Studying Organizationally-situated Improvisation in Response to Extreme Events*

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Abstract

Extreme events such as large-scale natural disasters create the need for cooperation within and among responding organizations. Activities to mitigate the effects of these events can be expected to range from planned to improvised. This paper presents a methodology for describing both the context and substance of improvisation during the response phase. The context is described by (i) analyzing communication patterns among personnel in and among responding organizations and (ii) determining the appropriateness of existing plans to the event. The substance of improvisation within this context is described by modeling the behavior and cognition of response personnel. Application of the methodology leads to descriptions of improvisation and its context that may be stored in machine-readable format for use either by researchers, responding organizations or designers of computer-based tools to support improvised decision making. Data collection strategies for implementing the methodology are discussed and selected steps illustrated using a data set from a large-scale natural disaster.

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Responding to Extreme Events

Extreme events such as large-scale disruptions following natural or technological disasters create the need for coordinated and collaborative response activities both within and among organizations. Response personnel may act alone or within *ad hoc* or established organizations; they may also adhere to or depart from their expected roles (Bosworth and Kreps 1986; Kreps and Bosworth 1993), undertaking activities that range from planned to improvised. When improvisation by individuals or groups takes place within either established or *ad hoc* organizations, it may be seen as organizationally-situated. The study of improvisation as a situated activity is particularly appropriate in emergency response: at the individual level, an expert may be called in to assist an organization, perhaps by marshalling its resources for new purposes; at the group level, an Emergency Response Organization may convene to assist the organization in coordinating its efforts with those of other organizations; at the organizational level, numerous agencies may need to coordinate their activities in order to respond effectively.

This research presents and illustrates a methodology for describing both the context and substance of improvised decision making in response to extreme events. The particular foci of this work are (i) providing guidelines on how data on organizationally-situated improvised decision making during emergency response may be captured, (ii) integrating analyses of the context and substance of organizationally-situated improvisation and (iii) suggesting how the results of these analyses may be stored for use by researchers or responding organizations.

The paper proceeds as follows. Prior research related to the study of organizationally-situated improvisation is reviewed. A methodology for describing, analyzing and modeling

organizationally-situated improvisation is then presented, with examples of its application given using data from Disaster Research Center archives (Quarantelli 1997). A discussion of outstanding questions and opportunities for future work concludes the paper.

Related Prior Work

Learning from Extreme Events

Both disaster researchers and responding organizations continue to benefit from technologies that enable improved collection and analysis of data during and after extreme events. Recognizing the rare opportunities that extreme events present for understanding the dynamics of response, the Disaster Research Center conducted numerous field studies involving collection of interviews as well as supporting documents such as emergency response plans, organizational charts and Congressional testimony (Quarantelli 1997). The Natural Hazards Research Center has continued in this tradition through its National Science Foundation-funded Quick Response Grant program. Yet it must be recognized that data collection following the occurrence of extreme events is almost always opportunistic (Drabek 1970; Wenger 1989). A challenge for researchers is therefore how to draw valid conclusions from data that have not necessarily been collected to support a specific research objective but that, in and of themselves, have significant value to society because of the events they describe. A parallel challenge for responding organizations is how to store and retrieve lessons that may be learned from analysis of prior responses.

Organizational Context

Relationships within and among organizations are relevant to the study of emergency response. As Drabek (2002a) notes, “the core of emergency management has to do with interorganizational relationships.” Within organizations, individual or group behavior may be

shaped by existing policies or protocols (Bigley and Roberts 2001). Pre-disaster organizational structures, which may be obtained from sources such as questionnaires, legislation or emergency response plans, are *planned-for*, since they are created to meet anticipated needs. Alternatively, because disasters may present unique challenges, they may also require that new organizations or organizational networks (Drabek 2002b) be formed or that existing organizations reconfigure themselves. The structure of such *unplanned-for* organizations will likely be obtained from heterogeneous and disparate data sources such as logs of communications that are channeled through an Emergency Operations Center (Quarantelli 1978; Scanlon 1994).

Social network modeling techniques may be used to describe behaviors of individuals and groups within both planned-for and unplanned-for organizations, and are thus appropriate for describing the organizational context of improvisation. As stated by Johnson-Laird (1983), "Social network models are characterized as internal symbolic representation of the world or aspects of the world. Individuals use these models to negotiate their lives, determine which actions to take, and construct the social world." They may therefore be used to characterize organizations' mental models (Johnson-Laird 1983). Social networks are typically defined by examining human behaviors such as communications and then constructing networks that enable detection of patterns in these behaviors. Possible data sources include communications logs (e.g., phone, email, memos), videotape, questionnaires, interviews and news reports. Questionnaires, for example, may be used to elicit from respondents the names of individuals with whom they had relevant discussions. Once the network is constructed, it may be analyzed to estimate the presence and strength of connections within and among organizations and to identify clusters of related organizations and individuals (Banks and Carley 1994).

Extreme events may perturb pre-disaster social networks, leading to their extension, dissolution, reconfiguration or construction. The connections among individuals that are implied by disaster plans or other data sources may then be compared to those that actually occur during the response to an actual or simulated event. Research by Kreps and Bosworth (1993) examines the extent to which responding individuals interacted with personnel within the same organized response or outside the organized response (see Muldoon, Bosworth, and Kreps 1998 for additional discussion). A study by Drabek (2002b) uses questionnaire data associated with an actual disaster to identify pre- and post-event multi-organizational networks structures, focusing on those that emerge during the response phase. An alternative approach to the use of field data is the use of data associated with a simulated emergency (Belardo, Pazer, Danko, and Wallace 1983; Drabek and Haas 1969; Gillespie and Colignon 1993). The methodology of a study by Gillespie and Colignon (1993) is one illustration of this approach. Questionnaires are administered to determine the form of the planned-for (or preparedness) network. Some of the organizations in the preparedness network then participate in a simulated response and a second questionnaire is administered to determine the form of the response network. The preparedness and response networks are then compared.

Improvisation and Planning

Preparedness for emergencies means organizing for response activities before the disaster occurs (Kreps 1991). Skill in emergency preparedness and planning is to be distinguished from skill in emergency management. As stated by Quarantelli (1987), “The latter does not follow from the former in the same sense as that good tactics do not follow directly from a good strategy.” For various reasons, contingencies arising during the emergency may require a plan to be revised. An emergency may evolve, so that existing plans are no longer applicable (Turner

1995). It may be multi-faceted, requiring responding organizations to combine many plans in unexpected ways. In a response involving numerous organizations, allocation of resources to certain tasks may make those resources unavailable for other tasks (Turner 1995). Responding to such unplanned-for contingencies may require responding organizations to develop and deploy new procedures in real-time.

Improvisation is one approach to addressing this requirement. Improvised decision making entails "reworking knowledge to produce a novel action in time to meet the requirements of the given situation" (Mendonça and Wallace 2002). Improvisation is therefore creative action in context, where the context is provided by the need to meet goals, such as mitigating economic or human losses, while satisfying time constraints. Klein states that "The need for improvisation is a continual aspect of team decision making. There can be errors of rigidly adhering to someone else's plan as well as inappropriately departing from the plan" (1993). Yet, as Weick (1993) notes in his seminal study of the Mann Gulch fire, "What we do not expect under life-threatening pressure is creativity." Indeed, there is considerable evidence to suggest that teams in decision settings like emergency management enact strategies based on recognizing characteristics of past problems in the current one (Klein 1993). A sobering conclusion of Weick's (1993) study of Mann Gulch is that, under certain conditions, teams may force their conception of the emergency to fit one they know how to address. To understand improvisation, it is therefore necessary to understand how decision makers "make do" with their existing knowledge when faced with unplanned-for contingencies.

Disaster Roles

As a practical matter, distinguishing planned from improvised behavior by response personnel requires access to plans, norms or standard operating procedures: in other words, to

valid descriptions of their behavioral expectations (i.e., their roles) (Merton 1957). Various situations may require or present opportunities for responding organizations or individuals to modify or abandon their expected roles (Webb, Beverly, McMichael, Noon, and Patterson 1998). Role performance is the dimension of role enactment that is used to describe whether a role has been followed or not (Kreps and Bosworth 1993). The reasons for departing from expected roles are varied: responsibility for addressing a contingency may not be immediately assignable to any particular organization (Scanlon 1994); personnel trained to accomplish the role may be unavailable; there may not be a role that is appropriate. An individual may of course improvise a role but follow a plan that is conventional for that role. During the response to the 2001 World Trade Center attack, for example, a group of spelunkers volunteered to aid in response efforts and were assigned to check the identification of people trying to enter a sensitive area. They performed this improvised role conventionally, by checking the identification of individuals who wanted to enter, and only admitting those who met certain criteria. When conditions such as these arise, roles may be transformed in a number of ways (Webb et al. 1998): a material role improvisation involves "changes in the tools or equipment used in the performance of disaster roles or in the physical location where those roles are enacted;" a non-material improvisation involves "changes in the things that people do or how those things are done."

Cognition in Improvisation

In seeking to understand how to plan for improvisation, it may be useful to develop methods for encoding and storing knowledge about how it is accomplished both behaviorally and cognitively. A number of methods for encoding knowledge for later retrieval are available (Hoffman, Shadbolt, Burton, and Klein 1995; Liou 1990). In a case-based reasoning system, prior situations (or cases) in which improvisation occurred might be indexed and stored for later

retrieval (Watson and Marir 1994). When an unplanned-for contingency occurs, the system must determine which case is most appropriate, since by definition no case exactly fits the contingency. The response contained in the most appropriate case must therefore be modified, creating additional challenges for decision makers.

An alternative approach, which follows from the theory of opportunistic planning, is to assemble a solution from the library of cognitive and behavioral processes contained within the system. The theory of opportunistic planning states that human problem solving is *incremental*, in that it proceeds in stages, and *opportunistic*, in that problem solvers will suspend pursuit of some goals when more pressing needs (or promising opportunities) arise (Carver and Lesser 1994). Opportunistic planning is closely akin to the "coordination by feedback" which takes place in an Emergency Operations Center (Dynes and Quarantelli 1977), where decision makers must be prepared to make decisions based on reports received from the field. The theory of opportunistic planning, as implemented in the blackboard computer architecture (Nii 1989), can be described as solution by assembly: software agents view the situation and make suggestions on how to solve all or part of the problem; a controller then decides how to mix and match the various suggestions into a course of action designed to address the situation.

Blackboard systems have been used to support or simulate decisions which require improvisation (Jagannathan, Dodhiawala, and Baum 1989; Pfleger and Hayes-Roth 1997). For example, in the Virtual Theater application (Hayes-Roth, Brownston, and van Gent 1995), a human user provides high-level directions to software-based computer characters whose task is to improvise a course of action while abiding by appropriate constraints. A character considers behaviors that satisfy the constraints and are consistent with the user’s directions and with the character’s perceptions of other characters’ actions. A controller then selects the best behavior

for the current situation. As an example, a direction to a character to "go to the pedestal" might be executed by the character through the action "hop to pedestal."

Perception, cognition and action in the blackboard system are dynamically-controlled since they can occur concurrently and asynchronously (Hayes-Roth, Pfleger, Lalanda, Morignot, and Balabanovic 1994). Hayes-Roth (1990) discusses control plans as time-ordered sequences of inputs, operators and outputs used for reasoning and decision making. A behavior embodies "the potential application of particular methods to particular tasks in particular contexts" (Hayes-Roth et al. 1994). Every behavior has one or more triggering conditions that are satisfied by particular events. A scheduler selects from triggered behaviors the one which best matches the plan (Hayes-Roth et al. 1994); an executor then performs the chosen behavior (Hayes-Roth, Brownston, and van Gent 1995). The Guardian project (Hayes-Roth 1995) is an attempt to provide intelligent patient monitoring software that can accommodate and process real-time data into recommendations on treatment strategies for emergency room patients. A number of operators (closely akin to standard procedures) are embedded in Guardian. A typical operator for Guardian is "diagnose." Diagnosis may be accomplished in a number of ways, depending, for example, on the estimated time available for undertaking the task. An input to the diagnosis operator may be current blood pressure; an output may be a clinical judgment on the at-risk level of the patient. Because planning is opportunistic, execution of an active plan can be suspended when the need arises.

A Methodology for Studying Organizationally-situated Improvisation

Disasters are social phenomena that may sometimes be addressed through improvisation by organizations and the individuals within them. It is therefore appropriate to examine improvisation as an organizationally-situated phenomenon that generates knowledge which can

be captured, encoded, analyzed and used. The methodology presented here addresses a three-fold question: where, when and how does improvisation occur in and among organizations?

- *Where* refers to the location(s) within established or *ad hoc* organizational structures in which improvisation occurs.
- *When* refers to the circumstances or conditions under which improvisation occurs.
- *How* refers to the cognitive-behavioral processes that take place during improvisation.

The proposed methodology for addressing these questions has three stages:

1. Identify social networks among responding organizations and individuals by drawing upon an analysis of reported or recorded communications;
2. Classify cases of decision making involving these personnel according to the appropriateness of plans, consistency of role and availability of decision support; and
3. Describe cognitive and behavioral processes in these cases so that improvised decision making can be better understood and supported.

Since the focus of this paper is on presenting the methodology, its full application is beyond the current scope. However, selected activities from each step are presented in order to provide suggestions on how such a full implementation might be accomplished. All examples are illustrated using data gathered following Hurricane Camille, a 1969 hurricane that at the time was the second most powerful to strike the United States, with wind velocities exceeding 200 mph and a tidal surge in excess of 24 feet (Office of Emergency Preparedness 1969). It caused extensive damage across Alabama, Mississippi, Louisiana, West Virginia, and Virginia, generating $1.4 billion of damages to the coast, killing over 300 people, injuring over 8,900 people and destroying more than 6,000 homes (Office of Emergency Preparedness 1969).

As in other disasters (Quarantelli 1997), Disaster Research Center (DRC) personnel conducted a field study of the response to Hurricane Camille that, in the months following the event, involved collection of interviews with affected personnel, as well as of other materials such as emergency response plans, after-action reports, Congressional testimony and newspaper reports. The interviews were available from DRC archives in typewritten form and amounted to approximately 270,000 words. To facilitate later analysis, all interviews were digitized and catalogued with a record number, the name and affiliation of interview subject, name of the interviewer(s) and date of the interview. Each line in each interview was numbered.

Establishing the Organizational Context

The focus of this first stage of the methodology is on determining the organizational context of improvisation using data from actual disaster response activities. It may therefore be seen to complement research discussed previously (Drabek 2002b; Gillespie and Colignon 1993; Kreps and Bosworth 1993). The context, as refelected in the social networks for the disaster, may be inferred by cataloguing reported communications that were relevant to response activities. If logs of communications are available, then there is little need to interview the actors to determine which links exist. Otherwise, recollections of actors must be relied upon. A typical social network consists of a set of nodes and a set of relations among the nodes. A node (or actor) may be an individual (i.e., an identifiable person or a functional position such as ‘police captain’) or an organization. An actor is either the speaker (i.e., sender) or addressee (i.e., receiver) of the communication.

Carley and Palmquist (1992) state that "[t]exts can be thought of as containing a portion of the author’s social/mental model at the time the text was created." Content analysis is an analytic technique that "focuses on counting what words or general concepts are present in a

text" (Carley and Palmquist 1992) and may be used to extract and analyze communications and interactions between two actors as reported in interview texts. To identify communications, the approach is first to generalize the concepts that appear in the text and then to code the set of relations among pairs of concepts (Carley 1997). A concept is "an ideational kernel, a single idea totally bereft of meaning except as it is connected to other concepts. A set of concepts is like a vocabulary or lexicon. There is presumed to be a countable and generally finite number of concepts at any one time in any one socio-cultural environment" (Carley 1997). The concepts of interest are phrases that contain words such as call, contact, request, ask, suggest, brief, phone, talk, report, message and instruction. If an identified communication was relevant to the response, then the actors who exchanged the communication are said to have had social contact, and a link is placed between them. The *parties* of the communication are the sender and the receiver of the information.

The *purpose* of a statement can be used to describe flows of information among response personnel and may be one of four types:

- Statement/Declarative: a narrative to reference a communication that has taken place between two actors.
- Question/Interrogative: contains interrogatives such as "what," "where," "how," and "when" and may contain words such as "ask" and/or "question."
- Command/Imperative: contains verbs such as "request," "perform," and "follow."
- Indeterminate: none of the above applies but a statement is evident.

It may therefore be possible to determine the *de facto* leadership structures implied by the communications among *ad hoc* and established organizations. For example, a large percentage of

command/imperative statements from one organization to another would suggest that the receiver of the commands was subordinate to the sender.

The *direction* of a communication indicates whether it traveled up, down or across (i.e., within the same level of) an organizational hierarchy, or whether it crossed organizations. Of course, crossing can occur when two individuals from different organizations communicate, two different organizations communicate, or an organization and an individual from a different organization communicate.

Finally, in the case of interview data, if the communication as reported by an interview subject involved the subject, a variable *report* is coded "yes" to indicate a first-hand report; otherwise it is coded "no."

The values of the preceding variables (parties, purpose, direction, report) define a social network denoted *Communications*, which may be depicted either as a matrix or as a graph. The (i, j)th cell in the *Communications* matrix contains the number of communications from actor i to actor j, so that senders are listed along the vertical axis and receivers are listed along the horizontal axis.

One of the primary goals in social network analysis is to identify central actors in the social network. Centrality may be defined in a number of ways (Freeman 1978/79; Wasserman and Faust 1994). Node degrees centrality accounts for the number of individuals or organizations that communicated with the actor (or counts the number of communications between the actor and individuals or organizations). Node degree-type measures may be used when examining whether some individuals or organizations are more involved in communications relevant to improvisation than others. One node degree-type measure is combined in-degree and out-degree: that is, the number of communications which an actor sent or received. (Freeman 1978/79). In

the context of organizationally-situated improvisation, social network analysis may be used to determine which actors communicated most with other organizations, and if so under what conditions, during response operations. It may be, for example, that an Emergency Response Organization communicated with a large and highly diverse set of individuals. A question which could therefore be addressed is whether central organizations engaged more often than non-central ones in improvisation.

Application: Modeling Communications among Organizations. Using Disaster Research Center interview data from Hurricane Camille, directed graphs—also known as a digraphs—may be constructed. A digraph is a graphical representation of a network whose edges are ordered pairs of vertices oriented to reflect the direction of the tie (i.e. sender vs. receiver) between two nodes (Wasserman and Faust 1994). An arrow (see Figure 1, below) indicates the direction of a communication. For this and the remaining examples, a total of 52 interviews were analyzed and 106 response personnel in more than 85 organizations identified. A total of 112 communications met the sufficiency criteria defined above (for additional tabulations, see Wong 1999).

In Figure 1, a dotted line indicates 3 or more communications; other lines represent one or two communications. The social network of organizations in Figure 1 suggests that among the senders the most central organizations were the Police Department (O4 and O80), the Emergency Operating Center (O62), the local newspaper (O20), National Guard (O10), and Civil Defense (O21 and O72). Among the receivers the most central organizations were National Guard (O10), Radio Station (O15), the Police Department (O4 and O80), the Weather Bureau (O27), and Civil Defense (O21 and O72).

Figure 1: Organization to Organization Social Network

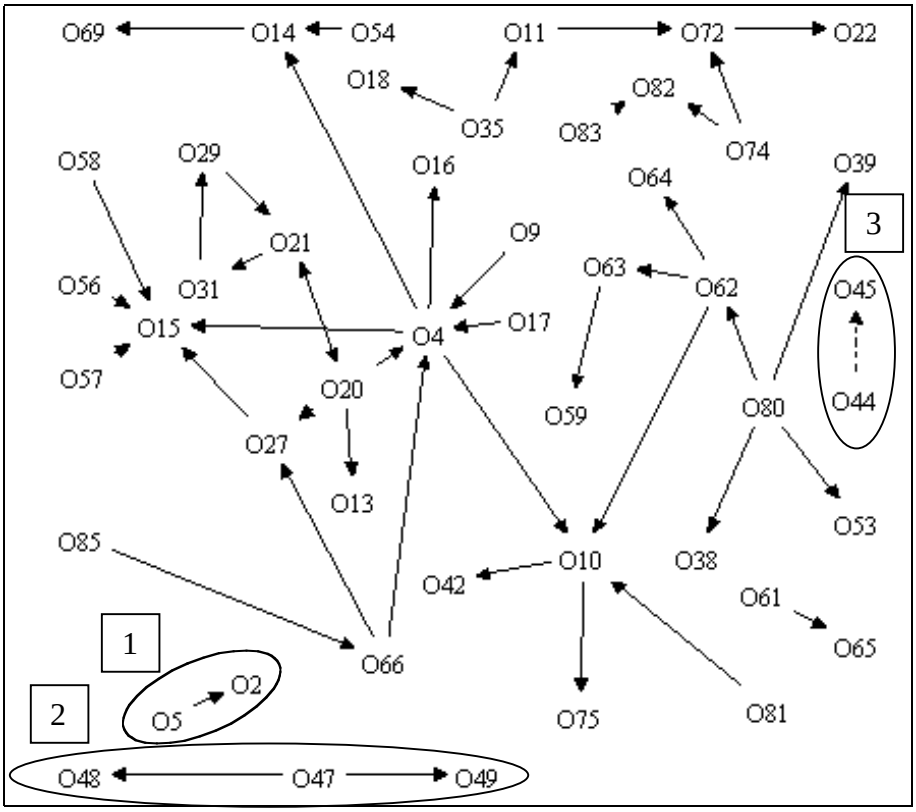

Figure 1 also shows that three isolated regions (labeled 1 through 3) are not connected to the rest of the network. These regions include region 1 of the Keesler AFB Command Center (O2) and the Air Force Base (O5), region 2 of National Warning Communication (O42), URS Research Company (O47) and the newspaper representatives (O49), and region 3 of Operations Command (O44) and County Civil Defense (O45). The isolates and disconnection are a result of communications conducted within the isolated organizations: a communication was conducted between two military posts in region 1; and between civil defense units in region 3. However region 2 suggests a different explanation that information was actually passed over to two different organizations from the National Warning Communication Center.

In addition to the visual analysis, basic matrix operations may be applied to the adjacency matrix to examine the centrality of the network. A simple measure of actor centrality is known

as degree centrality. The degree of an actor is defined as the number of vertices adjacent to a given vertex in a symmetric graph (Wasserman and Faust 1994). A more representative degree measure known as a normalized degree standardizes the degree index. The normalized degree is the degree divided by the maximum possible degree (Borgatti 1999). Table 1 lists the organizations with the highest normalized degree centrality as computed with *UCINET* 5.0 (Borgatti 1999).

Table 1: Organizations with Highest Centrality Degree

Org. No.	Organization	Degree	Normalized Degree
O4	Police Department	8	0.20
O10	National Guard	5	0.13
O15	WROA	5	0.13
O20	Mississippi Press Register	4	0.10
O62	Emergency Operating Center	4	0.10
O80	Police Department	4	0.10
O14	WCGM	3	0.08
O21	City Civil Defense	3	0.08
O27	Weather Bureau	3	0.08
O66	Sheriff Office	3	0.08
O72	Civil Defense	3	0.08

Of the organizations in the table, the Police Department, National Guard and radio station (WROA) played central roles as senders of communications since their respective normalized degree were greatest. These groups can be viewed as the ones that requested the appropriate authority for an update of the situation, announced to the public on the current condition of the Hurricane, and/or declared a curfew/warning. Among receivers, Civil Defense and a local radio station each had five communications, the Police Department had four, and the National Guard had three. These findings suggest that the community and response personnel sought information from these organizations.

Table 2 summarizes the purpose of communications with respect to direction. Most of the communications traveled across different organizations or groups, with some traveling up in the organization hierarchy. This result suggests that inter-organizational communications may

Table 2: Purpose vs. Direction of Communications

Purpose	Up	Down	Across	Over	Total
Statement/Declarative	5	1	2	19	27
Question/Imperative	1	1	0	17	19
Command/Interrogative	1	3	0	14	18
Indeterminate	5	2	0	51	58
Total	12	7	2	101	122

have been important for decision making. Improvisers acting within or among networks might therefore have interacted with others in different organizations. After the cataloguing and categorizing activities described in the following section are completed, additional analyses could be used to determine the extent of collaboration among organizations during improvised versus planned response activities.

Cataloguing and Categorizing Response Activities

Once the organizational context has been established, the next stage is to identify, describe and classify cases of emergency response decision-making. The identification and selection of cases for study is likely to arise from the particular needs of the study. Killian (2002) discuses some of the issues involved in identifying and selecting cases; Webb et al. (1998) and Kreps and Bosworth (1993) present two approaches to these activities. Case study methods (Yin 1993; Yin 1994) may be used to develop detail on the cases. Data sources that may be of use for this stage include communications logs, videotapes, questionnaires, interviews, news reports, after-action reports, testimony and emergency response plans and procedures. Classification is accomplished by applying content analysis (Carley 1990) based on keywords to the decisions

taken in the cases. Because perceptions in disasters "are even more selective and more narrow than at routine times" (Quarantelli 1997), corroborating sources may be sought in an attempt to find multiple perspectives on the same events.

Decisions in the identified cases are categorized along three dimensions: role, plan and support. The *role* dimension is used to indicate whether or not the actions are consistent with expectations for the role of the actor(s). Kreps and his colleagues (Bosworth and Kreps 1986; Kreps and Bosworth 1993) have investigated the taking on by an individual of duties that differ from those expected by the person's role. It may be desirable to extend this approach to groups or to organizations, since either may have expected role behaviors.

The *plan* dimension indicates whether an emergency response plan, standard operating procedure or the like was applicable to the decision. Documents such as disaster plans may be especially useful in identifying these procedures, though in some organizations these procedures may be unwritten but shared by members. It may therefore be necessary to supplement these documents with interviews. In considering whether or not an action followed a plan (or whether a plan applied to a particular disaster), it may be that a role improvisation occurs while a plan is being followed, since, as discussed previously, an individual may adopt a role in order to execute a decision for which a plan exists. Similarly, the framework allows classification of action not in relation to plan but consistent with role. Both of these situations are regarded as improvisational.

The *support* dimension refers to whether the decision was supported or not. Support may take various forms, such as requests for information or use of assistive technologies. This analysis complements the social network analysis done in Stage One since it identifies instances in which actors made requests of other actors (these would appear as Question/Imperative links) as well as those in which actors sought assistance through technologies such as databases.

Application: Classifying a National Guard Rescue Operation. The following example illustrates the application of the classification framework to a case (see van Epps 2001 for other examples). The data source for this step is an interview conducted with two National Guard personnel who helped manage the Guard's response operations. Line numbers are indicated in brackets (e.g. {L10570} indicates line 10570 in the transcript). This case concerns a Guard operation involving Lighter Amphibious Resupply Cargo vessels (LARCs), which are six-wheel drive vehicles capable of operating on land or water {L10598}. The case is constructed from an interview with two individuals in the National Guard: a major from the 138th Transportation Division and a state senator who was also an Acting Battalion Commander.

Before, during and after the response to Camille, the 138th Transportation Division of the National Guard conducted a number of transportation operations in connection with their evacuation and search and rescue responsibilities. The National Guard had had experience in conducting evacuation and search and rescue activities in storms (e.g., in Hurricane Betsy {L10560}, a tornado the previous year and small hurricanes "about every other year" {L10564}). Yet there was "no comparison" between these storms and Camille {L10570}. The Major noted about the Guard's storm-related activities that "Basically, the way our mission runs, is before the storm—you know, when the storm approaches—there's supposed to be evacuation. And then as it approaches it just, they evacuate and rescue." He also noted (possibly speaking about the Guard's Camille operations) that "after the storm passes—you know, that night and early the next morning when the storm passed—it's guarding. And, that basically runs, you know, the way our mission is supposed to run" {L9945-9949}.

The Guard's LARCs had not previously been used in hurricane response operations: "We didn't have them," {L10575} according to the Major, "until three years ago" {L10582}. Though

LARCs had been used by the Guard in floods for evacuation from low-lying areas {L10583}, the Major agreed with the interviewer that use of the LARCs in a hurricane "was pretty much a new experience" {L10588-10590}. Normally, they were used "to scout around in" by officers and liaisons {L10602-10603}.

Prior to the hurricane's onset, the Guard's "basic responsibility" was evacuation {L9893}. At the onset of the storm, there were sixteen LARCs "scattered out" between Ocean Springs, Biloxi, West Biloxi, North Biloxi, Gulfport, Long Beach, Pass Christian, and Bay St. Louis {L9905-9906}. The Guard was responsible for about 25 to 30 miles of coastline {L10592}.

During the hurricane, the need for LARC-type vehicles, particularly in search and rescue operations, was evident in Bay St. Louis, where non-LARC rescue vehicles were "washed out" due to water of levels of six to seven feet {L9898-9901}, so that the Guard units "were operating at a, at a great disadvantage" {L9903}. Similar situations were found elsewhere {L9916-9917}. However, owing to the severity of the winds, all Guard personnel were put on voluntary detail at about 21:00 hours {L9894-9895}. Most of the LARC units remained in the field {L9896} conducting search and rescue operations. About these operations the Senator commented that "During the height of the storm I'd say oh from seven o'clock at night 'til the storm was over and the tide receded, these people picked up over twenty-two hundred people with these LARCs, went places that trucks couldn't go. And because of high water they just picked people off tree tops, roof tops, [inaudible] one particular instance I remember they picked four people off a telephone pole, but off the roofs of automobiles and everything else" {L9909-9915}. It therefore seems that many requests for assistance were received in an *ad hoc* way. For example, a LARC

truck trying to reach one location might have stopped numerous times on the way to its destination to rescue people in need.

LARC units were able to communicate only between themselves (and then only between those with radios) and with an Army company in Ocean Springs {L9968-9970}. It should be noted, however, that the power outage in the communities reduced interference in inter-LARC radio transmissions, thereby effectively increasing transmission range {L10618-10620}. Communications with the Ocean Springs company were limited to within an approximate ten-mile radius, while the extent of the LARC unit operations was much greater {L9974}. Other limitations resulted from damage to various telephone and transmission systems (e.g., at City Hall {L10049}). Requests for assistance were sometimes sent via intermediaries (such as the police department or civil defense {L10364-10370}) to Guard dispatchers. However, the dispatches themselves would often in turn have to be sent via intermediaries to LARC units, resulting in time delays and missed opportunities. As a result, it was not possible to establish an efficient communications network linking important organizations {L9978, L9999-10016}.

Following the hurricane, approximately six LARCs were kept in the field for roughly nine days {L9931}. Their primary responsibility was to recover bodies from Bay of Biloxi and Bay of St. Louis and from coastal areas that were inaccessible by land or foot {L9924-9927}. LARCs do not seem to have been involved in the guarding operations.

The case is classified as *unsupported, unplanned, role-following*. It is *unplanned* since the Guard had never used LARCs in hurricane-related operations. Moreover, though the Guard had trained with LARCs, they were normally used for scouting operations by officers and liaisons following floods. It should also be noted that one unplanned-for contingency—power outages in nearby communities reducing radio interference—actually improved the capability of

LARCs to communicate with each other via radio. Finally, the use of intermediaries to send messages to Guard dispatchers with requests for assistance seems to have been unplanned. So, while the Guard's actions were consistent with their planned-for objective (in this case, post-storm search and rescue), the actions were executed in a novel way under unplanned-for conditions.

Guard activities were *unsupported* since communications with other agencies were severely limited due to breakdowns in the communications system. Although requests for assistance were sent, there were time delays and missed opportunities in receiving them. Even among the LARCs themselves, only those which had radios could communicate with each other.

LARC operators were *role-following*, since their activities were consistent with the LARC unit's role (e.g., search and rescue), though they were executed in a novel way under unplanned-for conditions. Interview subjects also noted that some prior experiences were relevant to the response.

Modeling Decision Making

The final stage of the methodology is to describe individual-level behavior and cognition and to store these descriptions in a computer-readable format. Modeling the cognition of disaster response personnel serves two purposes. First, formal models may contribute to the construction of a logic for supporting improvised decision making (Mendonça and Wallace 2002). Second, a catalog of cognition and behavior in emergency response could be used in training and simulation (Deng 1996; Dutta, Wiergenga, and Dalebout 1997; Watson and Marir 1994). The method applied here for encoding knowledge is based on a process-tracing technique used for describing cognition and behavior in human and computer agents (Hayes-Roth 1990) and

introduced in Section 2. Other techniques are also available (Cooke 1994; Hoffman, Crandall, and Shadbolt 1998).

Application: Modeling a National Guard Rescue Operation. The previous example of National Guard activities suggests why the theory of opportunistic planning is appropriate for describing emergency response decision making. Search and rescue operations were normally accomplished by non-LARC rescue vehicles, but these could not operate in high-water conditions. LARCs were then used as substitute vehicles, allowing Guard personnel to add functionality to their search and rescue operations, but also enabling them to respond opportunistically when they encountered stranded people in other inaccessible locations (e.g. roof tops and tree tops). In another aspect of opportunism, a LARC traveling to one location might stop to rescue stranded people it encountered along the way. Because Guard personnel were able to behave opportunistically, procedures could be developed and deployed nearly concurrently.

To illustrate how knowledge gleaned from the example may be encoded, decision making can be described in two parts, as shown in Figure 2. First, a process trace (Carroll and Johnson 1990; Woods 1993) describes the signals which decision makers received and the behaviors in which they engaged. Second, for a portion of the process trace, an hypothesized control plan is given which summarizes the tasks undertaken (i.e., the operators which were applied) as self-reported in the case, as well as the input to and output from each task (shown, respectively, as the first and second items in parentheses). The control plan is therefore a theory about the decision processes employed by response personnel.

Figure 2: Process Trace and Control Plan for Rescue Operation

Index	Process Trace	Control Plan
1	Evacuation and rescue operations begin in response to storm warnings	interpret sign(storm warning, begin evacuation and rescue)
2	Non-LARC rescue vehicles cannot be operated due to high water levels	implement plan(begin rescue, dispatch rescue vehicles) diagnose(high water, non-LARC vehicles infeasible)
3	LARCs dispatched for search and rescue	plan treatment(high water and stranded people, find amphibious rescue vehicles) implement treatment(find amphibious rescue vehicles, dispatch LARCs)
4	Some communications capabilities reduced	interpret sign(communications capability reduced, long-distance radio use limited)
5	Some communications capabilities enhanced	interpret sign(communications capability reduced, short-distance radio use enhanced)
6	Stranded people found	suspend plan(current search and rescue, new search and rescue) implement plan(new search and rescue, rescued persons)
7	Communications undertaken via intermediaries	plan treatment(long-distance radio use limited, alternative communications plan needed) implement treatment(alternative communications plan, short-distance radio transmissions)
8	Storm ends	interpret sign(clear weather, storm over)
9	LARCs recover bodies	plan treatment(persons missing, patrol area) implement treatment(patrol area, dispatch LARCs)
10	Operation concludes	

A decision aid in a similar situation might seek an output (such as `find amphibious rescue vehicles` at Index 3) that results in a feasible course of action (such as `dispatch LARCs` at Index 3 or `dispatch patrol boats`). Either of these would be an improvisation—in the form of a material equipment change (Webb et al. 1998)—from the standard operating procedure of using a conventional vehicle such as a Jeep. By extension, improvisation may therefore seen as involving any of the following:

(i.) the use of novel inputs for existing operators,

(ii.) the production of new outputs from existing inputs and operators or

(iii.) the development of new operators.

Both (i) and (ii) may be considered improvisation by substitution, a type of mix-and-match that is similar to a material improvisation. The third type is similar to a non-material improvisation and requires the decision maker to create new processes and to decide on which inputs and outputs are associated with it.

The methodology proposed by Hayes-Roth and colleagues is useful as a modeling tool, particularly for identifying and defining improvisation, but some limitations on its implementation using unstructured interview data should be noted. The imputation of cognitive processes may be difficult, since established methods of knowledge elicitation were not used in the interviews. The use of this data set also presents challenges to model-fitting, since many of the original interview subjects are unavailable for follow-up interviews, and even if available will likely have forgotten many important details. Finally, missing from this transcript and others are precise statements about the timing and duration of events, both of which are important to studies of improvisation (Weick 1997). It may be possible to draw upon other experts—even after the event has occurred—for help in defining the behaviors to be encoded.

Discussion

Because disasters are social phenomena, organizational context may impact where, when and how improvisation occurs. In order to gain insight into how organizational context may shape improvisation, a three-stage methodology has been proposed. In Stage One, organizational context is described by depicting social networks both before and after the onset of an extreme event. By identifying and classifying response activities—particularly improvised activities—in Stage Two, researchers may then begin to understand how pre- and post-event social structures

impact role performance under planned-for and unplanned-for conditions. Beyond social structure, the methodology also considers whether response personnel sought support, such as might be provided by a computer-based system. Finally, in Stage Three, knowledge associated with response activities may be encoded in computer-readable format both to expand theory of cognition in improvisation and to provide appropriate support to responding organizations in future disasters. The methodology therefore describes the context in which improvisation occurs and then, through progressive detailing, the characteristics of decision-making and decision makers' cognition in this context.

The methodology suggests how and what types of data may be collected to support inquiry into where, when and how improvisation occurs during response activities:

In Stage One, communication logs—perhaps collected in accordance with policy or regulation—may be available and prove more reliable than interview subjects' memories. Logs also allow researchers to identify the timing and parties of communications, thus creating a more complete picture of the social network at the time of important decisions. Additionally, the example of social network structure during the response to Hurricane Camille illustrates a benefit of using digitized descriptions of communications. The process of preparing hard-copy data for analysis may be time-intensive. Perhaps more importantly, availability of objective records of communications such as memos and phone logs may allow researchers more easily to sample randomly rather than opportunistically, thus strengthening the validity of research conclusions.

In Stage Two, description and classification of decision making episodes could benefit from the use of structured questionnaires, as has been done outside the domain of disaster research (Moorman and Miner 1998), as well as from the analysis of after-action reports or on-scene reports, such as may be gathered in military training situations.

In Stage Three, modeling cognition and behavior in improvisation will almost certainly require the collection of more detailed data—as could be provided through concurrent or retrospective verbal protocol techniques (Ericsson and Simon 1993)—gathered for the purpose of describing cognitive processes during the response to extreme events.

Conclusion

Field research on disasters and other extreme events poses a number of challenges to those seeking to understand these events, be they researchers or responding organizations. As stated in a recently-published compendium of papers on methodologies for disaster research, Stallings (2002) notes that "What makes disaster research unique is the *circumstances* in which otherwise conventional methods are employed. Put differently, it is the *context* of research not the methods of research that makes disaster research unique." The focus of this paper is on a context (organizationally-situated), a behavior (improvisation) and a phase of the disaster process (response to an extreme event). The approach of the methodology begins with a question of *where* in order to discover the organizational context of improvisation, then proceeds to *when* to describe the conditions under which improvisation occurs, and finally describes *how* cognition and behavior took place during improvisation. The knowledge to be gained by the proposed approach is intended to lead to increased understanding of how improvisation as a response to extreme events may be observed, planned-for and supported.

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