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Understanding Information Exchange During Disaster Response: Methodological Insights From Infocentric Analysis

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Abstract

We leverage economic theory, network theory, and social network analytical techniques to bring greater conceptual and methodological rigor to understand how information is exchanged during disasters. We ask, "How can information relationships be evaluated more systematically during a disaster response?" "Infocentric analysis"—a term and approach we develop here—can (a) define an information market and information needs, (b) identify suppliers of information and mechanisms for information exchange, (c) map the information exchange network, and (d) diagnose information exchange failures. These steps are essential for describing how information flows, diagnosing complications, and positing solutions to rectify information problems during a disaster.

Keywords

disasters, information, social network analysis, interorganizational coordination communication, exchange markets, infocentric social network analysis, wildfire

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Understanding Information Markets During a Disaster Response: The Need for an Infocentric Approach

During a disaster, a fundamental management challenge is communication and information exchange in what is usually a highly complex and uncertain environment (Kapucu, 2006). In these conditions, communication and information needs are diverse, unpredictable, and continuously changing with regard to scope, urgency, and information type (Comfort & Kapucu, 2006). Consequently, effectively coordinating relevant information among and across stakeholder groups can be a significant challenge. Communication under these dynamic and ambiguous conditions has often been studied under the domain of crisis and emergency communication (Heath, Jaesub, & Lan, 2009; Seeger, 2006; Seeger, Sellnow, & Ulmer, 2003; Williams & Olaniran, 1998) but with little focus on methodological innovation related to how such efforts could be structured for better understanding. The research question we address in this article is:

> How can we more systematically evaluate information exchanges during a disaster response?

In this article, we describe a methodological approach—"infocentric analysis"—that can be used to better inform disaster response.

Despite the crucial need for understanding how to ensure accurate and timely information during disaster (Comfort & Kapucu, 2006), many aspects of disaster management have been under-conceptualized (Herzog, 2007; Magsino, 2009; McEntire, Fuller, Johnston, & Webber, 2002). In particular, the extant literature on disaster communication among responders has been dominated by a technocentric perspective, aimed at diagnosing the causes and consequences of failures in the communication infrastructure (Comfort & Haase, 2006; Dilmaghani & Roao, 2007). Although infrastructure is a key component in understanding the flow of information during a response, technology operates within a much broader social context defined by a network of responders exchanging an array of information. Crisis communication scholars often investigate the message and processes associated with the timely, accurate distribution of information during the event (Seeger, 2006; Seeger et al., 2003). In addition, there is a small but growing literature aimed at investigating interactions among responders using a network-level perspective as a means for understanding information exchange (Choi & Brower, 2006; Comfort & Kapucu, 2006; Kapucu, 2005, 2006; Magsino, 2009). There remains a dearth of theoretical and methodological approaches for capturing the structure of interactions among responders related to specific domains of information to aid in the diagnoses of communication breakdowns.

Toward this end, we argue for the value of an infocentric approach. The import of such an approach is rooted in two key theoretical propositions concerning the nature of information and its exchange during a disaster. We start with the proposition that information is not monolithic. There are multiple types of information being sought and exchanged during a disaster, and different types of information will lend themselves to different mediums of exchange all the while facing unique challenges. Second, we posit that information needs are not universal among responders. Responders will have different information needs based on their functional role in the response, the context of the incident itself, and a responder's position in the network. Consequently, if one desires to understand the structure and dynamics of information exchange, a theoretical and methodological approach must be articulated that is infocentric, capable of representing the unique collection of responders and the pattern of exchanges among them associated with a specific domain of information.

Drawing from general economic theory, we approach the challenge of effective information exchange during a disaster as a problem of information asymmetry among those who possess information (suppliers) and those who need it (consumers). Disasters can be straightforwardly conceptualized in terms of a market or network of actors (e.g., residents, leaders, and staff of various organizations and agencies) who both supply and demand information from other actors within the network to be effective in accomplishing their goals (e.g., managing the fire, avoiding injury or loss of life, protecting personal and community assets, restoring vital services). Under dynamic conditions characterized by complexity and uncertainty, the mechanisms of exchange that link information suppliers with information consumers can be unclear. More specifically, transaction cost theory provides a valuable theoretical lens for conceptualizing the dynamic flow of information within the network of agencies responding to a disaster. In addition, using social network analysis (SNA) techniques can provide insight into information dynamics during a disaster. SNA is a diverse and growing group of methodological techniques that allow researchers to represent relationships, relational structure, and their consequences through various protocols that take into account representation of individuals, groups, or organizations; boundary definition; sampling; instruments for measurement; and visualization approaches.[1] However, SNA techniques are a methodology and not a theory. Consequently, we need to leverage appropriate theory to guide application and interpretation of the approach. This focus on information flow within an information market allows us to empirically document information asymmetries and their consequences, as well as provide insight into how such asymmetries might be addressed for better disaster management. More specifically, we demonstrate how infocentric analysis can be used to document the information markets activated during an incident, the nature and structure of these markets, and adequacy of the information exchange among the subnetwork of responders active within a given information market.

This article proceeds in seven sections. First, we lay out theoretical concepts from economics, network theory, and SNA that inform thinking about information exchange and how these concepts apply in a disaster context. Second, we describe our innovative approach—"infocentric analysis"—that brings greater conceptual and methodological rigor to understanding information supply, demand, and exchange failures during a disaster response. In the remaining sections, we demonstrate how this approach can be used to improve understanding of information exchange within the specific context of a forest wildfire event.

Exchange Relationships, Network Governance, and SNA

Our infocentric perspective on disaster communications among responders is grounded in theories related to economic exchange. General economic theory suggests that concepts like information asymmetry, uncertainty, risk, and transactional costs may be helpful in understanding how information is exchanged (Comfort, Kilkon, & Zagorecki, 2004; Stigler, 1961; Williamson, 1991). Information asymmetries arise in situations when one individual or organization has more knowledge than another. When used in a market context, buyers of products seek information to make good choices, often under imperfect circumstances (Stigler, 1961). When sellers or buyers of goods are not fully informed about the risks they take, they may behave differently from the way they would behave if risks were fully understood. This is known as "moral hazard." Another class of problems, "adverse selection," occurs when sellers do not have full information about buyers and so may provide suboptimal choices for them to purchase. The basic theory behind information asymmetry suggests that more optimal choices will be made under conditions of better information exchange, and we would expect these principles to apply to a disaster context (Comfort et al., 2004).

Although these theoretical concepts are usually used in a market context to understand private firm behavior, we apply them to the quasi-public realm of disaster management. During a disaster, the continuously changing context affects the scope, urgency, and type of information needed and makes balancing the supply and demand of information challenging. Individuals involved in a disaster usually have different sets of information, and those who have information (supply) may not connect effectively with those who desire the information (demand). Such highly dynamic and uncertain situations can further exacerbate the potential negative consequences of any information asymmetry as poor information exchange can limit effective coordination and lead to problems for all parties during an incident.

Although general economic theory is helpful for conceptualizing the nature of exchange relationships, it tells us little about how to manage or govern under these conditions. More specifically, transaction cost theory and network governance perspectives are helpful for understanding the structural forms that can guide these exchange relationships. Williamson (1991) argues that to minimize information exchange transaction costs, governance structures will emerge to support those relationships that are lowest in associated costs and highest in relative advantages related to the task at hand. Different governance structures exist to accommodate the diversity of potential exchange relationships. For instance, hierarchical coordination is a structure used to establish control among those governed by allocating responsibility and specifying tasks. This structure is seen as most efficient during periods of stability where there is time to identify problems and correct mistakes. However, under urgent and dynamic conditions where individuals lack relevant information or the ability to meet new demands quickly, hierarchical coordination breaks down (Comfort & Kapucu, 2006). In these situations, Jones, Hesterly, and Borgatti (1997) point to the importance of network governance structures in mediating transaction costs in dynamic situations where exchanges need to be coordinated quickly—conditions that typify disaster contexts.

A SNA is a particularly appropriate methodological approach for assessing network governance structures as it focuses on distinguishing and describing structural components of a network to explain certain outcomes (Provan & Kenis, 2008). SNA uses individuals (nodes) and the relational links (ties) that comprise the network as a focal unit of analysis.

Within the disaster literature, the application of network analytic methods to examine existing systems of emergency management is a small albeit growing area of research (Kapucu, 2005, 2006; Magsino, 2009; Topper & Carley, 1999). In assessing the role of interorganizational networks in disaster circumstances, scholars have examined cross-agency coordination in dynamic contexts (Kapucu, 2005), boundary spanners in multiagency coordination (Kapucu & Van Wart, 2006), relative interaction within and between stakeholder groups during Katrina (Comfort & Haase, 2006), brokerage roles within emergent interorganizational networks (Lind, Tirado, Butts, & Petrescu-Prahova, 2008), emergency medical preparedness and response (Tierney, 1985), and county-level emergency management and the differences between the communication networks that exist in actual practice versus those proposed in county plans (Choi & Brower, 2006). Other scholars have identified SNA as a rich field and method to be applied to disaster situations but have found existing theory and applications lacking (Magsino, 2009).

The infocentric approach we present here advances the literature on the role of networks in disasters by adapting SNA techniques to empirically document and analyze the information market that emerges during disaster response. We argue that general economic theory has two principal contributions to make to understanding information exchange markets in disaster response. First, it provides the conceptual foundation for thinking about actors within a social network, their exchange patterns, and the nature of linkages between them. Second, it structures methodological tools for modeling and interpreting these exchanges. Systematically structured and applied, the use of SNA methods can provide insights into the information exchange market and assist in diagnosing problems of supply and demand of information.

Infocentric Analysis

To understand potential information asymmetries during a disaster response, infocentric analysis first seeks to identify what types of information are in supply and demand. This stands in contrast to prominent applications of SNA approaches that simply document or visually depict information sharing relationships while leaving the content ambiguous. Infocentric analysis then seeks to map the unique network of suppliers and consumers related to a particular type of information. The assumption underlying this approach is that there are multiple types of information in demand within a network, and the presence or absence of a communication tie between two actors is insufficient evidence to assess the effective flow of a particular type of information between suppliers of information and those who need it. Consistent with communication process models, communication in infocentric analysis is viewed as two directional and content specific. Furthermore, effective communication within the information market is evaluated from the perspective of the consumer in terms of whether it met their needs, not the supplier.

Thus, this approach can describe the essential characteristics related to information exchange, including the structure of the information market, types of information demanded, identification of those who supply and

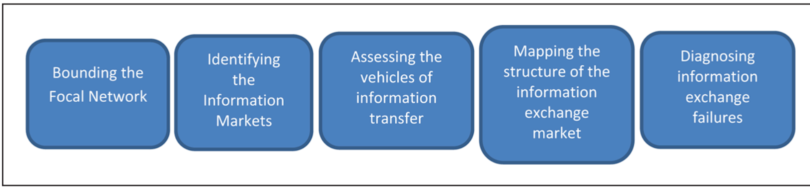

Figure 1. Infocentric analysis process

demand different types of information, and specific vehicles of information exchange. Infocentric analysis also can assess the capacities and diagnose the weaknesses of this structure. For example, are certain modes of information exchange more or less effective for certain types of information? To what extent are key actors effectively supplying specific information to those who demand it? Are certain information markets deemed more or less satisfactory than others? If so, why? Are there information exchange relationships that were unexpected that might be leveraged more fully in the future? Are there missing linkages between those who supply information and those who demand it within the network? Are there ineffective linkages between those who supply information and those who demand it?

In this way, infocentric analysis describes the information exchange market and identifies ways to facilitate better information exchange during a disaster response. The analysis process can be organized into five sequential stages: (a) bounding the focal network, (b) defining the information market, (c) identifying and assessing the vehicles of information transfer, (d) mapping the network structure of the information market, and (e) identifying and diagnosing information exchange failures, as depicted in Figure 1. In the following sections, we demonstrate the application of each of these stages and the insights that can be gained using a case study of a 2009 wildland fire.

Wildfires, Incident Command Systems (ICSs), and Information Needs

Wildfires are the subject of this study because they are one of the most common natural hazards in the United States (EM-DAT: OFDA/CRED International Disaster Database, 2012). Because of their more routine nature, they offer the opportunity to identify and test theory, methods, and practice related to disaster contexts.

Forestlands in the United States are characterized by a declining state of ecologic health and increased propensity for catastrophic wildfire (Schmidt, Menakis, Hardy, Hann, & Bunnell, 2002). Many factors contribute to the current wildfire problem. Shifts in community and residential patterns during the 1990s and early 2000s have meant that more people have moved into the wildland–urban interface (WUI), the area where private homes and other human development meet or intermingle with undeveloped wildland (Beebe & Omi, 1993; Hammer, Stewart, & Radeloff, 2009; Radeloff et al., 2005). Climatic conditions (National Wildfire Coordinating Group [NWCG], 2009), insect and disease outbreaks (Logan, Régnière, & Powell, 2003), prolonged drought (Kitzberger, Swetnam, & Veblen, 2001), and propagation of exotic and indigenous species (Hale, Frelich, & Reich, 2006) have contributed to changed forest structure and function. Coupled with increased density of trees and brush due to fire suppression, forested landscapes are increasingly susceptible to larger and more frequent wildfire events (Pollet & Omi, 2002). Despite greater attention from the federal agencies charged with wildfire management and firefighting efforts exceeding US$1 billion on a regular basis throughout the 2000s, the risk to life and property has not subsided (NWCG, 2009).

A large wildfire event typically is managed through the Incident Command System (ICS). ICS was developed in the 1970s out of a need to centralize authority among multiple organizations during wildfire incidents (Irwin, 1989). While ostensibly a strict hierarchical structure, the ICS may also be networked with the local community and other organizations to coordinate response. Participants within the wildfire incident can be broadly partitioned into four stakeholder groupings. The first group includes the core units of the Incident Management Team (IMT), who typically assumes command in managing a large-scale wildfire and largely controls the dissemination of information during the incident. The second group is the local fire response agency that requests the IMT and plays a role in coordinating disaster response. The third group consists of local cooperators that represent of a variety of local organizations and agencies that have specialized roles related to disaster preparedness and response. The final group comprises individuals affected by the disaster who are participating in a loose "emergent system" (Drabek & McEntire, 2002, 2003). This group may comprise private citizens who work together but are not part of an institutionalized or structured response (Stallings & Quarantelli, 1985). They may have varying degrees of organization and work independently or in groups.

Method

We pilot tested our infocentric social network approach during a 2009 wildfire. Information needs emerge rapidly and change quickly during a wildfire.

Consequently, site visits needed to occur during or immediately after an event. Labeled "quick response research" by Taylor et al. (2007), this type of research requires extensive planning and rapid implementation to ensure that information channels and information exchange between stakeholders are accurately captured. Case selection criteria for this study were focused on wildfire events located near communities in close proximity to US Forest Service (USFS) lands that were administered by a federal IMT (IMT2). The communities surrounding the Dry Creek Fire Complex[2] met these criteria. Site visits by the research team began 9 days after the initial fires began and continued for 10 days with additional phone interviews conducted within 23 days of initial fire ignition.

During this fire, we implemented and refined the methodological protocol documented here. Prior to fire season, we developed an interview protocol containing both closed and open-ended questions that were subsequently administered to individuals who held a leadership role in the management of the fire. Interviewees fell into one of four categories: the IMT2, local national forest, local cooperators, and key community information brokers. Questions were targeted to allow for (a) identification of the network, (b) definition of individual information markets, (c) identification of the vehicles for information exchange, and (d) identification of information exchange failures. Our research team consisted of four individuals. Teams of two conducted the interviews. One person asked questions while the other person tracked the protocol to ensure all questions were addressed. All interviews were digitally recorded, transcribed, and returned to each interviewee for validation. Data were analyzed using a combination of social network analytic and statistical analysis software including UCInet (Borgatti, Everett, & Freeman, 2002) and SPSS.

Case Example: The Dry Creek Fire Complex

The Dry Creek Fire Complex started as a result of a widespread lightning storm that ignited numerous fires within the region including three large fires burning within the Dry Creek Ranger District as well as an additional 34 smaller fires. Due to persistent dry conditions and wind patterns in the local national forest, fire size increased dramatically from 100 acres to approximately 1,000 acres within several hours. At the same time, another complex of fires on private and state land adjacent to the Dry Creek area was being fought by State IMT (referred to hereafter as IMT1).[3] As a result of the number of fires and subsequent increase in fire activity on federal lands, a more experienced IMT2 assumed command of the Dry Creek Fire Complex on Day 3. By the time the three main fires were contained 12 days following ignition, more than 10,000 acres had been burned, costing an estimated US$7.7 million in suppression expenses.

The Dry Creek Fire Complex was confined to a single county and located within one USFS Ranger District. The forest is characterized by a fragmented land ownership pattern—USFS land and state-owned parcels are intermingled with private property and rural neighborhoods. This jurisdictional patchwork of management responsibility is not uncommon in Western forest communities and contributes to the complexity of fire management.

The area covered in the Dry Creek Fire Complex included three communities that were largely rural. Two of the communities were significantly threatened by the fires. Residents of both communities, as well as nearby Forest Service facilities and private campgrounds, were evacuated. Power and telephone services were disrupted during the period of extreme fire behavior. In addition, the two major highways that served as primary thoroughfares were closed due to safety concerns. The proximity to the fire and subsequent evacuation of residents, compounded by an inability to communicate or receive outside information, created significant disruptions in residents' daily lives and in the operations of several businesses within the two most affected communities.

Applying Infocentric Analysis to the Dry Creek Fire Complex Case Study

In the following section, we describe the five stages of infocentric analysis, as indicated in Figure 1. For each stage, we demonstrate its application in documenting and assessing the information markets of the Dry Creek Fire Complex.

Bounding the Focal Network

The first challenge in utilizing any social network-based methodology is boundary specification. Boundary specification requires delimiting which actors will be considered "in" the network and which ones subsequently will be excluded from consideration. These decisions are high consequence as different boundaries may reveal very different network properties (Laumann, Marsden, & Prensky, 1989). Consequently, the significance of any given network property cannot be understood absent of understanding the boundary decision within which this property was observed.

While it has received limited scholarly attention, boundary specification of a network within a disaster context is particularly significant as boundaries are not self-evident. The emergent nature of disaster response makes network boundaries both ambiguous and dynamic (Drabek & McEntire, 2002, 2003). This requires the researcher to create and articulate decision rules for determining network membership and to consider the ramifications of these boundary decisions when interpreting network analysis results. Laumann et al. (1989) describe two approaches to boundary specification in network studies. The realist approach utilizes group boundaries that are defined and set by the network actors themselves. For example, members of a baseball team define and set their own boundaries as to who is and is not part of the team. The nominalist approach defines network membership based on theoretical concerns of the researcher. For example, the researcher may be interested in studying a network of organizations that are active in responding to a given disaster.

In general, we find that understanding information exchange in disasters benefits from a hybrid approach. The realist approach is partially appropriate due to the predefined roles of some participants in a disaster network. In wildfire response, the ICS structure defines a formal network of responders to a wildfire event. These are key individuals who have specific leadership responsibilities during a fire. Furthermore, disaster planning and preparedness efforts in some communities may have established a disaster response network (e.g., Choi & Brower, 2006). These efforts create a formal network of organizations, agencies, and individuals who have recognized capabilities and responsibilities during a disaster.

However, a purely realist approach has several limitations when applied to a disaster response context. First, communities may vary greatly in the extent and inclusiveness of their disaster planning efforts, both of which will affect the face validity of the realist network in representing the actual disaster response. Second, because the response to a large-scale disaster, such as a wildfire event, is complex and difficult to fully anticipate in advance, the actual network of responders is often emergent (Choi & Brower, 2006; Drabek & McEntire, 2002, 2003). Furthermore, research by Choi & Brower (2006) shows that actual network structure can become decoupled from the formally prescribed network structure outlined in disaster management plans, particularly when issues of organizational capacity arise. Last, while it is likely that all responders are known by some part of the network, increases in scale, specialization, and functional divisions that occur in managing large-scale disasters make it difficult for any one member to fully grasp the scope of the entire network (Moynihan, 2009). As such, a nominalist strategy that defines network membership based on a set of a priori decision rules may be necessary.

In the Dry Creek Complex, we started with a realist approach: Our overarching interest was to capture the communication networks of four main stakeholder groups playing critical leadership and information brokering roles in responding to the wildfire. These were (a) representatives from the federal IMT2 who had a formal role in managing the fire, as outlined in ICS-100 training manuals[4] (n = 4); (b) representatives from the lead local disaster response agency, in this case, the local national forest, who had formal leadership responsibilities in managing the fire (n = 8); (c) individuals representing local cooperators on the fire who had formal leadership responsibilities related to wildfire response, evacuation, or road closures (e.g., County Sheriff's Department, County Fire Department, Red Cross; n = 9); and (d) key individuals who sustained involvement in a formal (e.g., media) or informal (e.g., small business owner) information brokering role within their community during the course of the fire (n = 5). An initial population of network members was identified via formal roles in the ICS as well as a review of online newspaper content, twitter feeds, websites, and email lists within the affected areas. To allow for the variability of network structures in disasters, we subsequently included a nominal approach with snowball sampling approach (Wasserman & Faust, 1994) in which all network members were asked to nominate other key individuals that community members would go to for information. IMT2 and local national forest members were also asked to identify any missing representatives who played critical leadership or information brokering roles during the fire. Our final sample of responders and information brokers was represented by 26 entities. During our interviews, we asked these participants to reflect on their experience over the course of the fire. Consequently, their perspectives represent a generalization of their experience over several days.

Defining the Information Markets During a Disaster: What Information Do Actors Need?

The next task is to identify the information markets activated during a disaster response in terms of the types of information that are in demand within that network and where the demand is localized. An information market is a nominal place where suppliers and consumers of a given type of information interact. The focus for this inquiry is to understand what types of information actors need to be effective in their roles. Because roles and responsibilities are known to vary within the network, it is assumed that information needs would likewise vary.

To date, there has been limited empirical research documenting the information markets within the context of disaster response. Understanding the information needs of key individuals within the disaster response network is of practical importance. For managers, effective information management

Table 1. Information Types Demanded During Dry Creek Fires

Information typologies in demand	% of network that wanted type of information
Fire status and behavior	100
Evacuation and road closures	60
Inter/intra-unit communication	48
Resource status and availability	40
Values-at-risk	32
Information administration	20
Infrastructure	20
Fire potential	20
Fire costs	16
Wildland Fire Decision Support System	8
Medical response	8
In-brief packet	4
Cause of fire	4

Note: See Appendix A for descriptions of specific types of information.

requires a situational awareness of who needs to know what by when. An understanding of the information needs of network members allows managers to question their own assumptions about the information needs of others within the response network. Procedurally, the information market can be assessed qualitatively via face-to-face interviews with network members. Each member of the network was asked to describe their role and responsibilities during the fire. Members were then asked to reflect on and list the types of information they needed to be effective in carrying out these roles and responsibilities.

For the Dry Creek Fire Complex, members identified multiple types of information that they reported as critical to them effectively carrying out their roles. Responses were qualitatively coded by the research team using open-coding content analysis (Miles & Huberman, 1994). An initial coding framework was identified by university-affiliated members of the research team by first assigning a thematic code to each type of information respondents indicated they needed to do their job. For example, if respondents indicated they needed information about what the fire was doing, it was coded as fire status information. Similar codes were then grouped together with an eye toward developing a parsimonious framework of homogeneous information types. This framework was then peer checked by USFS affiliated member of our research team. Analysis of these data resulted in 13 different information

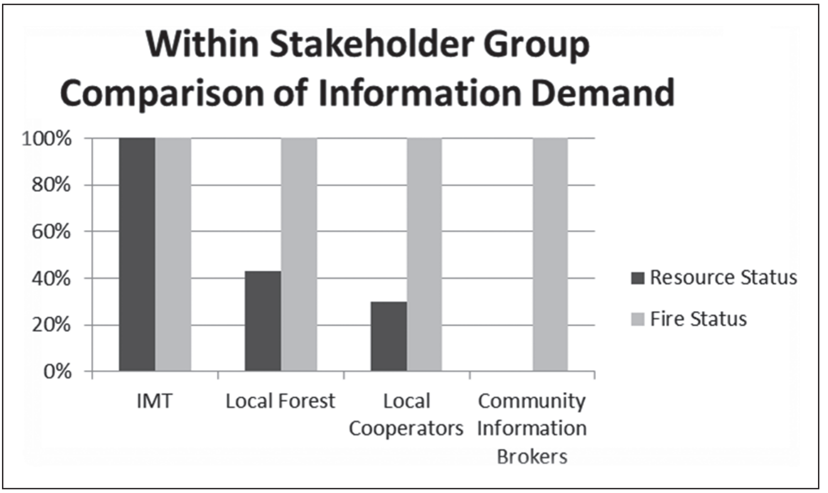

Figure 2. Resource status versus fire status: comparisons of different information demanded by group
Note: IMT = Incident Management Team.

types across the entire network. These types, along with their frequency in the network, are summarized in Table 1. Network members of the local national forest command staff identified an additional category of administrative information that included the technical aspects of how to compile the mandated Wildland Fire Decision Support System (WFDSS)[5] and information about fire costs and financial management of the fire.

This approach to defining the information market allowed us to understand where demand for different types of information was located within the network. In the Dry Creek Fire Complex, some information demands were generally localized to particular positions and interests. Identifying where demand is localized can give clues to the underlying structure and dynamics of the disaster response network. For example, Figure 2 shows a comparison among four categories of stakeholders (i.e., representatives of the IMT2, the local national forest, local cooperators, and key community information brokers) in terms of their demand for two different kinds of information. Demands for information about resource status and availability (e.g., firefighters, fire trucks) were prominent among members of the IMT2 but more diffuse among the local national forest and local cooperators. There was no market for this type of information among community information brokers. In contrast, demand for information concerning the current status and behavior of the fire was ubiquitous throughout the network. This supports the premise that different types of information may be associated with unique subnetworks of supply and demand even within the same overarching disaster response network.

Last, defining the information markets allows the researcher to understand the breadth of information demands across different stakeholders. In the Dry Creek Fire Complex, the average person in the network identified 3.8 different types of information they needed to be effective in their role. The most any one stakeholder reported needing was 8 different types of information. IMT2 representatives in the Dry Creek Fire Complex had quite diversified information demands relative to other network members. On average, IMT2 representatives required 6.75 different types of information. This is consistent with their responsibilities related to information collection and dissemination in the wildfire response. In contrast, local national forest representatives reported requiring an average of 4.29 different types. Local cooperators and community information brokers' information needs were narrower, reporting needs for 2.9 and 2.33 different types of information, respectively.

Understanding differences among responders regarding the breadth of their information needs allows scholars and practitioners to consider variation in the information-processing capacities of different network members and the strengths and weaknesses of different network characteristics, as well to anticipate potential challenges. For example, the consequences of being nested within a highly centralized, sparse, or hierarchical network may be much more acute for those actors with a greater breadth of information needs. Centralized or hierarchical networks attempt to maximize efficiency through channeling information through key network positions. The importance of such key positions for an actor with more diverse information needs is far more acute than an actor with more limited information needs. Similarly, it is reasonable to assume those with more diverse information needs will face the greatest challenges meeting those needs in sparsely connected networks in which information must travel a greater social distance between the primary supplier and a given consumer. Conversely, densely connected networks are associated with their own form of challenges for those with greater breadth of information needs. When information is diffused among an array of actors rather than centralized through key information hubs, actors may become overwhelmed in maintaining sufficient ties.

Identifying suppliers and vehicles of information transfer. The next step is to assess the exchange mechanisms that link suppliers of information with those who demand it. The focus here is to understand how members of the network get the information they need. In a wildfire context, different information exchange modalities are assumed to have different strengths and weaknesses for different types of information (e.g., McCaffrey, 2004; Olsen & Shindler, 2007; Steelman & McCaffrey, 2012). For example, when the content of the information is more complex and necessitates significant interpretation on the part of the recipient, more direct forms of communication may be more effective for adequately meeting information demands (Monroe, Pennisi, McCaffrey, & Mileti, 2005). However, when demand for certain types of information is widely dispersed, information is straightforward, and/or uniformity of information distribution is paramount, other modalities such as websites or information hotlines may be more appropriate. Given that primary lines of communication can be compromised during a disaster, understanding use of nontraditional or secondary sources of information may be valuable for managers in identifying alternative or supplemental avenues for addressing information demands during the course of the disaster.

To assess the vehicles of information exchange, participants are first asked to verbally summarize and validate the types of information they need. Once the accuracy and completeness of the list of information types has been validated, participants are asked—for each type of information they identified—to describe to whom or where they went to get that information. It is important in this design that the researcher clarify to participants that they are to identify where they went *seeking* information regardless of whether the information they received from that source was adequate to meet their needs. This allows the researchers to distinguish the structure of the information market from the effectiveness of the information exchange.

At this stage, descriptive analyses are used to examine the different mechanisms of information exchange activated (i.e., person-to-person interactions, meeting attendance, or other modality). These include frequency of use, correspondence between certain modalities and information types, and between stakeholder group and information type. This information is valuable for helping scholars and practitioners consider both the dominant mechanisms of information exchange and whether certain mechanisms are more strongly associated with specific information markets or responders.

In the Dry Creek Fire Complex, information was supplied to network members through a variety of exchange mechanisms. Network members frequently reported receiving multiple types of information from the same source. Interestingly, across the network, 73% of the total number of information exchange ties occurred via person-to-person interactions. Person-to-person interactions occurred through various channels, including personal emails, phone conversations, incident radio communication, and face-to-face communication. Fourteen percent of information exchange ties were via attendance at meetings where information was being disseminated. The final 14% of information exchange ties were via other media and included daily incident status reports, newspapers, monitoring two-way radio traffic, websites, broadcast radio stations, and information hotlines.[6] The overwhelming reliance on person-to-person interactions in this incident may reflect the very rural nature of the community as studies have shown levels of urbanization to be associated with higher levels of alternative information media.

Within the Dry Creek Fire Complex incident, meetings were most commonly used to gather information on the status and behavior of the fire. They were also identified as vehicles for getting and sharing information concerning jurisdiction and coordination with other units or organizations in the network. There were fewer reports of meetings being used to obtain information on evacuation and road closures as well as resource status and availability. In terms of alternative venues for gathering information, analysis indicated that specific venues were used for getting certain information. For example, the Local National Forest Visitors' Center was identified as primarily a source for getting information about fire status, evacuation, and road closures. Network members monitored radio traffic exclusively for fire status and fire potential information. In general, alternative venues to meetings and person-to-person interaction were primarily utilized to get information on fire status (65%), resource status (12%), and evacuation and road closures (14%).

Mapping the Structure of the Information Exchange Markets

An information market is composed of a specific type of information, the responders who sought that type of information (consumers), and the sources they sought to obtain that information from (suppliers). The pattern of relationships among suppliers and consumers for a given information market, or across all information markets, can be graphically represented and analyzed using SNA to understand the social structure of the network. A network map consists of a set of nodes that are linked together by a given tie. In infocentric analysis, the nodes represent suppliers and consumers of information. The ties represent an information exchange in which a consumer sought information from a supplier. Because consumers can seek information from a variety of sources, suppliers can be organizations, people, meetings, or other media (e.g., websites, newspapers, etc.).

Network analysis provides a flexible graphical tool for visually examining different aspects of information exchange. Different analysis approaches will highlight different phenomenon. At the most macro level, a scholar

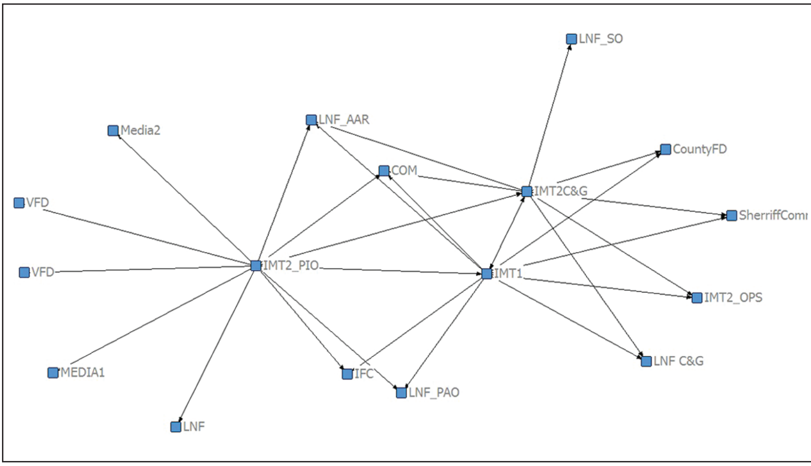

Figure 3. Network map of central information suppliers
Note: For a complete list of all participants and acronyms used in the network maps, please refer to Appendix B.

may choose to visualize all information exchange relationships across all information markets. However, in more complex networks such as the one in our case example, such graphs tend to be of limited analytic utility as the large number of nodes and ties graphically create a visual jumble that is difficult to interpret. In these cases, it is prudent to graphically isolate different aspects of the network for analysis. For example, SNA maps can be used to examine the structure of a specific information market associated with a subset of individuals involved in the exchange of evacuation and road closure information, as depicted in Figure 5. Alternatively, as illustrated in Figures 3 and 4, one may examine the networks of a specific actor or set of actors. These are referred to as ego networks because only nodes linked to a predefined set of actors (egos) are visually represented in the map (Wasserman & Faust, 1994).

However, it is important to note that the analysis of any SNA map is a qualitative endeavor—requiring interpretation from the scholar. Therefore, the power of these visual tools is magnified when integrated with analysis of quantitative network characteristics and thick qualitative descriptions from interviews. Accordingly, in addition to a visual depiction of the structure of the information markets, we use SNA methods to provide quantitative tools for representing key attributes of the structure of the network of responders as well as each information market.

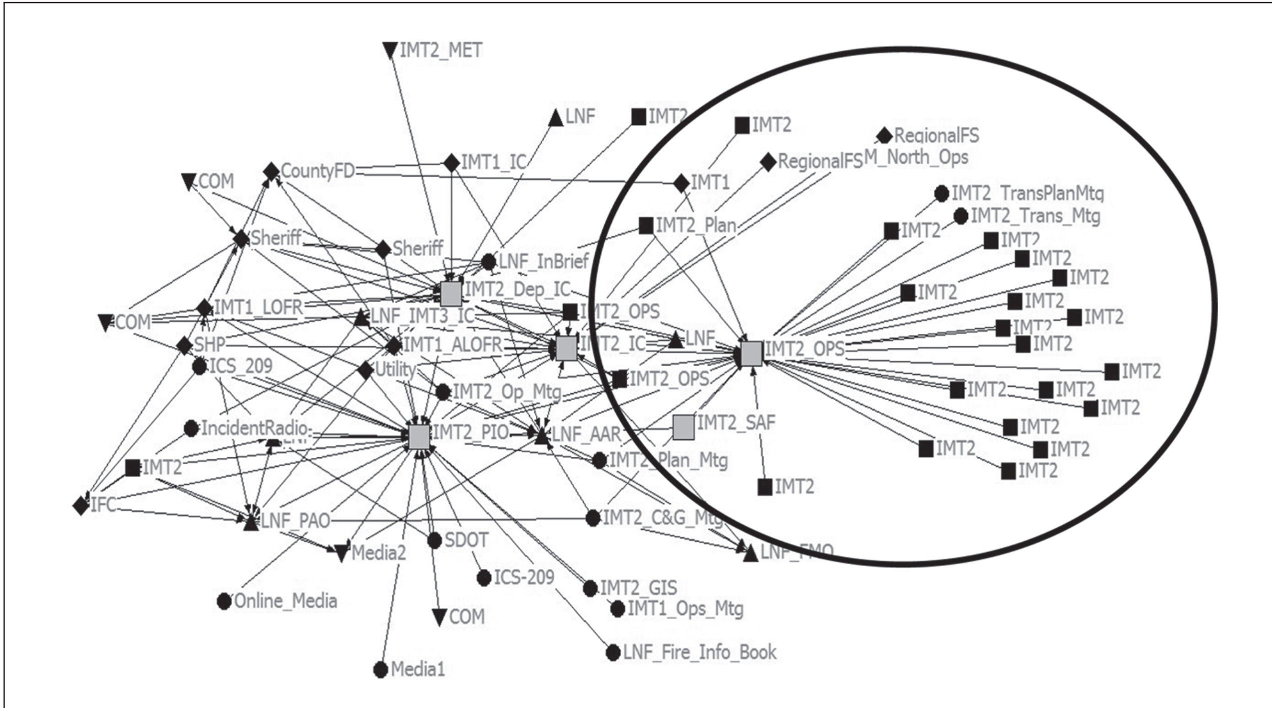

Figure 4. Ego network of IMT2 unit leaders
Note: IMT2 = federal Incident Management Team. For a complete list of all participants and acronyms used in the network maps please refer to Appendix C.

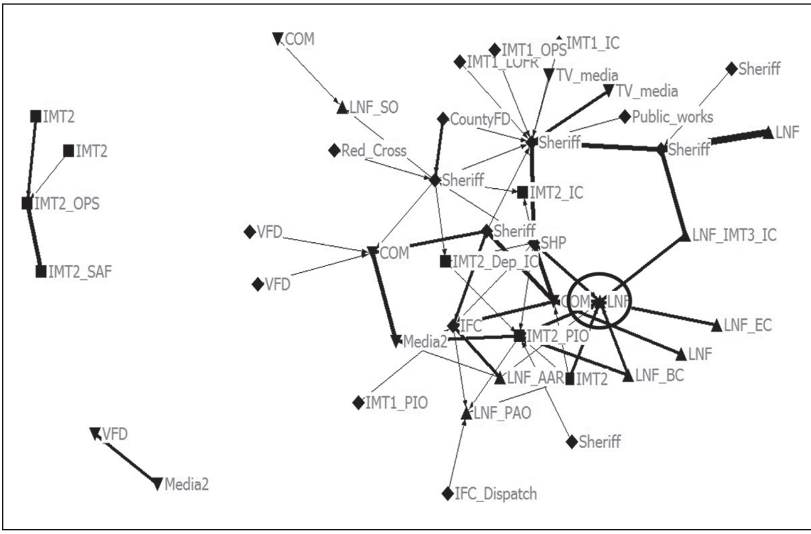

Figure 5. Network map of adequacy of evacuation and road closer information
Note: In this map, thicker lines represent less adequate ties. The thicker the line, the less adequate the tie. For a complete list of all participants and acronyms used in the network maps please refer to Appendix D.

Centrality is a general measure that indicates the number of ties or connections that a network member has to others (Wasserman & Faust, 1994). Out-degree centrality allows the researcher to quantitatively examine the most central information suppliers during a disaster based on the number of ties to network members who sought information from them. In-degree centrality allows the researcher to identify the most central information consumers. Analyses can focus on specific information exchange markets or alternatively can look at centrality across all information exchanges within the responder network. In our approach, we begin with identifying the central suppliers and consumers of information and then focus on central actors within different information markets.

Central suppliers of information. In the Dry Creek Fire Complex, three actors emerged overall as key information suppliers. The most central supplier overall was the IMT2 Public Information Officer (PIO). In light of past research on disaster response networks, which have demonstrated that bureaucratic design can become decoupled from networks in practice (e.g., Choi & Brower, 2006), this provided important validation of the PIO role given their explicit information dissemination function. The second most central supplier of information was the IMT1 responsible for managing an adjacent fire complex that was ignited by the same lightning storm. Coordination between the two teams was important given the close proximity of the fires. The third most central supplier was the IMT2 command staff for the Dry Creek Fire Complex.[7] An SNA map of the ego networks of these three central suppliers was created to examine who was seeking information from these suppliers. As shown in Figure 3, the IMT2 PIO served as a central information supplier to more local actors such as local volunteer fire departments and local media, while both IMT2 and IMT1 supplied information to a highly similar set of consumers consisting primarily of local national forest representatives and local cooperating agencies.

Central consumers of information. Another important analysis for understanding information markets during a disaster is to identify the central consumers of information. Degree centrality of information consumers has to do with who in the network was most active in demanding information from the most number of different sources. Interestingly, in addition to being the chief supplier of information overall in the network, the IMT2 PIO had the highest overall centrality as a network consumer of information. Other central consumers included the IMT2 command staff and Dry Creek Ranger District command staff. Within this network, the IMT2 had the most diverse information needs and was both the dominant supplier and consumer of information.

Central suppliers and consumers by information market. Disaggregating the different information markets allows the researcher to understand the supply and demand relationships for specific information types. This evaluative approach allows us to assess whether the right balance between supply and demand has been met and provides structure for a normative assessment to achieve a more optimal balance. For example, Table 2 depicts networks associated with three prominent information markets: fire status and behavior, evacuation and road closures, and resource status and availability. These results highlight how different members in the network may become more or less central within different information markets. As shown, law enforcement emerges as highly central information suppliers concerning evacuation and road closures but is not particularly central in the overall response network. Interestingly, results suggest that the IMT2 remains a significant supplier and consumer of information for all three types of information, even though evacuation and road closures are not within the purview of their direct authority.

Table 2. Network Supplier/Consumer Centrality in Information Markets

Fire status and behavior		Evacuation and road closures		Resource status and availability	
Central suppliers	Central consumers	Central suppliers	Central consumers	Central suppliers	Central consumers
IMT2 PIO[a]	Community information brokers	State Highway Patrol	Community information broker	Official incident status reports (ICS-209)	County Fire Department
IMT2 Operations Meetings	District forest command staff[b]	County Sheriff deputies	County Sheriff command staff[c]	IMT2 command staff[d]	District forest command staff
Incident radio communication	IMT2 PIO	IMT2 PIO	IMT2 PIO	IMT2 Planning Meetings	IMT2 Operations Unit

Note: IMT2 = federal Incident Management Team; ICS = Incident Command Systems.
[a]IMT2 Public Information Officers.
[b]District command staff include district fire management officer and fire battalion chief.
[c]County Sheriff command staff includes station commander, captain, and lieutenant.
[d]IMT2 command staff includes incident commander, deputy incident commander, operations section chief, and planning section chief.

Identifying and Diagnosing Information Exchange Failure

Failures in Demand. In addition to understanding the information demands within a network, infocentric analysis allows the researcher to compare etic and emic perspectives on information needs. Emic perspectives belong to insiders within the network, whereas etic perspectives concern those of outside observers (Guba & Lincoln, 1994). What members of a network perceive they need to know and what outsider experts assert members *should* know are not always in alignment. This raises the opportunity for comparison of what the demand for information should be for a given position within the response in comparison with the actual demand. In other words, are actors in the network aware of what they do not know?

Assessing perceptions of supply and demand requires the researcher to articulate assumptions about what effective information exchange networks look like to provide a basis for comparison with the observed network. In the Dry Creek Fire Complex, we were particularly interested in the mechanism through which IMT2 representatives, who were from outside the area, sought and received information about local context in which they were working.

During interviews with the IMT2, informants described needing access to a relatively wide array of information. However, the research team observed that there was limited mention of seeking information about the local context.

Local cooperators and community information brokers validated this observation and were critical of the IMT2 for their lack of attention to local resources, knowledge, and assistance in their operational response. An infocentric analysis can help illuminate some of the structural failures that can result from not knowing what you do not know. Figure 4 highlights the ego networks of IMT2 representatives. The IMT2 Operations section (IMT2 Ops), which is responsible for developing and directing tactical assignment and operational resources, is connected to numerous units within IMT2 but far fewer community information brokers. This is an indicator that there may be structural issues associated with getting local context information integrated into operational functions. Qualitative data from interviews confirm this was indeed the case during the Dry Creek Fire. The challenge is in diagnosing why pertinent information about local context failed to reach IMT2 Ops and how to realistically address those challenges to rectify the balance of supply and demand.

Information Asymmetries and Failures in Supply. Last, infocentric analysis seeks to assess the effectiveness of the information exchange and identify information asymmetries resulting from failures in supply. Examining the adequacy of information received via information exchange ties can be used to assess information asymmetries. There are many options for assessment. Here we present three approaches: (a) adequacy of exchanges by information market, (b) adequacy of exchanges within and between stakeholder groups, and (3) specific exchange failures.

Adequacy of exchanges by information market. A network approach allows each information exchange relationship to be evaluated. Our method defines and evaluates effective information exchange based on perceptions of information consumers. Several evaluations of the information exchange can be obtained, including whether the information received was adequate to meet the consumer's needs, the timeliness of the information, and/or trustworthiness of information. Across the network, the researcher is then equipped to examine whether certain information markets were viewed overall as more or less effective. For the Dry Creek Fire Complex, we focused on adequacy measures to illustrate our approach.

With a few exceptions, information consumers generally felt that the information they received was reported as quite adequate. Among IMT2 and local national forest staff, information administration and WFDSS information markets were perceived as the most adequate in meeting consumers' demand. The structure of these information markets may be more institutionalized via

Table 3. Between and Within Stakeholder Group Adequacy of Information (All Information Types)

	Information consumers			
Information suppliers	IMT2	Local national forest	Local cooperators	Community information brokers
IMT2	**3.84**	3.58	3.79	3.33
Local national forest	3.00	**3.73**	2.83	3.33
Local cooperators	3.94	3.80	**3.82**	2.50
Community information brokers	3.50	3.50	3.50	**3.50**
Overall average	**3.57**	**3.65**	**3.49**	**3.17**

Note: IMT2 = federal Incident Management Team.

standard operating procedures and protocols that facilitate information exchange. Information types such as values-at-risk and evacuation and road closures, which engage a more complex network of stakeholders in both supply and demand, were rated the least adequate by consumers.

Adequacy of exchanges within and between stakeholder groups. In addition to understanding the overall adequacy of different information markets, it is informative to understand whether there are certain consumer groups who are more satisfied than others. This can be examined within a specific information network or across the network as a whole. For example, evacuation and road closure information was identified as one of the least effective information markets using the above analysis. compares adequacy of evacuation and road closure information exchanges between the IMT2, local national forest representatives, local cooperators, and key community information brokers. As can be seen, the information market concerning evacuation and road closures was the least adequate at meeting the needs of the community members who served in information-brokering roles.

Although the above analysis provides us with descriptive information about who was best and least served by the information market for a specific type of information, it does not illuminate whether there were certain exchanges that were particularly problematic. The social network technique of block modeling assists the researcher in examining interactions between groups.[8] In the Dry Creek Fire Complex, network blocks based on stakeholder affiliation are used to examine the relationships within and between the IMT2, local national forest, local cooperators, and community information brokers across all types of information (see Table 3). On average, consumers generally rated the adequacy of information they received from members of their own stakeholder group more positively than information received from other groups (see ratings bolded in Table 3). For instance, the majority of the IMT2 rated intragroup information as very adequate (3.84) but rated information adequacy with the local national forest as only somewhat adequate (3.00).

Together, these analyses enabled identification that local community information was the most problematic interaction on the Dry Creek Fire. Less than adequate information between stakeholder groups indicates a potential supply problem and could lead to suboptimal decision making. Community information brokers rated evacuation and road closure information at 2.92 and their interactions with local cooperators at 2.50 (Table 3). Local cooperators are central suppliers of evacuation information, so these scores together provide some support for the need to focus on rectifying information asymmetries between key community information brokers and local cooperators, especially around evacuation and road closures. Local cooperators in turn were relatively critical of the information they received from the local national forest representatives. Across the stakeholder groups, average information adequacy scores were highest for the IMT2 and lowest for community information brokers. In other words, community information brokers felt that the information they received was least adequate, whereas the IMT2 perceived the information they received as the most adequate. Last, the IMT2 was, on average, perceived to be the most adequate supplier of information.

Identification of specific exchange failures. Finally, infocentric analysis allows the researcher to closely examine particular information exchange networks and identify specific instances and patterns of inadequate information exchange. The network map in Figure 5 depicts the information exchange network for road closures and evacuations during the Dry Creek Fire Complex. This diagram further supports our inference of those best and least served by the information exchange market from the consumer's perspective. The thicker lines are representative of lower adequacy scores between the two ties. A central consumer of information in this network is a community information broker (COM) who sought information from a variety of sources. The lines indicated that less adequate information came from the State Highway Patrol (SHP) and the County Sheriff. One Volunteer Fire Department (VFD) was completely outside the network and only received information from the media. This meant they were completely disconnected from the main information flow about road closures and evacuations. The specificity of the data provides insight into less effective linkages and how some of the relationships could be leveraged more constructively.

Conclusion

We sought to answer the question, "How can information relationships during a disaster response be evaluated more systematically?" Communication has often been seen as key to improving responses to disaster, and crisis communication scholars have focused on the messages and processes that can improve communication during a disaster (Heath et al., 2009; Seeger, 2006; Seeger et al., 2003; Williams & Olaniran, 1998). In this article, we described the application of a new methodological protocol, an infocentric analysis approach, for assessing information exchanges among actors in a disaster response setting. Our goal was to supplement the crisis communication literature with a conceptually robust methodological framework for understanding specific types of communication dynamics that could help build understanding across fields.

Although some authors have leveraged network theory and applied SNA to evaluate disaster and emergency management issues (Comfort & Haase, 2006; Kapucu, 2005; Lind et al., 2008; Magsino, 2009; Tierney, 1985; Topper & Carley, 1999), the application of SNA methodological tools in the disaster communication context has generally been identified as underdeveloped (Magsino, 2009). By framing information asymmetries from the perspective of the consumer, we provide a framework of information supply and demand that can guide how more optimal choices can be made under conditions of information exchange (Comfort et al., 2004; Stigler, 1961; Williamson, 1991). In addition, by leveraging transactional cost theory to conceptually guide how SNA techniques can be used for assessing information flows, we provide greater insight into patterns of disaster response communication. This melding of transactional cost theory along with SNA techniques builds on the previous efforts of Jones et al. (1997) to demonstrate how such techniques can be applied under conditions of uncertainty and complexity. Finally, in this article, we move conventional SNA beyond merely documenting information-sharing relationships to establish a theoretically driven protocol for understanding what specific information is being shared, the unique subnetworks among which this information is shared, and the adequacy of this information from the consumers' perspective. These elements allow for a more systematic and comprehensive analysis and assessment of asymmetries in the information exchange market during a disaster response. More clearly understanding these relationships for different types of information can help disaster management professionals and researchers better identify information exchange failures and aid in the diagnosing of potential alternatives to remedy such failures.

The value of the data presented here is somewhat limited because we draw from only one case study to illustrate how these concepts and the method can be used. The generalizability of the conceptual approach is most significant. Nonetheless, we do build some initial data on information patterns in disaster contexts.

Wildfire information needs are complex and dynamic where a range of information is needed to manage the fire, avoid injury or loss of life, protect personal property and community assets, maintain vital services, and build relationships and trust. On the Dry Creek Fire Complex, the methodology revealed patterns in information consumed and demanded, market exchange mechanisms, key vehicles for information transfer, and network structures of specific information markets. We found that overall most parties were obtaining the information they needed but that there were issues with supply and demand for specific types of information by certain information consumers. For instance, the IMT2 was not necessarily aware that it needed to be asking for local contextual information. The volunteer fire departments, key consumers for evacuation and road closure information, were completely outside that particular information market. Identification of these information exchange deficits is an important step in being able to develop protocols that ensure local conditions are accounted for and important local cooperators, such as volunteer fire departments, are receiving adequate information to effectively carry out their roles and responsibilities.

The case study presented here leverages the wildfire context due to its prevalence as a hazard in the United States. The five steps described in our protocol can be applied to other disaster settings but should be appropriately contextualized to specific situations. We anticipate that our approach to info-centric analysis will be refined over time as others adopt, modify, and learn from its application. We look forward to engaging in this discussion to collectively improve the theories, methods, and applications for better disaster management.

Appendix A

Description of Information Type

Information typologies	Specific information needed
Fire status and behavior	Where is the fire located? What is the fire doing right now?
Evacuation and road closures	What areas are being evacuated and when will evacuations be lifted? Which roads are closed and when will road closures be lifted?
Inter/intra-unit communication	What is going on with neighboring fires and how are they being managed? What is happening with the transition to the IMT2? Who do we need to be cooperating with about what?
Resource status and availability	What resources and personnel are available to allocate? Where are they?
Values-at-risk	What values (e.g., structures, archaeological sites) are at risk?
Information administration	What information is the public receiving? Are we receiving feedback? Is that the information we want them to get? How is the public reacting? What information do other agencies need?
Infrastructure	What is happening with the power, phone, and other utilities?
Fire potential	What is the weather expected to be like? Will this impact fire behavior?
Fire costs	How much is the fire response going to cost? Is it within the budget?
WFDSS	How do we compile the WFDSS? What information is needed?
Medical response	How many have been injured and what are the causes of their injuries? How are they being cared for?
In-brief packet	What information needs to be conveyed to the incoming IMT2?
Cause of fire	What caused the fire to start?

Note: IMT2 = federal Incident Management Team; WFDSS = Wildland Fire Decision Support System. See Table 1.

Appendix B

List and Description of Network Map Labels

Abbreviated network label	Organization	Unit	Stakeholder group
CountyFire_ Command	County Fire Department	Dry Creek Division command staff	Local cooperator
Sheriff_ Command	County Sheriff Department	Dry Creek Station command staff	Local cooperator
DryCreek_ Command	Local National Forest	Dry Creek Ranger District command staff	Local forest
DryCreek_VFD	Dry Creek Volunteer Fire Department		Local cooperator
Cedarville_VFD	Cedarville Volunteer Fire Department		Local cooperator
DryCreek_Staff	Local National Forest	Dry Creek Ranger District general staff	Local forest
IMT2_C&G	Incident Management Team 2	Command and general staff	IMT2
IMT2_OPS	Incident Management Team 2	Operations Unit	IMT2
IMT2_PIO	Incident Management Team 2	Public information officers	IMT2
IMT1_Command	Incident Management Team 1	Command staff	IMT1[a]
COM	Community Residents and Businesses		Community information broker
LNF_AAR	Local National Forest	Agency administrator representative[b]	Local forest
LNF_PAO	Local National Forest	Public affairs officer	Local forest
LNF_SO	Local National Forest	Forest Supervisor Office	Local forest
IM_News	Local newspaper		Community information broker
SIFC	Interagency Fire Center		Local cooperator
Searchlight_ News	Local newspaper		Community information broker

Note: IMT2 = federal Incident Management Team; IMT1 = State Incident Management Team. See Figure 3.
[a]Incident Management Team 1 assigned to neighboring fire.
[b]In the Dry Creek Fires, the Dry Creek District Ranger served as the AAR.

Appendix C

Expanded Network Map Abbreviations

Abbreviated network label	Organization/unit/modality
IMT2	Incident Management Team 2
IMT2_OPS	IMT Operations Unit
IMT2_Plan	IMT2 Planning Unit
IMT2_SAF	IMT2 Safety Unit
IMT2_IC	IMT2 incident commander
IMT2_Dep_IC	IMT2 deputy incident commander
IMT2_PIO	IMT2 public information officers
IMT2_GIS	IMT2 GIS specialists
MT2_MET	IMT2 incident meteorologist
RegionalFS	Regional Forest Service Office
IMT2_TransPlanMtg	IMT2 Transition/Planning Meeting
IMT2_TransMtg	IMT2 Transition Meeting
IMT2_C&G_Mtg	IMT2 Command and General Staff Meetings
IMT2_Plan_Mtg	IMT2 Planning Unit Meetings
LNF_In-Brief	LNF In-Briefing
IMT2_Op_Mtg	IMT2 Operations Unit Meetings
CountyFD	County Fire Department
LNF	Local National Forest
LNF_IMT3_IC	LNF incident commander (Dry Creek District)[a]
LNF_AAR	LNF agency administrator representative
LNF_FMO	LNF fire management officer
LNF_PAO	LNF public affairs officer
LNF_Fire_Info_Book	LNF Fire Information Manual
IMT1	Incident Management Team 1 (neighboring fire)
IMT1_IC	IMT1 incident commander
IMT1_LOFR	IMT1 liaison officer
IMT1_ALOFR	IMT1 assistant liaison officer
IMT1_Ops_Mtg	IMT1 Operations Unit Meeting
SIFC_PAO	Interagency Fire Center
COM	Community information broker
Sheriff	County Sheriff Department
Utility	Electric/Phone Utility Company
SHP	State Highway Patrol
SDOT	State Department of Transportation
IncidentRadio	Incident radio communication
ICS	Official incident status reports
Press	Nonlocal television and newspaper
Local Press	Local newspaper
OnlinePress	Online news source

Note: IMT2 = federal Incident Management Team. See Figure 4.
[a]Incident Commander prior to arrival and transition to IMT2.

Appendix D

Expanded Network Map Abbreviations

Abbreviated network label	Organization/unit/modality
IMT2	Incident Management Team 2
IMT2_IC	IMT2 incident commander
IMT2_Dep_IC	IMT2 deputy incident commander
IMT2_PIO	IMT2 public information officers
IMT2_OPS	IMT2 Operations Unit
IMT2_SAF	IMT2 Safety Unit
IMT1	Incident Management Team 1 (neighboring fire)
IMT1_IC	IMT1 incident commander
IMT1_LOFR	IMT1 liaison officer
IMT1_OPS	IMT1 Operations Unit
IMT1_PIO	IMT1 public information officers
CountyFD	County Fire Department
LNF	Local National Forest
LNF_SO	LNF Supervisors Office
LNF_IMT3_IC	LNF incident commander (Dry Creek District)[a]
LNF_AAR	LNF agency administrator representative
LNF_PAO	LNF public affairs officer
LNF_BC	LNF battalion chief (Dry Creek District)
LNF_EC	LNF fire engine captains
VFD	Local Volunteer Fire Department
COM	Community information broker
IFC	Interagency Fire Center
IFC_Dispatch	Interagency Fire Center Dispatch
Public_Works	County Department of Public Works
Sheriff	County Sheriff Department
Red_Cross	Local Red Cross
SHP	State Highway Patrol
TV	Regional television stations
Press	Nonlocal newspaper
LocalPress	Local newspaper

[a]Incident Commander prior to arrival and transition to IMT2. See Figure 5.

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All views expressed in this article are those of the authors.

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Notes

1. For in-depth descriptions, see Butts (2008, 2009).
2. The name of the fire and locations has been altered to protect the confidentiality of our interviewees.
3. The Number 1 in this label refers to the fact that the adjacent fire was managed by the *state* Type 1 IMT as opposed to the federal IMT responsible for the Dry Creek Fire Complex, which was a Type 2 IMT (hence IMT2).
4. These are the manuals used to train anyone engaged in the Incident Command Systems system.
5. This system is intended to assist fire managers/analysts in determining the appropriate management response for fire incidents. The Wildland Fire Decision Support System was conceived as a way of integrating the various applications used to manage incidents into a single system, which streamlines the analysis and reporting processes.
6. Percentages add to more than 100% due to rounding errors.
7. The IMT2 command staff includes the incident commander and deputy incident commander.
8. Block models compute the average tie relation within and between actors sharing a common affiliation such as stakeholder group. For more discussion, see Hanneman and Riddle (2005).

References

Beebe, G. S., & Omi, P. N. (1993). Wildland burning: The perception of risk. *Journal of Forestry*, *91*, 19-24.

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

Butts, C. T. (2008). Social network analysis: A methodological introduction. *Asian Journal of Social Psychology*, *11*, 13-41.

Butts, C. T. (2009). Revisiting the foundations of network analysis. *Science*, *325*, 414-416.

Choi, S. O., & Brower, R. S. (2006). When practice matters more than government plans. *Administration & Society*, *37*, 651-678.

Comfort, L. K., & Haase, T. W. (2006). Communication, coherence, and collective action. *Public Works Management & Policy*, *10*, 328-343.

Comfort, L. K., & Kapucu, N. (2006). Inter-organizational coordination in extreme events: The world trade center attacks, September 11, 2001. *Natural Hazards*, *39*, 309-327.

Comfort, L. K., Kilkon, K., & Zagorecki, A. (2004). Coordination in rapidly evolving disaster response systems. *American Behavioral Scientist*, *48*, 295-313.

Dilmaghani, R. B., & Roao, R. R. (2007, January). *Hybrid communication infrastructure and social implications for disaster management*. Paper presented at the 40th Hawaii International Conference on System Sciences, Waikoloa, HI.

Drabek, T. E., & McEntire, D. A. (2002). Emergence phenomena and multiorganizational coordination in disasters: Lessons from the research literature. *International Journal of Mass Emergencies and Disasters*, *20*, 197-224.

Drabek, T. E., & McEntire, D. A. (2003). Emergent phenomena and the sociology of disaster: Lessons, trends, and opportunities form the research literature. *Disaster Prevention and Management*, *12*, 97-112.

EM-DAT: OFDA/CRED International Disaster Database. (2012). *Report created for 2000-2009 for all natural disasters in the United States*. Retrieved from http://www.emdat.be/disaster-list

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *The handbook of qualitative research* (pp. 163-194). Thousand Oaks, CA: Sage.

Hale, C. M., Frelich, L. E., & Reich, P. B. (2006). Changes in hardwood forest understory plant communities in response to European earthworm invasions. *Ecology*, *87*, 1637-1649.

Hammer, R. B., Stewart, S. I., & Radeloff, V. C. (2009). Demographic trends, the wildland-urban interface, and wildfire management. *Society & Natural Resources*, *22*, 777-782.

Hanneman, R. A., & Riddle, M. (2005). *Introduction to social network analysis*. Riverside, CA: University of California. (Published in digital form: http://faculty.ucr.edu/~hanneman/)

Heath, R. L., Jaesub, L., & Lan, N. (2009). Crisis and risk approaches to emergency management planning and communication: The role of similarity and sensitivity. *Journal of Public Relations Research*, *21*, 123-141.

Herzog, R. J. (2007). A model of natural disaster administration: Naming and framing theory and reality. *Administrative Theory & Praxis*, *29*, 586-604.

Irwin, R. L. (1989). The incident command system (ICS). In E. Auf der Heide (Ed.), *Disaster response: Principles of preparation and coordination* (pp. 133-163). St. Louis, MO: Mosby.

Jones, C., Hesterly, W. S., & Borgatti, S. P. (1997). A general theory of network governance: Exchange conditions and social mechanisms. *Academy of Management Review*, *22*, 911-945.

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

Kapucu, N. (2006). Interagency communication networks during emergencies: Boundary spanners in multiagency coordination. *American Review of Public Administration*, *36*, 207-225.

Kapucu, N., & Van Wart, M. (2006). The evolving role of the public sector in managing catastrophic disasters. *Administration & Society*, *38*, 279-308.

Kitzberger, T., Swetnam, T. W., & Veblen, T. T. (2001). Inter-hemispheric synchrony of forest fires and the el Niño-Southern oscillation. *Global Ecology and Biogeography*, *10*, 315-326.

Laumann, E. O., Marsden, P. V., & Prensky, D. (1989). The boundary specification problem in network analysis. In L. C. Freeman, D. R. White, & A. K. Romney (Eds.), *Research methods of social network analysis* (pp. 61-87). Fairfax, VA: George Mason University Press.

Lind, B. E., Tirado, M., Butts, C. T., & Petrescu-Prahova, M. (2008). Brokerage roles in disaster response: Organisational mediation in the wake of Hurricane Katrina. *International Journal of Emergency Management*, *5*, 75-99.

Logan, J. A., Régnière, J., & Powell, J. A. (2003). Assessing the impacts of global warming on forest pest dynamics. *Frontiers in Ecology and the Environment*, *1*, 130-137.

Magsino, S. L. (2009). *Applications of social network analysis for building community disaster resilience: Workshop summary*. Washington, DC: National Academies Press.

McCaffrey, S. M. (2004). Fighting fire with education: What is the best way to reach out to homeowners? *Journal of Forestry*, *102*, 12-19.

McEntire, D. A., Fuller, C., Johnston, C. W., & Weber, R. (2002). A comparison of disaster paradigms: The search for a holistic policy guide. *Public Administration Review*, *62*, 267-281.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage.

Monroe, M. C., Pennisi, L., McCaffrey, S. M., & Mileti, D. (2005). *Social science to improve fuels management: A synthesis of research related to communicating with the public on fuels management efforts*. St. Paul, MN: North Central Research Station, US Forest Service, USDA. Retrieved from http://nrs.fs.fed.us/pubs/gtr/gtr_nc267.pdf

Moynihan, D. P. (2009). The network governance of crisis response: Case studies of incident command systems. *Journal of Public Administration Research and Theory*, *19*, 895-915.

National Wildfire Coordinating Group. (2009). *Quadrennial fire review*. Washington, DC: National Association of State Foresters.

Olsen, C. S., & Shindler, B. A. (2007). *Citizen-agency interactions in planning and decision making after large fires*. Portland, OR: Pacific Northwest Research Station US Forest Service, USDA. Retrieved from http://www.fs.fed.us/pnw/pubs/pnw_gtr715.pdf

Pollet, J., & Omi, P. N. (2002). Effect of thinning and prescribed burning on crown fire severity in Ponderosa Pine forests. *International Journal of Wildland Fire*, *11*, 1-10.

Provan, K. G., & Kenis, P. (2008). Modes of network governance: Structure, management, and effectiveness. *Journal of Public Administration Research and Theory*, *18*, 229-252.

Radeloff, V. C., Hammer, R. B., Stewart, S. I., Fried, J. S., Holcomb, S. S., & McKeefry, J. F. (2005). The wildland-urban interface in the United States. *Ecological Applications*, *15*, 799-805.

Schmidt, K. M., Menakis, J. P., Hardy, C. C., Hann, W. J., & Bunnell, D. L. (2002). *Development of coarse-scale spatial data for wildland fire and fuel management*. Fort Collins, CO: Rocky Mountain Research Station, US Forest Service, USDA. Retrieved from http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_061488.pdf

Seeger, M. W. (2006). Best practices in crisis communication: An expert panel process. *Journal of Applied Communication Research*, *34*, 232-244.

Seeger, M. W., Sellnow, T. W., & Ulmer, R. R. (2003). *Communication and organizational crisis*. Westport, CT: Praeger.

Stallings, R. A., & Quarantelli, E. L. (1985). Emergent citizen groups and emergency management. *Public Administration Review*, *45*, 93-100.

Steelman, T., & McCaffrey, S. (2013). Best practices in risk and crisis communication: Implications for natural hazards management. *Natural Hazards*. *65*(1), 683-705.

Stigler, G. J. (1961). The economics of information. *Journal of Political Economy*, *69*, 213-225.

Taylor, J. G., Gillette, S. C., Hodgson, R. W., Downing, J. L., Burns, M. R., Chavez, D. J., & Hogan, J. T. (2007). Informing the network: Improving communication with interface communities during wildland fire. *Human Ecology Review*, *14*, 198-211.

Tierney, K. J. (1985). Emergency medical preparedness and response in disasters: The need for interorganizational coordination. *Public Administration Review*, *45*, 77-84.

Topper, C. M., & Carley, K. M. (1999). A structural perspective on the emergence of network organizations. *Journal of Mathematical Sociology*, *24*, 67-96.

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. New York, NY: Cambridge University Press.

Williams, D. E., & Olaniran, B. A. (1998). Expanding the crisis planning function: Introducing elements of risk communication to crisis communication practice. *Public Relations Review*, *24*, 387-400.

Williamson, O. E. (1991). Comparative economic organization: The analysis of discrete structural alternatives. *Administrative Science Quarterly*, *36*, 269-296.

Bios

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