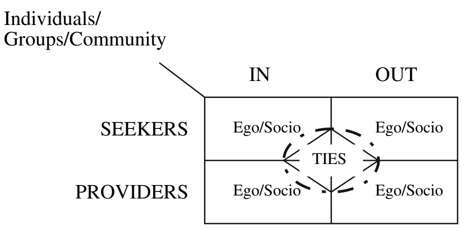
There, however, is considerable variability across contexts in the subset of theories that appear to be relevant in explaining the emergence of networks. Clearly there is a need for a contextual "meta-theory" of the social drivers for creating and sustaining communities that explains when and why some subset of the theories outlined in the MTML model is more important than others. One possible explanation centers on the nature of the tasks being carried out by the community. These could include, but are not restricted to, *exploring* new ideas, *exploiting* existing resources, *mobilizing* towards collective action, *bridging* across boundaries, *bonding* for social support, or *swarming* wherein a latent networks is rapidly activated. In order to accomplish each of the activities, we would expect to see some (but not all of the) theoretical explanations to be more relevant. For instance, communities geared towards exploration are more likely to be driven by theories of self-interest. That is, in order to maximize the ability to obtain novel information, each person seeks out ties with those with whom they do not already have indirect ties thus minimizing the chance of getting redundant information. However, in an emergency response, where mobilization and swarming is at a premium, theories of balance and collective action should be more influential. Hence, we would expect to see networks where structural signatures provide evidence for theories of collective action (individuals coordinating via emergent leaders) and balance (friends forging "swift trust" links with friends of their friends).

Types of Ties

As in all social network analyses, the identification of the various types of relationships is the root of understanding the connections between nodes. At each levels of analysis, connections can be categorized into communication, advice, kinship, friendship, professional (work related), membership-based (example: clubs, the gym, school), religious, proximal (example: neighbor), and various types of resource sharing.

Network links are often identified by observing, collecting survey data, and determining ties based on formal chains of command. Types of ties can also be inferred based on electronic traces (such as links between websites, and mining the text on these websites) (see Fig. 4). During any major operation such as disaster response, organizations report status through standardized written communications. One predominant form of these communications is the Situation Report or SITREP. During disasters, SITREP are often posted on the Web to provide information about an agency's response. Using text mining tools such as Data-to-Knowledge and Text-to-Knowledge (D2 K and T2 K), networks can be inferred unobtrusively in near real time.

Fig. 4 Ties in IOSP framework



Observational studies of network links can be achieved through news media—this would be suitable for examining how countries interact in responding to a disaster, such as multinational relief efforts following the Boxing Day tsunami. In these cases the researcher must rely upon domain knowledge and expert judgment to assess the nature and importance of the ties.

Survey data is collected in various ways, ranging from random sampling to convenience sampling to opportunistic sampling. For network data, snowball sampling is common; here one asks a respondent to name their contacts, and then goes to those contacts and repeats the question. By tracking through the links in the network, snowball sampling traces the main lines of connection (Thompson and Frank 2000). The statistical properties of all but the random sampling procedure are complex, limiting the generalizability of whatever inferences the researcher makes.

Chain of command data is often derived from organizational charts and reporting structures. The most famous example concerns the Enron dataset, in which emails among Enron employees that had been seized by the government were obtained under FOIA for research purposes. Many researchers have analyzed that data (Diesner et al. 2006), and a key component of such analyses is to account for the normal email communication associated with the institutional hierarchy. These studies often also involve text mining, since one wants to use the text in the email to automatically classify the kind of tie that the communication represents (Diesner and Carley 2005).

The Dynamic Nature of Disaster Networks

The dynamic nature of interorganizational and individual networks over the entire duration of the disaster period will complicate network measurement and analysis. But this is the primary characteristic of social networks in disaster contexts and it is crucial to conduct research in a way that captures these transitional elements. There is no strong theory for the general study of dynamic models of this kind. Currently, the best available tools take traditional summaries of the properties of static networks, such as average in-degree (the number of links pointing to a network member as having a relationships) or density (the total number of overall links present in relation to the total possible links in the network), and plot these against time.

Social networks change in four ways over the course of a disaster. Networks are first characterized as pre-disaster networks, that is, those that existed prior to the occurrence of the disaster. Changes in such networks are typically slow and not especially purposeful. Banks and Carley (1996) described several models for such change, and the process is largely one of "in-filling" the social networks (e.g., friends of friends become friends).

During a disaster, many ad-hoc social networks form, among the seekers and providers, both in and out of the disaster area. These types of networks often come together quickly and are likely to dissipate as the network members move through the recovery phase. For example, temporary shelters typically connect previously unconnected people. These seekers and providers often form strong relationships based on mutual understanding and trust. These types of ad-hoc networks may be influential in the decisions that network members are making regarding their movement in and out of this and other networks.

Emergent networks are those characterized by new ties (social relations) and new functions (goals or tasks) (Stallings and Quarantelli 1985). For people who have lost their previous network and are unable to reconnect it, the emergent network is the pathway back to normalcy. For organizations, the emergent network represents new opportunities for collaborations and partnerships.

Finally, stationary ties are those unaffected by the disaster. These ties persist and are unaffected by movement, social infrastructure devastation, or inconsistent communication. These types of ties are often kinship ties (e.g., a father/daughter tie remains as such regardless of the condition of the social context). These stationary ties play an important role in disaster research, with the majority of findings from individual social support studies indicating that disaster victims activate their kinship ties when they are in need or in crisis (Quarantelli and Dynes 1977; Marsden 1987; Chatters et al. 1989; Shavit et al. 1994; Haines et al. 1996; Hurlbert et al. 2000; McPherson et al. 2006).

These characterizations of networks expose themselves in various settings. For individuals in hurricane settings, one expects that during the preparation phase a typical actor provides help to those in their social network (say in boarding up a house or caravanning out of the city). During the evacuation phase, the social network is much sparser, pared down to all but kinship ties. During the recovery, a fragile emergent network is built, but the diversity within that network is not great and the formation of ties is driven by immediate needs. Finally, some people may successfully reconstruct most of their original network, or build a new and robust network in a fresh location. Each of these phases would be visible in a time series plot of density or network activity.

For organizations in hurricane settings, there is a greater range of behavior. A relief organization might draw upon pre-existing ties to accumulate resources in readiness, and then have an explosion of new ties to individuals who are helped. At the same time, their ties to other organizations might be competitive or cooperative, which affects the number and kinds of contacts that are made. Additionally, one might find emergent clique structure for faith-based, federal, and local groups. Longitudinal plots of structural properties of such networks could reveal much of this kind of story.

Edwards (1998) suggested that to account for this dynamic nature of disaster networks, ecological models need by applied. In her words,

> "Ecological models characterize human systems as integrated networks of social units – individuals, families, organizations, and institutions – that exist within a constantly changing physical environment. Human behavior is conceptualized as an organized process of ongoing, negotiated interactions that take place within larger natural processes…[which] provides an interpretive framework that explicitly recognizes the dynamic, reciprocal influence of the interdependent systems that constitute the natural and social worlds (p. 119)."

The network perspective takes account of dynamics. Past research on dynamic networks has focused on in-filling in static networks (Bearman et al. 2004), in terms of either descriptive statistics or mathematical models. This process is not as dominant in disaster networks, although it surely plays a role in the formation of temporary networks among refugees in shelters and coordination among relief agencies. In contrast, disaster research focuses on the kinds of changes that are forced upon the pre-existing network by circumstances and the kinds of adaptive responses that the thinned out networks make as they attempt to secure and distribute resources or achieve other objectives.

Further progress in disaster networks can proceed in several different directions. One approach is to build visualization tools that create "movies" that show how (small) networks lose and gain ties in response to particular kinds of disruption (Moody et al. 2005). A second approach is to create mathematical models for how resources flow through a social network. A third approach is to identify statistical tools for testing whether a particular model of network change is corroborated by one's data (Sanil et al. 1995). None of these is especially easy to realize.

Examples

All of the techniques mentioned here are embodied in the Social Network Analysis (SNA) methodology. As mentioned, SNA is a theoretical framework that suggests questions to ask, data to gather, and analyses to perform. A main goal to explain the degree to which network actors connect to one another and the structural makeup of collaborative relationships (Scott 1991). Although the application of SNA is not new in interdisciplinary research, it is new in disaster research. To this point, few studies have actually utilized SNA in their methods section and those that have, have done so primarily at the egocentric level, or as a descriptive tool at the sociocentric level.

The strength of SNA is its ability to address old questions in new ways, and we therefore provide here some examples of how SNA has been used in disaster research. By using the various relational and attribute data operationalized in the previous section to map onto theoretical and practical issues of concern to researchers interested in understanding disaster response, we provide a roadmap for future research on social networks and disasters by illustrating both how SNA has been used in the past and where it can be incorporated into questions addressed by disaster researchers in the future.

First, the typical network analytic tools (cross-sectional and dynamic, statistical and computational) that have been mentioned throughout this paper can be deployed to test hypotheses that map onto theoretical and practical issues of concern to researchers interested in understanding disaster response, particularly within the MTML framework (Monge and Contractor 2003). In this paper, we have mapped out the various levels of analysis, units of measurement, types of ties, and operationalization of social networks. We now present past applications and future prospects for SNA by summarizing work on a consistently important question in disaster research: What kinds of networks aid in recovery from disasters?

To answer this question, Hurlbert et al. (2000) applied egocentric network analysis. Through telephone interviews, the authors collected data from residents of three towns in three parishes following Hurricane Andrew. Their survey data was used to characterize the activation of core network ties, measures of the core network structure, and positional characteristics (age, education, marital status). Using OLS regressions, the analysis showed that the structures of individuals' core networks affect the degree to which individuals activate ties from those networks to gain informal support. Specifically, they found that "individuals embedded in higher-density core networks, core networks with more gender diversity, and networks that contain higher proportions of men, kin, and younger individuals, activated core network ties for informal support to a greater degree than did individuals embedded in core networks lacking these characteristics (Hurlbert et al. 2000, p. 598)."

At the sociocentric level, there is an absence of research applying SNA at the individual level. Organizational research, on the other hand, is more characteristic of the SNA disaster research. To answer the generic question "What kinds of networks aid in recovery from disaster?" SNA has been applied to identify patterns of interorganizational networks that participate in emergency response management. Kapucu (2005a, b) measured degree, closeness, betweeness, and flow betweeness centrality and clique and sub-groups to identify the pathways between actors. Using these measures, along with network visualizations, the patterns of emergency response organizations are described and discussed with the purpose to inform the need for future collaboration at the sociocentric level. Likewise, researchers used network analysis to characterize the communication processes among organizations participating in response operations following Hurricane Katrina, finding a pattern of asymmetry in the communication processes among participating organizations (Comfort and Haase 2006).

Following the events of Hurricane Katrina, a series of social network-related disaster research was funded by the National Science Foundation. The authors of this paper participate in these research projects. Examples of research conducted as part of this effort include a University of Mississippi team of researchers investigating social networks within South Mississippi after Hurricane Katrina. This team developed a survey instrument in which respondents were asked to list up to ten individuals they were close to and their relationship with these individuals. To assess intensity (or social proximity) of each relationship, respondents used two Likert scales. The first scale recorded how close the respondent was to the named individual and the second scale recorded how close this person thought they were to the respondent. A similar method was used to capture individual respondents' group networks. Respondents recorded how many groups (up to ten) they belonged to—examples of groups such as churches, PTA Associations, Knights of Columbus, Alcoholics Anonymous, and less formal groups such as weekly card games and sport teams were provided to aid the respondent. To capture change in social networks in a disaster context, respondents also recorded their networks before Hurricane Katrina, five months after Hurricane Katrina, and who they believed would remain in their network 1 year later.

A second example of social network disaster research following Hurricane Katrina includes research conducted at Duke University. This research team conducted a social network analysis of survey data from a random sample of New Orleans residents, using covariate information and dynamic models to describe changes in both the needs and the support structure over time. The nodes in these networks define roles rather than individuals—they include such things as survey respondent, family, friends, other evacuees, church group, FEMA, Coast Guard, and so forth. Edges represent a help relationship, indicating whether a node supplied assistance to another node. Over time, the kind of help needed and the sources of assistance changed, and selected covariates are important in describing this change.

Together, researchers at the University of Illinois at Urbana-Champaign, and the University of California at Irvine are participating in a third ongoing network study. This project advances our understanding of interorganizational coordination in disaster response by analyzing the emergent multi-organization networks (EMONs) involved in the response to Hurricane Katrina. Using novel computational methods (specifically text mining techniques using D2 K and Crawdad), the research captures and integrates data from web sites (specifically situation reports or SITREPS posted daily by the organizations involved in Hurricane Katrina response) to produce estimates of multi-organizational interaction over time (Cai et al. 2004). Validation of these efforts is done by comparing the automated generated networks (at Illinois) with manually coded networks (at the University of California Irvine) using the same initial set of SITREPS. The resulting estimated networks were used to test multi-theoretical multilevel (MTML) models to explain organization's motivations to create, maintain, dissolve, and reconstitute the inter-organizational links (Monge and Contractor 2003; Contractor et al. 2006). The models were tested using exponential random graph modeling (ERGM) techniques (Wasserman and Robins 2005; Robinson et al. 2006).

By capturing networks while they are forming, it is possible to diagnose these networks for potential points of failure and adjust resource allocations accordingly. For instance, network maps (see Fig. 5) suggest that at early stages after the onset of Hurricane Katrina, organizations within the Petroleum, Transportation, Animal, and Forestry sectors were closely coordinating among themselves but not with the overall Emergency Management effort. Further, real time analyses of these network maps between August 30th 2005 and September 2nd, 2005 may have flagged an issue we learned all too late—while the American Red Cross was moving towards the center of the multi-organizational response network, FEMA was moving towards the periphery of the network (see Fig. 6).

Using Crawdad software (Dooley et al. 2004) to mine the SITREPS for key concepts, network links were created between the organizations authoring reports during 7 two-day time periods (between 24 August and 6 September 2005). These network snapshots are being analyzed using LPNET (Robins et al. 2005; Robins et al. 2005; Schuldes 2007).

Finally, at the RAND Corporation, a longitudinal survey of Hurricane Katrina evacuees has been conducted to assess, among other things, the impact of individual social networks' on recovery decisions. Past research indicates that a person's social network has strong influence on important life decisions, emphasizing the influence

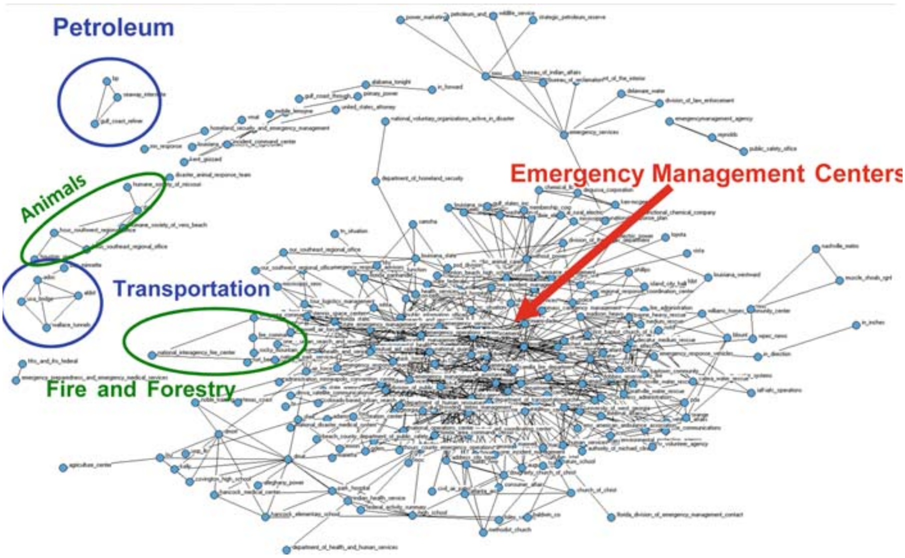


Fig. 5 Organizational links showing closely coordinating cliques

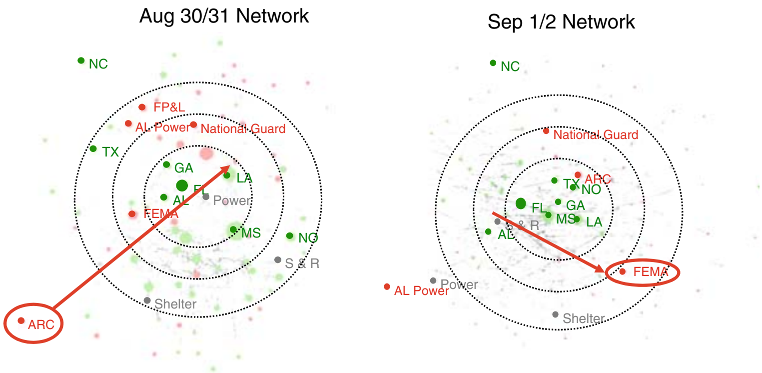


Fig. 6 Exchange of network position between ARC and FEMA over time

of social cohesion and social networks on an individual's decision making process. While we would accept that such statements indicate that the quality of social relationships can, to some extent, influence decision making, the extent of that influence and its size relative to other influences remains to be determined, specifically in the context of disaster victims' social networks. Questions regarding how hurricane evacuees activated their network ties following the disaster are explored in this study. Social network (ego-centric such as: size, frequency, heterogeneity) and other social support variables are assessed to determine the quality and makeup of factors that influence decision-making in terms of how one chooses to relocate following a disaster.

Conclusion

Disasters present social scientists the opportunity to study human behavior at times in which social adaptation and instinct are often more clearly revealed. More importantly, though, social science research has potential value in mitigating disaster loss, improving disaster responses, and evaluating government performance.

In this paper, we have presented a framework for describing social networks in disaster-settings. We next discussed core concepts, operationalizations, levels and units of analysis, and general findings associated with SNA applied to disaster relief and recovery. The various examples of ongoing SNA research on Hurricane Katrina generally show that informal personal and group relationships play an important role in disaster relief efforts independent of government aid and survivors' personal conditions (income, education, level of damage).

These SNA studies generally point toward a more complete understanding of who is at-risk, who recovers, and how survivors recover from disasters. Vulnerable or at-risk populations are typically defined in terms of personal or physical attributes. Personal attributes typically include an individual's socio-economic status, employment, disabilities, and age. Physical vulnerabilities may include the housing status and quality, or availability of personal transportation. SNA studies suggest new variables and measures for identifying vulnerable or at-risk populations. Social or network vulnerability assesses the extent to which socially isolated disaster survivors are less likely to adapt and recover after a crisis. Inter-organizational SNA studies may provide insights on the rate, nature, and efficiencies of disaster recovery efforts.

SNA studies lastly may lead to some practical, policy-based recommendations. First, these studies underscore the value of community-based assessments of residents' network vulnerabilities. These network vulnerability studies may be a useful disaster mitigation strategy. Understanding the spatial or geographic correlates of socially isolated disaster survivors may allow governmental and non-governmental emergency management teams to better target relief efforts. Future SNA research will need to investigate these spatial correlates. A second policy implication is for governmental emergency management to be sensitized to the importance of informal personal and organizational networks in relief efforts. Government emergency management should work to leverage greater public-private synergies for disaster relief efforts. Further study of inter-organizational networks (both public and private) in a post-disaster setting may allow planners to improve the speed, coordination, and breadth of coverage of disaster relief.

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