Emergent Coordination in the World Trade Center Disaster*†

Miruna Petrescu-Prahova‡ Carter T. Butts§

4/1/2005

Abstract

In this paper, we investigate coordination within responder radio communications during the World Trade Center disaster. Using a network analytic approach, we identify agents who exhibit high levels of coordinative activity. Agents are further classified by whether they appear to occupy formal roles whose responsibilities include coordination of communication, and by whether the agents belong to organizations whose mission includes emergency response. We find that, regardless of organizational type, the great majority of coordinators are emergent (i.e., do not occupy formal coordinative roles). At the same time, where agents with formal coordinative roles are present, they are substantially more likely to become actual coordinators. Uniformity of effects across organizational types suggests that emergent coordination in crisis situations is not strongly contingent on responder training or organizational structure.

Keywords: social networks, emergent organization, communication, organizational response, 9/11

1 Introduction

The importance of effective coordination during disasters has been documented by researchers and practitioners alike (Dynes, 1970; Drabek et al.,

*This material is based upon work supported by the National Science Foundation under award NSF ITR #0331707.

†The authors would like to thank Kathleen Tierney, Remy Cross, Katie Faust, and Jeanette Sutton for their input and encouragement.

‡Department of Sociology, University of California, Irvine

§Department of Sociology and Institute for Mathematical Behavioral Sciences, University of California, Irvine; SSPA 2145, University of California, Irvine, CA 92697; buttsc@uci.edu

1981; Auf der Heide, 1989). In a context dominated by "many people trying to do quickly what they do not ordinarily do, in an environment with which they are not familiar" (Tierney, 1985, p.77), achieving such coordination is often problematic. For instance, while most emergency response organizations contain institutionalized coordinative roles (e.g., dispatchers, desk operators, etc.), initial response activities are often conducted by persons who do not belong to such organizations. Even within such organizations, conditions in the field may create coordination demands which cannot be satisfied via conventional procedures. Where such circumstances arise, we may expect to observe the emergence of "ad hoc" coordinators from the responder population.

While the phenomenon of emergent coordination is well-known to disaster researchers (see, e.g. Dynes, 1970; Weller and Quarantelli, 1973; Stallings and Quarantelli, 1985; Drabek, 2003) numerous questions remain. For instance, the relative prevalence of individuals taking on coordinative roles (versus non-coordinative roles) during the immediate post-impact period is a question with significant implications for the design of responder information systems, as is the relative prevalence of institutionalized versus emergent coordinators. A related issue is the extent to which emergent coordination is associated with decentralized communication networks, as opposed to networks in which communication is concentrated within a small number of hands. Finally, it is of both practical and theoretical interest to determine the extent to which these factors vary between emergency response organizations and organizations not normally tasked with such activities (e.g., building maintenance teams or transportation workers).

These questions of coordination and structural adaptation in emergency phase communication networks are the central concern of this study. To address them, we turn to data on responder radio communication networks during the World Trade Center disaster. By examining the structure of these networks, we are able to identify agents who are engaged in a high degree of coordinative activity; we then consider the extent to which such coordinators are institutionalized versus emergent (on the one hand), and the extent to which institutionalization per se is predictive of coordinative activity (on the other). We also compare these relationships for organizations of different types, to assess the impact of organization type on emergent coordination. As we shall see, these analyses suggest a prominent role for emergent coordinators throughout the WTC emergency phase response.

1.1 Organizational response to disaster

Disasters are by definition events of an "accidental or uncontrollable" nature (Drabek, 1986), in which social processes are substantially disrupted (Fritz, 1961). Although they do not necessarily reduce the capacities of individuals or organizations to cope (Dynes, 2003), disasters present new and often unexpected problems to solve. The nature of the organizational response to such problems may involve novelty in both structure and modes of task performance, a fact which is usefully captured by Dynes's (1970) four-fold typology of organizational behavior during disasters. In Dynes's terminology, the *established organization* responds using its existing structure and routines. Typical examples of such organizations include police and fire departments, which are routinely involved in emergency situations in the community. In the *expanding organization*, by contrast, established tasks are performed by an increasing number of agents – the structure of the organization expands to incorporate these new members. In the case of the Red Cross, for instance, search and rescue activities are performed by volunteers who are recruited to serve in response to a particular disaster. The *extending organization* employs its existing structures to meet the requirements of the disaster, while changing its routines and modes of task performance. This type is common among organizations whose involvement in an emergency response setting is unanticipated, e.g., firms which may be directly or indirectly impacted by disaster (see Wahle and Beatty, 1990, for a practitioner-oriented view). In the *emergent organization*, both the organizational structure and the modes of task performance employed in the response are substantially novel; these organizations have no predisaster existence and therefore no continuity or preexisting formal structure (Dynes, 1970).

Regardless of the type of response, organizational effectiveness depends substantially on communication, particularly the collection and distribution of accurate information. This need may be especially acute during the emergency phase of the post-impact period, when uncertainty regarding both situation and response is high and immediate action is required to avoid further losses to lives and/or property. To meet the demand for communication, existing communication networks may have to be repurposed (e.g., in the extending organization), and/or new ones may have to be created (e.g., in the emergent organization). Such structural adaptations may incorporate both novel uses of technical infrastructure and modifications to established social roles, depending on available resources and environmental constraints. Where individual agents or infrastructural elements cannot be relied upon,

effective adaptation may be in the direction of decentralizing communication and coordination activities so as to reduce dependence on particular units (Pfeffer, 1978, pp20–21,134–135); loosely coupled structures (Aldrich, 1979; Weick, 1976) may thus be expected to emerge as organizations restructure to minimize the effect of external perturbations. The capacity to make such adjustments is a key element of organizational resilience (Kendra and Wachtendorf, 2003), and is a factor in organizational learning (Carley and Hill, 2001).

Consonant with the above, Dynes has argued that emergencies are characterized by decentralized and pluralistic decision making, and thus that autonomy of decision making – rather than centralization of authority – should be encouraged (Dynes, 2003, p.19). This structural shift tends to open up channels of communication which would normally be inhibited by status differentials. "The loss of status symbols, the shifting of personnel to new positions, and the influx of new personnel all contribute to a fluid status structure within the organization, and this accentuates the flow of information along the increased channel of communication" (Dynes, 1970, p.176). Such changes, however, produce a new problem: how is coordination of communication to be achieved in a decentralized environment? To some extent, coordination may be performed by designated agents whose formal institutional roles mandate coordinative activity. Examples of these *institutionalized coordinators* include call desk operators, dispatchers, and liaison officers. While institutionalized coordinators may be expected to play an important role (particularly in established and extending organizations), substantial decentralization also requires the assumption of coordinative responsibilities by agents whose duties typically lie elsewhere. These *emergent coordinators* arise due to demands on the communication structure which exceed the capabilities of conventional coordination mechanisms. By their nature, then, emergent coordinator roles are situationally contingent and may be expected to feature more strongly in some contexts than others.

1.2 Radio communication networks during the emergency phase

As noted above, the effectiveness of the emergency phase response as a whole is highly dependent on the effectiveness of communication, due to the need for coordination of time-sensitive response activities. If vital response activities such as search and rescue, medical care, traffic control, and resource allocation are carried out in an unstructured manner, the result can be duplication of effort, omission of tasks, and even counterproductive activities

(Auf der Heide, 1989). While emergency phase communication occurs via multiple conduits, one of the central technologies for responders in the field continues to be the two-way radio. Radio provides real-time voice communication for distributed units with minimal infrastructural requirements, a combination which is difficult to achieve with alternative technologies (e.g., telephony). Standard radio communication systems suffer from various well-known problems, ranging from the lack of common frequencies among response organizations to interference problems and "urban canyon" effects. Nevertheless, the ubiquity and versatility of radio communications make them an important target for disaster research.

While technical issues related to radio communication have attracted a great deal of attention (National Commission on Terrorist Attacks Upon the United States, 2004), fundamental organizational issues are no less central to understanding the role of radio communication in response. Where communication breaks down, "people problems" can play as large a role as incompatible frequencies or interference (Auf der Heide, 1989). For example, the so-called "Robinson Crusoe" syndrome ("we are alone on this island") emerges when an individual or organization fails to factor in other individuals or organizations in conducting their activities. In such circumstances, agents may fail to exchange information with one another, despite possessing the technical means to do so. Also problematic is lack of consensus over who has responsibility for the collection and dissemination of various types of information, and over who should have access to it. Finally, agents who possess critical information may not be aware that other agents require it, and therefore do not pass it on. Thus, effective radio communication poses the same difficulties of coordination as those mentioned above.

Somewhat paradoxically in light of the recommendations of Dynes (2003), one structural signal of efficient coordination is centralization. Summarizing the results of his now-famous early work on the effects of structure in communication networks, Bavelas (1950) notes that "in patterns with a high, localized centrality, organization evolves more quickly, is more stable, and errors in performance are less" (p. 730).[1] By communicating with multiple alters, agents serving as "hubs" can consolidate information regarding events and activities, thereby reducing their alters' communicative load. Efficiency may be further increased, in many cases, by reducing redundant communication among non-hub agents; effectively, the task of information

[1]Some evidence suggests (see, e.g. Baron et al., 1992) that complex, non-decomposable information tasks may favor decentralized structures; however, achieving problem segmentation (and hence decomposability) is itself a mark of effective coordination systems (Perrow, 1970).

consolidation and allocation is delegated to the hub agents, freeing others to focus on other tasks. While such indirect communication may raise the concern of information loss due to relay error (Drabek, 1985), it should be borne in mind that hub dominated networks can often allow for flexible message passing using few intermediaries. Furthermore, centralized structures are relatively well-buffered against the loss of non-hub members and the injection of inaccurate information by agents (Carley, 1992). In contrast with the above, a heavily decentralized network will generally be either poorly connected (harming effectiveness) or have a large number of redundant communications (harming efficiency). Densely clustered networks are typical of team structures, and can be effective where communication is inexpensive. Their presence in an emergency-phase radio network suggests that communicants were unable to successfully concentrate coordination into a limited number of hands; while this may not be a maladaptive response, it certainly indicates the presence of more contacts than are needed to maintain connectivity. Uniform, "random" communication structures suggest a still more primitive state of affairs, in which there is no clear evidence of task or role consolidation within the responder population.

This interpretation, then, suggests that the emergence of strong coordinative roles will be mirrored by the centralization of the organizational communication structure, with highly central agents occupying the coordinative roles. In particular, we expect coordinators to possess two distinct structural characteristics. First, coordinators should have a large number of communication partners – by definition, coordinators must be involved in communications with multiple agents. Second, coordinators should *mediate* communications among their partners; that is, the fastest route for passing messages from one agent to another should typically be through a coordinator. In the language of network analysis (Wasserman and Faust, 1994), coordinators can be said to be agents whose positions are high in both *degree* (number of partners) and *betweenness* (extent of mediation). As these quantities may be measured directly from the realized communication network, they may be employed to identify coordinators in practice. Further analyses may then be utilized to determine the extent to which empirically identified coordinators are institutionalized versus emergent in nature.

We have presented so far two seemingly opposite views of how a communication network should be structured in a disaster. One line of reasoning suggests that decentralization is desirable because it opens up channels of communication hitherto closed due to status differentials (Dynes, 2003). The second approach suggests that coordination (and, therefore, centralization) is vital for an efficient response (Auf der Heide, 1989). The two views can be

brought together, however, if we understand the differences between global and local coordination. Decentralization, while necessary, does not automatically imply the total disappearance of coordinator roles, but instead the tendency for coordination to take place at a local, rather than global, level (by local, in this context, we mean subgroup level). The effectiveness of a communication network during a disaster may rest ultimately on its capacity to allow decentralization and the emergence of local coordinators at the same time.

In this study we conduct an investigation of coordinative behavior within the radio communication networks of various first responder groups in the context of the World Trade Center Disaster. Before turning to the details of the data, however, we pause to consider some pertinent aspects of the WTC response more broadly.

1.3 World Trade Center Disaster - The Response

Disaster response features actions by a series of formal organizations whose training is geared toward dealing with crisis situations. However, in many cases the very first responders, the persons who are directly involved in giving first aid or coordinating evacuations are not members of these organizations, but resident or transient bystanders. In order to differentiate between the two groups, we refer to the former group as "specialist responders", and to the latter as "non-specialist responders." To make a parallel with Dynes' categorization, the "specialist responders" can be thought of as members of established organizations, whereas "non-specialist responders" fall closer to his definition of members of extending organizations, The following two sections summarize the accounts about each group's involvement in the WTC disaster.

1.3.1 Specialist Responders

In the post-impact period of the WTC disaster, the agencies that were called immediately at the scene and were most involved throughout the response period were the Fire Department of New York, the New York Police Department, the Port Authority Police Department, and the Office of Emergency Management and Interagency Preparedness (National Commission on Terrorist Attacks Upon the United States, 2004). Although there are some sources of information about the interventions undertaken by these agencies (National Commission on Terrorist Attacks Upon the United States, 2004; McKinsey and Company, 2002b;a), the most detailed data available

concerns the Port Authority of New York and New Jersey (PA). As a result of a lawsuit filed by the New York Times in 2003, the PA released a set of documents pertaining to the events of September 11, 2001. The complete set contains reports of PA police officers and transcripts of radio and telephone conversations between PA employees (both police officers and other personnel) conducting activities inside the World Trade Center complex and the PA command centers at airports and other facilities.

The Port Authority of New York and New Jersey manages and maintains the bridges, tunnels, bus terminals, airports, and seaport that are vital for the trade and transportation needs of the bistate region. The PA facilities include the LaGuardia, John F. Kennedy and Newark Liberty airports, the Holland and Lincoln tunnels, and the Port Authority Trans-Hudson train system. The PA has its own police department, whose officers are trained in fire suppression methods as well as in law enforcement. There is a separate command for each of the Port Authority's facilities, including the World Trade Center. The Port Authority Trans-Hudson operated a train station directly underneath the WTC complex, while Newark Airport was the departure airport for one of the hijacked airplanes.

One of the few existing studies that focus specifically on emergency response organizations is Wenger et al. (1989). The authors analyze police and fire departments in eight communities during a disaster, presenting the structural changes these departments are likely to undergo in a disaster context. In the case of police departments, these changes can be observed in three critical areas: the authority structure, the decision-making process, and the use of formal and informal communication systems.

The authority structure is altered by the fact that higher ranking officers tend to assume more authority than usual and, on the other hand, some officers in the field receive orders from non-police emergency officials. This modified authority structure can present problems consisting of "conflicting directives, a lack of coordination among the units, and the imposition of a non-traditional source of supervision over the individual officers" (Wenger et al., 1989, p. 29). As a consequence, decision-making is decentralized and may become indiscriminate, with officers being unable to grasp the whole picture and assigning wrong priority levels to various actions. Such a situation happened on September 11, as noted by the McKinsey and Company (2002a), which contains an analysis of NYPD response activities on that day. One of the problems identified by this report was the lack of a "central point for collation and systematic analysis of information regarding [the] incident, with leaders acting largely on personal observations" (McKinsey and Company, 2002a, p. 28).

The communications center plays a crucial role in everyday police work - dispatchers send and receive all radio communications with police officers on the road, handle telephone calls to and from the public and other agencies, and decide whether to send an officer to an incident, and, if so, which officer (Kirmeyer, 1988). During a disaster, however, the volume of communications increases dramatically, and may overload the system. Turning again to the McKinsey and Company (2002a), the communication problems identified by the report refer to the fact that NYPD officers were highly reliant on their cell phones, which were mostly inoperable because of system overload and infrastructure damage, and that communications were severely hampered by the failure of land-lines around the incident site. Radio communication suffered as well, with only 42 percent of officers being able to clearly decipher traffic (McKinsey and Company, 2002a, p. 25). Moreover, the NYPD had "no clearing house for distilling, correcting and disseminating accurate information to responders"(McKinsey and Company, 2002a, p. 28), which created a high level of uncertainty.

As we can see, decentralization does occur, at least in the case of specialist responders, but not always with healthy consequences. A certain level of coordination, especially with regard to information analysis and dissemination, is necessary for an effective intervention.

1.3.2 Non-specialist Responders

In the case of a disaster, many organizations and individuals that are not normally involved in emergency operations may become involved, because they happened to be in the area. As noted by the 9/11 Commission Report (2004), the WTC disaster is no exception to this general principle: the very first rescue and evacuation activities were initiated and performed to a great extent by civilians who worked in the WTC, as well as by PA civilian employees. "The first response came from private firms and individuals – the people and companies in the building. Everything that would happen to them during the next few minutes would turn on their circumstances and their preparedness, assisted by building personnel on-site" (National Commission on Terrorist Attacks Upon the United States, 2004, p. 286). Studies of rescue activities in other disasters show that this type of involvement is a consistent pattern. Individuals who are in the impact area and who have not been severely injured turn immediately to help those around them (Dynes, 1970; Tierney et al., 2001). Our data includes communications among building employees in the mechanical/electric, operations, and vertical transportation units during the first hours of the disaster, and so

will allow us a glimpse into the manner in which these personnel responded to the extreme changes in their environment.

Another related phenomenon which must be taken into account in this analysis is the "ripple effect" of a disaster. Apart from organizations that are strictly in the impact zone and are directly affected, there are other organizations located in the proximity, which may be indirectly affected by the events and forced to respond in one form or another, e.g. by ensuring the safety of their workers and customers. The data set we have available allows us to investigate this aspect by analyzing the radio communications among employees of the PATH system and Newark Liberty Airport.

2 Data

The data employed in this study is the set of transcripts of radio communications between responders to the WTC disaster, each transcript representing all conversation on a single radio channel for a specified period. There are 19 transcripts in all, but two of them cover the same channels (in poorer quality versions), and thus the total number of transcripts we analyze is 17. Their length ranges from 7 to 80 pages (median 43, IQR 35). All transcripts begin immediately after the first airplane crashed into the North Tower at 8:46 am, and their length depends on the channel used and the location of the communicants, which in some cases is tantamount to their survival. The transcripts of conversations between employees located within the WTC itself are roughly 1 hour and 15 minutes in length, while all the others are 3 hours and 33 minutes long. The primary contents of each transcript is summarized below:

path.ch27.r3.communications communications among PATH personnel, who attempt to locate one another and account for their colleagues

lincoln.tunnel.police Lincoln Tunnel Police Department coordinates traffic through Lincoln Tunnel and cooperates with other police units to give them access to New York City

newark.ch23.ewr.command mobilization of police and fire units and equipment to be deployed at the WTC. This channel is also used by personnel who are making sure that no unauthorized persons enter the Newark Airport, which is closed at that time

newark.ch25.ewr.TACI Newark Airport command communicates with police units deployed at the WTC

newark.ch26.CPD Newark Command Post tries to communicate with the command post vehicle in the field and assess the general situation of the emergency response activities

newark.ch36.ops.terminals Newark Airport is closed, so the control desk coordinates personnel to take care of stranded passengers, luggage, and airplanes, and to evacuate terminals

newark.ch39.maintenance maintenance personnel communicate among themselves, trying to determine what has happened at the WTC

path.ch26.r1.trainmaster due to the attacks, service at the WTC PATH station is interrupted, and the control desk is coordinating the train traffic in the rest of the system

spen1.ch15 the State Police Emergency Network is used by New Jersey State Police units to coordinate their efforts and gather resources from all locations, as well as to regulate access into NYC via bridges and tunnels

spen2.ch16 the PA Command Post communicates with police units inside WTC on State Police Emergency Network 2. After the South Tower collapses, they are trying to evacuate the North Tower

wtc.chw.police PAPD officers coordinate the evacuation of WTC buildings

wtc.chy.ops operations personnel from WTC self-evacuate and reassemble in a different location on one of the nearby streets

wtc.chz.vertical.transp vertical transportation personnel self-evacuate and regroup at a different location outside

newark.ch38.facilities Newark Airport personnel communicate while taking the necessary steps to close down the airport

path.ch21.r2.trainmaster communications between the PAPD central desk and the PAPD PATH desk, and PAPD officers deployed at the WTC

wtc.chx.security security personnel try to organize the rescue of civilians trapped in different parts of the North Tower

wtc.chb.mech.electric WTC electric and mechanical personnel coordinate to self-evacuate and regroup at a different location outside

It should be noted here that transcription of the original voice communication recordings was performed at the discretion of the Port Authority, and we do not have detailed information regarding this process. Where possible, we have performed internal checks to verify the accuracy of the transcription process using other available documentation. Our verifications suggest that the transcription is consistent and that the transcripts are accurate representations of the original conversations. Nonetheless, it should be borne in mind that conclusions reached in this study are to some extent conditioned upon the accuracy of the initial transcription.

2.1 Transcript Coding

Each of the transcripts described above contains a list of statements exchanged between responders, presented in the chronological order of their transmission. The transcriber also provides a name tag for the sender, at the beginning of each statement. Based on the information available, this name tag includes some or all of the following: gender, name, rank, and organization. The information included in the name tags was used to code the identity of the sender for each transmission. The identity of the receiver was inferred from information contained in the statement (either a name or an indication that the statement was part of an ongoing conversation for which the participants had already been identified).

The task of identifying senders and receivers proved to be difficult in many cases. Although the transcriber provides some information regarding the identity of the sender, there are two problems which make the identification difficult. First, transcribers do not provide the same amount of information across transcripts – some state only the gender of the sender, while others give additional information such as an indication of the organization with which the sender is affiliated. Some transcribers additionally split the transcript into segments of conversation, uniquely identifying senders within each segment; this was not performed in all cases. Second, the original recordings appear to have been garbled in many places, indicated by the transcriber via "inaudible" tags. Where transmission content is marked inaudible, identifying information is sometimes lost. Given these constraints, sender/receiver coding was accomplished using a combination of transcriber-supplied information, communicants' use of names and callsigns, sequence information, and conversational cues. Where one-to-many communications were found, they were coded as dyadic communications from the sender to each of the named recipients. Because we do not have complete rosters for the organizations involved, communications where the recipients

were named as a group ("all units", "all mechanical personnel") were not included in the list of coded communications. The resulting list of discrete communications by sender and receiver was then employed to construct the aggregate communication network for each transcript.

2.2 Network Extraction

Once each discrete communication was coded for sender and intended recipient(s), a communication network was extracted from the data for each transcript. Each network in question is a directed multigraph (Wasserman and Faust, 1994) on the set of named communicants, where each (i, j) edge represents a distinct communication in which actor j was a designated recipient of a message from actor i. For purposes of the present research, this multigraph was further simplified into a digraph in which an (i, j) edge exists if and only if there exists at least one (i, j) edge in the corresponding multigraph. Except as noted otherwise, all analyses shown here refer to these directed graphs.

3 Analysis

We begin our analysis of the WTC radio communication networks by a visual inspection of the sociograms (network diagrams) for each channel. Figures 1 and 2 depict the networks for specialist and non-specialist responders, respectively. Individual responders within each network are represented by circles (*vertices*), while ties between responders are represented by arrows (*edges*). To highlight potential coordinators, vertex sizes have been scaled by the corresponding individual's total number of communication partners (i.e., total degree (Wasserman and Faust, 1994)).

As Figures 1 and 2 clearly show, coordinators play a substantial role in mediating communication for all WTC channels. In each case, a small number of high-degree vertices act to connect a large number of agents who do not otherwise communicate with one another. The result is a collection of highly structured networks, in which coordination tasks appear to have been concentrated into a relatively small number of hands. This is clearly the case for both specialist and nonspecialist responder networks, suggesting that this concentration is not a property of specialization alone. Indeed, comparison of the two sets on a standard measure of concentration (degree centralization) does not reveal a significant absolute difference in mean centralization scores ($p = 0.0954$, one-tailed permutation test). It would seem,

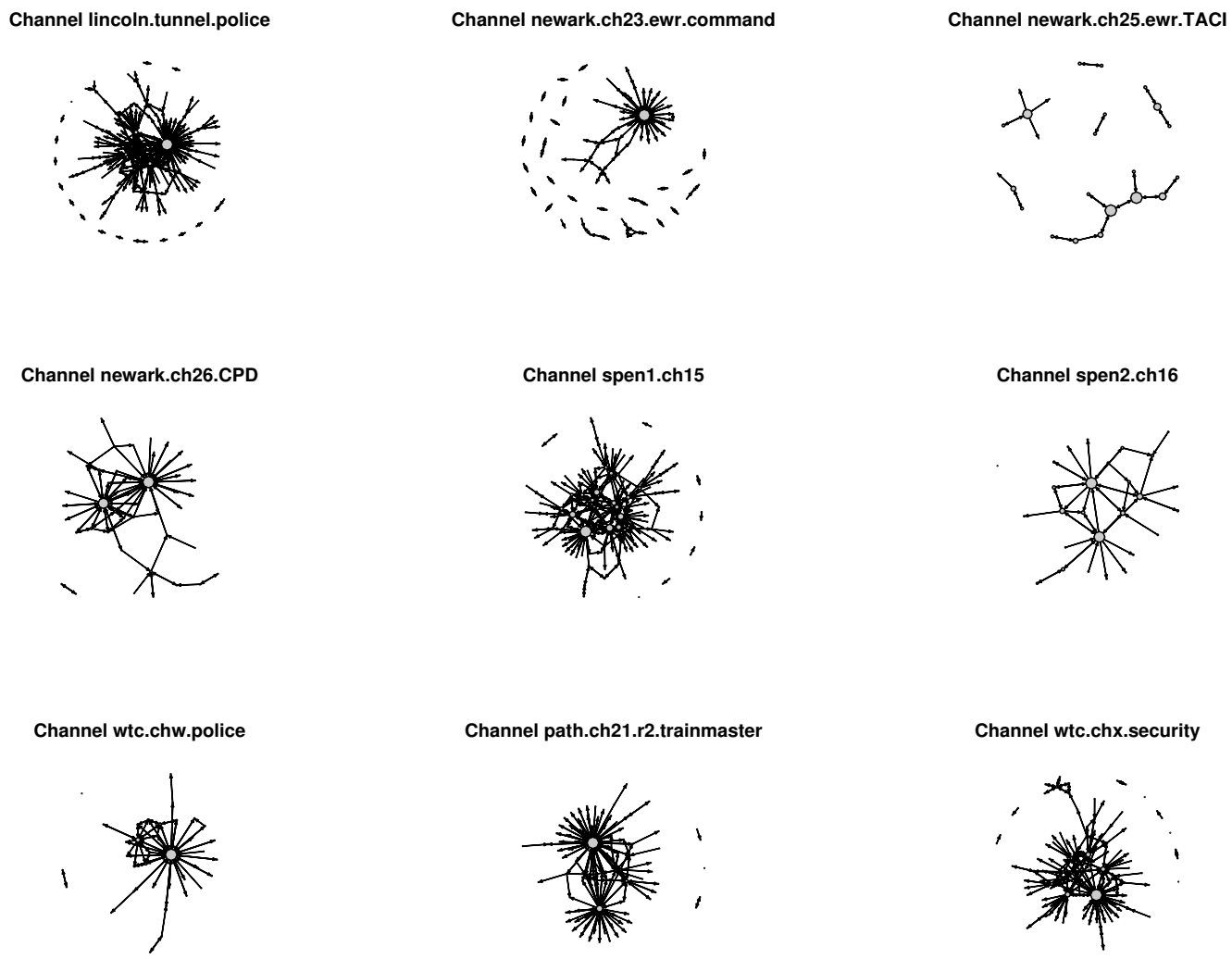

Figure 1: Sociograms for WTC Radio Communications, Specialist Responders

then, that the domination of responder communication networks by a relatively small number of agents with many communication partners should be viewed as a common property of networks in the World Trade Center disaster, rather than a phenomenon restricted to networks formed by professional responders.

While the sociograms of Figures 1 and 2 confirm that prominent coordinators are present within each communication network, they provide little insight as to the nature of the agents who occupy those positions. Similarly, it is difficult to ascertain from sociograms alone the extent of the relationship between the two necessary elements of coordination: *direct* communication with many alters, and *mediation* of communication among alters with limited alternative means of contacting one another. The first of these elements corresponds to the network property known as *degree*, i.e., the number of alters to which a given ego is tied.[2] The second of these elements can be assessed in several ways, but the most common is via a structural property known as *betweenness* (Wasserman and Faust, 1994). As the name implies, the betweenness of a given ego is a measure of the extent to which ego lies on the shortest paths between many pairs of alters. A responder in a high-betweenness position, then, is likely to serve as a critical linch-pin in any attempt at rapid message-passing among disparate groups of responders. While betweenness and degree are often correlated, they are distinct concepts: a responder embedded in a large, tightly connected team might have high degree and low betweenness, while a responder serving as the sole bridge between two otherwise disconnected teams might have high betweenness and low degree. (See also Freeman (1979) for a more wide-ranging discussion.) It is the conjunction of these two formal properties, then, which defines a coordinative position.

With this in mind, we proceed to examine the joint distributions of betweenness and degree for the WTC communication networks. These are shown for the specialist responder networks in Figure 3, with distributions for non-specialist responder networks given in Figure 4. To assist in identifying coordinative positions, 90% quantile lines have been superimposed for both measures; thus, the upper right quadrant of each plot can be interpreted as containing positions which effectively serve as coordinators for the corresponding network. (While the 90% threshold is somewhat arbitrary - chosen based on an examination of the underlying distributions -, the results shown here are robust to reasonable alternatives.) As both Fig-

[2]Note that we here consider both incoming and outgoing ties (total degree), unless otherwise indicated.

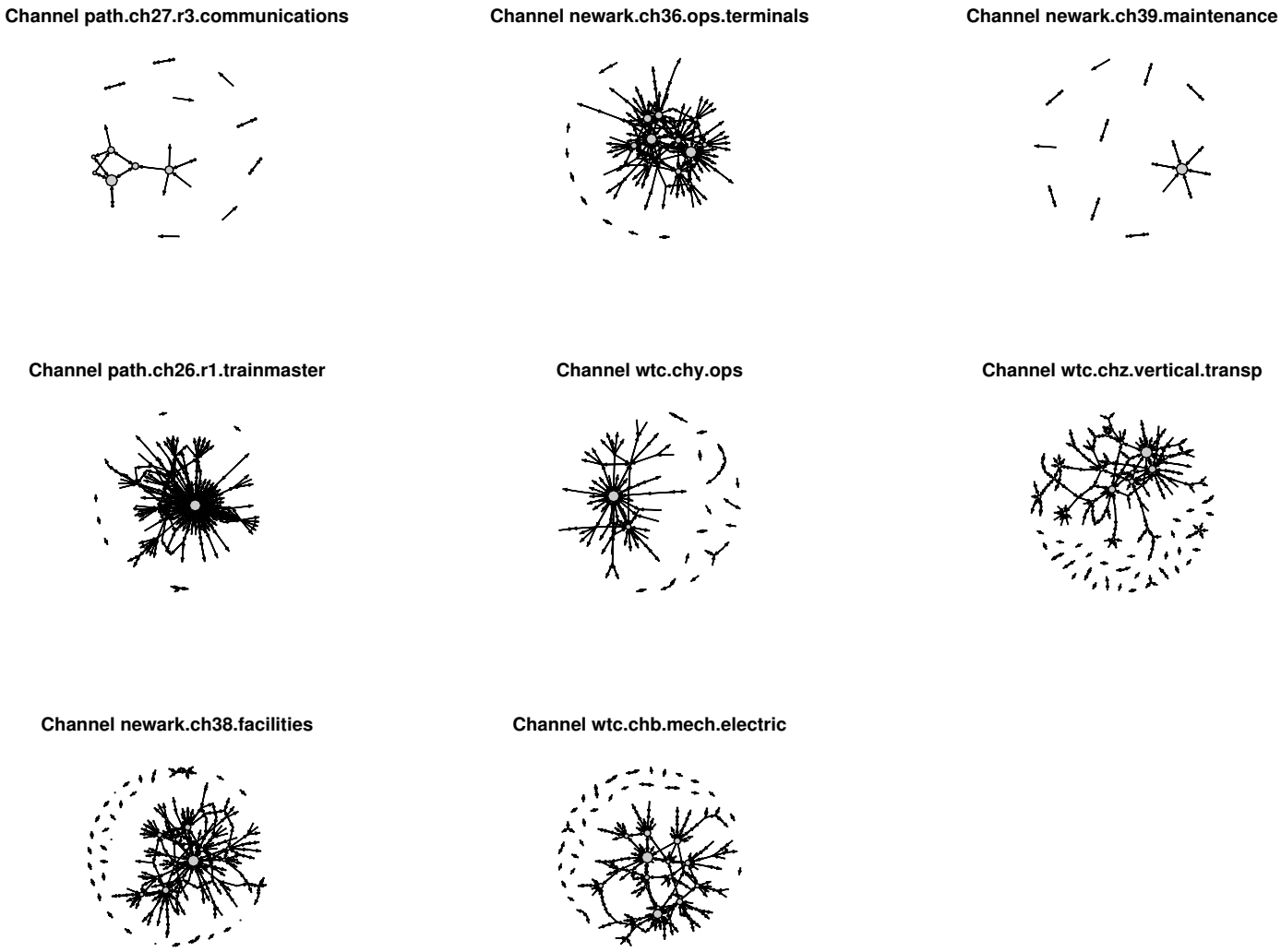

Figure 2: Sociograms for WTC Radio Communications, Non-Specialist Responders

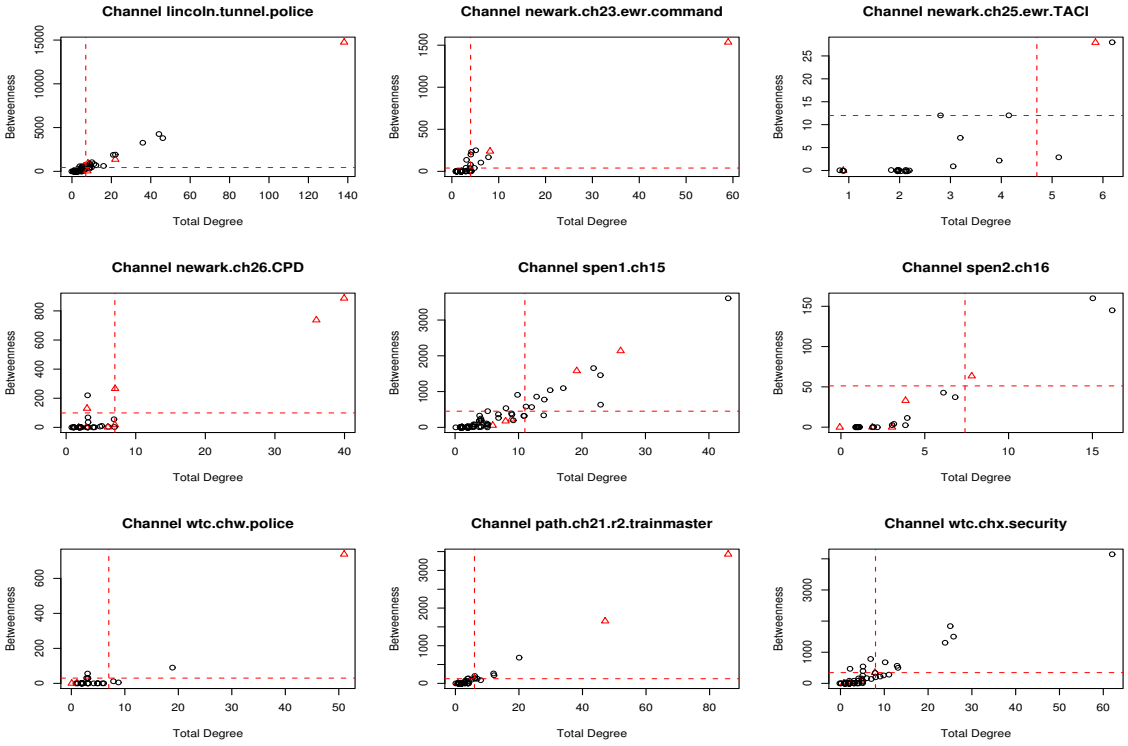

Figure 3: Combined Centrality Scores by Role Type, Specialist Responders

ures suggest, degree and betweenness are very highly correlated for these networks (median $\rho = 0.969$, IQR 0.0529). This implies that – in these networks – responders with large numbers of partners also mediate ties between numerous alters, and vice versa. We can thus reasonably speak of agents' overall extent of coordination within the communication system without distinguishing between degree and betweenness per se.

In addition to showing the degree/betweenness relationship for each network, Figures 3 and 4 allow us to identify differential occupancy of coordinative positions by responders with or without institutionalized coordination roles. Specifically, responders with such roles are designated in each figure via light-colored triangular markers, as opposed to the darker circular markers used for undifferentiated responders. Using the joint 90% threshold as the practical truncation point for coordinator status, it is plain that both

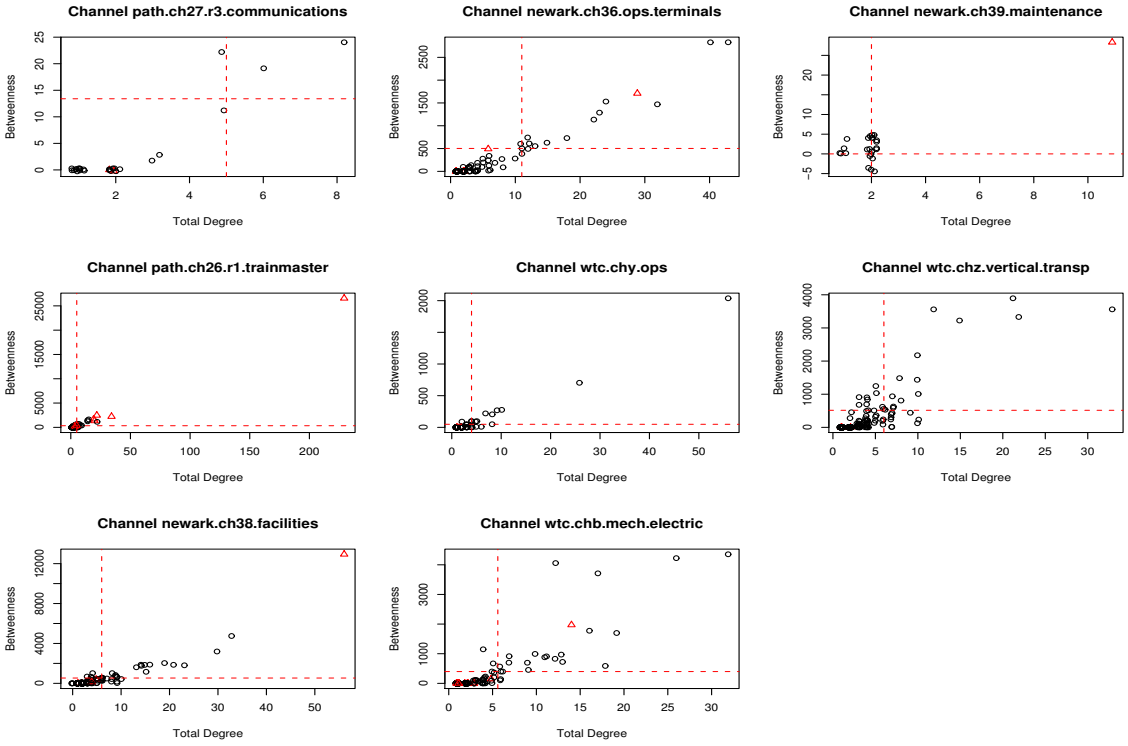

Figure 4: Combined Centrality Scores by Role Type, Non-Specialist Responders

institutionalized and emergent coordinators are found across the WTC communication networks. Although networks can be found for which each type dominates, the most common pattern appears to be a mixture of coordinators with and without institutionalized roles; this is true for both specialist and non-specialist responder networks. Nor does this result appear to depend upon the choice of a 90% threshold – as Figures 3 and 4 show, mixtures of institutionalized and emergent coordinators can be found throughout the upper tails of most betweenness/degree distributions. It is thus immediately apparent that we must reject the simple hypotheses that coordination activities in the WTC were simply a matter of formal, institutionalized role performance, and that overwhelming differences in coordinator types were present for specialist versus non-specialist responders.

	Specialist Responders		Non-specialist Responders	
	Coordinators	Non-coordinators	Coordinators	Non-coordinators
Institutionalized	16	36	12	32
Non-institutionalized	49	688	113	1048

Table 1: Coordinator Role by Institutionalized Status, Specialist and Non-specialist Responders

Simple inspection, however, cannot establish the relative prevalence of coordinator types, nor assess whether minor but significant differences might exist between specialist and non-specialist responder networks. For this reason, we now turn to a more detailed analysis. Frequency statistics for observed coordinator roles by institutional and specialization status are shown in Table 1. Collapsing rates across responder type, we note immediately that a substantial majority (over 85%) of coordinators are emergent, while a minority (29%) of institutionalized agents are coordinators. This is clearly consistent with the notion that realized coordination roles during emergencies are not generally predetermined, and that most individuals occupying these roles come to do so on the basis of situational factors. This is not the whole story, however: when we consider the odds of assuming a coordinative role, we find that the institutionalized agents are 3.4 times as likely to do so as agents without an equivalent status ($\chi^2 = 42.7574$ on 1 df, $p = 6.2e - 11$). This apparent paradox is resolved by noting that institutionalized agents make up just under 5% of the population; thus institutionalization *does* greatly contribute to the chance that any given agent will take a coordinative role, but this effect is overwhelmed by the fact that there are many more potential emergent coordinators from which to select.

Given the potential group differences, it is natural to ask whether institutionalized status affects specialist and nonspecialist responders in the same way. To test the hypothesis of a possible effect of specialization, we follow the standard procedure of comparing the fit for a loglinear model with all one and two-way marginals to the fit for the saturated model for Table 1 (Bishop et al., 1975). The one and two-way effects model fits well (LR $\chi^2 = 1.4558$ on 1 df, $p = 0.228$), providing no evidence of a three-way interaction between specialist status and the institutionalization-coordinator relationship. (Similar results were also obtained from an equivalent Monte Carlo test ($p = 0.23$).) Thus, we find no difference in the effect of institutionalization for the two groups. There is one caveat to this result, however: institutionalized coordination roles are 1.8 times as common in specialist responder networks as they are in non-specialist networks ($\chi^2 = 8.3582$ on

1 df, $p = 0.004$). Somewhat more institutionalized coordinators are likely to appear in specialist networks, then, simply due to a higher incidence of agents with institutionalized communication roles. The impact of specialization thus lies in its effect on the mix of responders at the scene, rather than on the tendency of individuals to take on coordinative roles.

4 Conclusion

The purpose of this study was to shed some light on the problem of coordination in communication during disasters, by investigating whether institutionalized coordinators (i.e., people whose role in the organization is specifically to coordinate communication) are more central in emergency phase communication networks, and whether specialist and non-specialist responder organizations have different responses to the challenges posed by a disaster environment to their communication structure.

Our main findings may be summarized as follows. First, respondent communication networks within the WTC disaster – regardless of source or responder type – are dominated by a relatively small number of agents acting as coordinators, who are linked to many communication partners. While both institutionalized and emergent coordinators are found across the WTC networks, the vast majority of coordinators appear to be emergent (in the sense of having no institutionalized coordinative role). That said, agents with institutionalized coordinative roles are much far more likely to wind up as de facto coordinators than agents without such roles; prior institutional arrangements do affect the response process. Somewhat surprisingly, networks of specialist responders seem to display the same chance of coordination given institutionalization. Because these networks do tend to contain more agents with institutionalized coordinative roles, however, they end up containing a somewhat larger number of institutionalized coordinators. In the end, however, this effect is small compared to the overall prevalence of emergent coordination in these networks.

The unexpected lack of differentiation between specialist and nonspecialist responder networks suggests that the same processes may be governing emergent coordination in each, and that the factors which shape these processes are not ones which vary strongly across organizational type. It is tempting to propose that these factors may be due to the crowded, confused nature of the WTC site, but this is not consistent with the fact that many of the networks analyzed here involved communication among those at remote locations. As we do not currently have baseline communication

data for these organizational populations, we cannot say for certain that these effects do not reflect day to day similarity, but this would seem to run counter to prior studies of such organizations. What can be said is that the substantial role played by emergent coordination at the WTC for responders of all types underscores the importance of identifying the processes by which coordination emerges during the early phases of disaster. Mechanisms such as preferential attachment (e.g., a tendency to call those who have recently been heard on-air leading to a positive feedback loop of participation) or differential opportunity (e.g., the delegation of coordination to those agents who happen to reside in safer locations) are among the many which would seem to be worthy targets of investigation. By obtaining a deeper understanding of the processes by which coordinators emerge during times of crisis, organizations of all types can be better prepared to develop an effective response.

5 References

Aldrich, H. E. (1979). *Organizations and Environments*. Prentice-Hall, Englewood Cliffs, NJ.

Auf der Heide, E. (1989). *Disaster Response: Principles of Preparation and Coordination*. Mosby, St. Louis, MI.

Baron, R., Kerr, N., and Miller, N. (1992). *Group Processes, Group Decision, Group Action*. Open University Press, Buckingham, UK.

Bavelas, A. (1950). Communication patterns in task oriented groups. *Journal of the Acoustical Society of America*, 22:271–282.

Bishop, Y. M. M., Fienberg, S. E., and Holland, P. W. (1975). *Discrete Multivariate Analysis: Theory and Practice*. MIT Press, Cambridge, MA.

Carley, K. (1992). Organizational Learning and Personnel Turnover. *Organization Science*, 3(1).

Carley, K. M. and Hill, V. (2001). Structural change and learning within organizations. In Lomi, A. and Larsen, E. R., editors, *Dynamics of Organizations: Computational Modeling and Organizational Theories*, chapter 2, pages 62–92. MIT Press, Cambridge, MA.

Drabek, T. E. (1985). Managing the Emergency Response. *Public Administration Review*, 45.

Drabek, T. E. (1986). *Human System Responses to Disaster: An Inventory of Sociological Findings*. Springer-Verlag, New York.

Drabek, T. E. (2003). Strategies for Coordinating Disaster Responses. Program on Environment and Behavior Monograph 61, Institute of Behavioral Sciences, University of Colorado, Boulder, CO.

Drabek, T. E., Tamminga, H. L., Kilijanek, T. S., and Adams, C. R. (1981). *Managing Multiorganizational Emergency Responses: Emergent Search and Rescue Networks in Natural Disaster and Remote Area Settings*. Number Monograph 33 in Program on Technology, Environment, and Man. Institute of Behavioral Sciences, University of Colorado, Boulder, CO.

Dynes, R. R. (1970). *Organized Behavior in Disaster*. Heath Lexington, Lexington, MA.

Dynes, R. R. (2003). Finding Order in Disorder: Continuities in the 9-11 Response. *International Journal of Mass Emergencies and Disasters*, 21(3):9–23.

Freeman, L. C. (1979). Centrality in social networks: Conceptual clarification. *Social Networks*, 6:223–258.

Fritz, C. E. (1961). Disasters. In Merton, R. K. and Nisbet, R. A., editors, *Contemporary Social Problems*, pages 651–694. Harcourt, New York.

Kendra, J. M. and Wachtendorf, T. (2003). Elements of Resilience After the World Trade Center Disaster: Reconstituting New York City's Emergency Operations Center. *Disasters*, 27(1):37–53.

Kirmeyer, S. L. (1988). Observed Communication in the Workplace: Content, Source, and Direction. *Journal of Community Psychology*, 18:175–187.

McKinsey and Company (2002a). Improving NYPD Emergency Preparedness and Response. Report to the New York Police Department.

McKinsey and Company (2002b). Increasing FDNY's Preparedness. Report to the Fire Department of the City of New York.

National Commission on Terrorist Attacks Upon the United States (2004). The 9/11 Commission Report: Final Report of the National Commission on Terrorist Attacks Upon the United States. New York.

Perrow, C. (1970). *Organizational Analysis: A Sociological View*. Wadsworth, Belmont, CA.

Pfeffer, J. (1978). *Organizational Design*. AHM, Arlington Heights, IL.

Stallings, R. A. and Quarantelli, E. L. (1985). Emergent Citizen Groups and Emergency Management. *Public Administration Review*, 43:93–100.

Tierney, K. J. (1985). Emergency Medical Preparedness and Response in Disasters: the Need for Interorganizational Coordination. *Public Administrative Review*, 45.

Tierney, K. J., Lindell, M. K., and Perry, R. W. (2001). *Facing the Unexpected: Disaster Preparedness and Response in the United States*. Joseph Henry Press, Washington, DC.

Wahle, T. and Beatty, G. (1990). Emergency Management Guide for Business and Industry. Technical report, Federal Emergency Management Agency, Washington, DC.

Wasserman, S. and Faust, K. (1994). *Social Network Analysis: Methods and Applications*. Cambridge University Press, Cambridge.

Weick, K. A. (1976). Educational Organizations as Loosely Coupled Systems. *Administrative Science Quarterly*, 21:1–19.

Weller, J. and Quarantelli, E. L. (1973). Neglected Characteristics of Collective Behavior. *American Journal of Sociology*, 79:66–85.

Wenger, D., Quarantelli, E. L., and Dynes, R. R. (1989). Disaster Analysis: Police and Fire Departments. Final Project Report 37, Disaster Research Center, University of Delaware, Newark, DE.