Cause and Effect: A Qualitative Analysis of Obstacles to Information Sharing During a Regional Disaster Exercise

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ABSTRACT

After large-scale disasters, diverse partner agencies rely heavily on an information-sharing environment that supports collaborative work. In the U.S., this occurs under the Incident Command System (ICS), a structured organizational framework for coordinated action. We explore obstacles to information sharing and coordination observed at a county-level Emergency Operations Center (EOC) operating under ICS during the response phase of a large-scale regional disaster exercise. Textual observations collected in situ are analyzed for both the effect/manifestation and cause/source of barriers to information sharing. Two-thirds of barriers that manifest as computational issues are not caused by technology breakdowns, and a third caused by unclear processes manifest as computational issues. Overall, obstacles to collaborative work that appear to be related to computational issues are generally attributable to non-technical causes. This indicates that resources directed at improving collaborative management of disasters by enhancing technological capabilities are likely to be misdirected.

Keywords

Information Sharing; Disaster Response; Qualitative Analysis; Collaboration; Coordination

INTRODUCTION

Collaborative action during and after large-scale disasters is characterized by complexity, uncertainty, and the need for information. To achieve effective collaboration, independent yet partner agencies and organizations, each with their own jurisdictions, practices, policies, technologies, missions, and cultures, need to coordinate and share information. These independent and diverse partner agencies rely heavily on an information-sharing environment that supports collaborative work. In the U.S., this occurs under the Incident Command System (ICS), developed after 9/11 as a structured organizational framework for coordinated action. Although management of a disaster has numerous facets, a critical component is the capability of diverse federal, state, local, tribal, territorial, international, and private sector (FSLTTIP) entities to share information for activities such as damage assessment and response, asset requesting and tracking, and situational awareness. It is this information-sharing component, and the interoperability of the systems to support these activities, that is the focus of this paper.

In June 2016, Cascadia Rising, the largest regional disaster response exercise ever conducted in the Pacific Northwest took place. This multi-state, international response to a massive earthquake and tsunami scenario provided the opportunity to observe the information sharing and interoperability among multiple partners during a complex, dynamic, non-routine event. Students were trained to conduct fieldwork study observations of emergency operations and coordination centers (EOCs/ECCs) as they activated to conduct and coordinate simulated field response operations both within their jurisdictions and with neighboring communities, state EOCs, Federal Emergency Management Agency (FEMA), and major military commands. Field study observations were conducted at state and county locations, providing an opportunity for analysis of information sharing and interoperability issues. Here we focus on a county EOC engaged in disaster response.

Prior work on information sharing during disaster response has tended to focus on the technological challenges, highlighting the technical issues that enable or inhibit information sharing, and viewing additional technology as the solution (Allen et al., 2014; Maitland et al., 2009; Reddy et al., 2009). Some researchers have investigated disaster response from an organizational perspective (Bharosa et al., 2010; Lee et al., 2011); however, there is still a preference for the development of information technologies to support the collaborative processes (Allen et al., 2014) rather than addressing the coordination of emergent groups during non-routine events characterized by complexity and uncertainty.

Based on previous studies (Haselkorn et al., 2014, 2015, 2016), we hypothesized that during the large-scale disaster exercise we would observe considerable informal information sharing as well as obstacles to information sharing that were not caused by technology, although they might manifest themselves that way. We posited that the uncertainty and complexity that characterizes non-routine events, even operating under ICS, would produce many obstacles to information sharing associated with human, organizational, and process issues. In this paper we unpack the symptoms that we observed and identify the etiology of the issues, thus allowing us to make suggestions to improve coordination and information sharing during the response phase of a disaster.

This paper is organized as follows: first, we briefly describe ICS and the exercise upon which this qualitative analysis is based; second, we review the relevant literature relating to information sharing and interoperability challenges unique to disaster events; third, we review our methods, including the development of a framework and management tool that supported qualitative analysis of information sharing during disaster response; fourth, we describe and discuss our results; and finally, we discuss the implications of our results and present additional research opportunities. Our analysis shows that the majority of barriers that manifest themselves as computational issues are, in fact, often due to a different underlying cause. This has implications for stakeholders, decision-makers, and practitioners working in disaster response roles, providing insight into more effective allocation of funds/resources to solve the relevant underlying issues, rather than those that may not be as problematic as previously assumed.

BACKGROUND

Disaster Response

A key element of disaster response in the U.S. post 9/11 is the ICS, a structured management framework for meeting the demands of small or large emergency situations (Department of Homeland Security 2008: 45-46). The ICS and its overarching plan, the National Incident Management System (NIMS), are mandated for use by all agencies that receive federal preparedness grants in the management of domestic incidents—which effectively means that the ICS will be activated in all emergencies (Dawes et al., 2004).

In the event of an emergency in the state of Washington, the ICS is implemented through EOCs—physical locations staffed by personnel who are structured according to the ICS. When incidents occur, they are typically managed at the lowest possible geographical, organizational, and jurisdictional levels—jurisdictions, working in collaboration with county and other local emergency management agencies, provide the initial response to the local incident. It is expected that local (city, county) departments assess what has happened in their area, including what is needed in terms of resources and action, and report this to the local EOC. In situations where the capacities or resources that are required exceed what the local jurisdictions can provide, the local jurisdiction may request assistance from the State Governor by proclaiming a local state of emergency. Depending on the scale of the disaster, the Governor may follow up with a State Proclamation of Emergency, initiating applying ICS at the state level, leading to the activation of a State EOC (SEOC) in order to respond to impending or existing disasters and emergencies. The proclamation by the Governor is a prerequisite for access to the full range of federal disaster recovery programs available to the state. Once established, the Washington SEOC supports state agency, local jurisdiction, and tribal nation operations in response to an emergency or disaster. The primary roles of the (S)EOC are to communicate, coordinate, dispatch, and track resources, and to collect, analyze, and disseminate information. At all levels, the ICS structure is designed to offer scalable components that function at a level consistent with the complexity of an event (Washington State 2008).

CASCADIA RISING: REGIONAL DISASTER EXERCISE

The four-day-long Cascadia Rising Disaster Exercise of June 2016 simulated the challenges and issues that would be faced in the event of a regional catastrophic earthquake. The scenario for the exercise was the most complex disaster scenario that emergency management and public safety officials in the Pacific Northwest could face—a Magnitude 9.0 subduction zone earthquake along the Cascadia Subduction Zone, followed just minutes later by a 100-foot tsunami:

> *"In the early morning hours (PDT) on June 7, 2016, a 9.0 magnitude earthquake resulting in the complete rupture of the 700-mile Cascadia Subduction Zone fault line occurs. The duration of the earthquake lasts over four minutes. The affected area encompasses 140,000 square miles directly impacting the states of Oregon and Washington and the Canadian province of British Columbia. Over 10 million people reside in the direct impact zone. The disaster causes widespread damage to critical infrastructures and the built environment and causes thousands of deaths and injuries."* (FEMA 2010)

Cascadia Rising was a multi-state effort involving agencies across the FSLTTIP. In Washington state, the main exercise was led by the Washington State Emergency Management Division. Exercise participants entered into an ICS structure to simulate the disaster response phase and engage in numerous post-disaster missions, many involving complex information-sharing scenarios, such as the introduction of assets from the federal government, the requesting of those assets by county EOCs through the SEOC, and the tracking of those assets by the SEOC and Washington Army National Guard (WANG). Each EOC was required to fully activate and staff their respective operations to manage disaster response within their jurisdiction while simultaneously coordinating with other EOCs and departments, agencies, and simulated first responders to meet exercise objectives.

A primary goal of Cascadia Rising was to test the effective coordination and integration of government agencies at all levels, working with the military, tribal nations, non-government organizations, and the private sector. Of particular interest were the core capabilities that enable this diverse community to conduct complex disaster operations as a unified team.

At the local and state level, one focus was the handling of resource requests and resource tracking during emergent and complex events. Of particular interest to organizers was the use of two internet-based information management systems intended to support these activities: (1) WebEOC—a mature system implemented with diverse configurations across many, but not all, of the participating agencies, and (2) the Washington Information Sharing Environment (WISE)—a more recent system, developed and used by the WANG to gather and make visible event-related information.

RELATED WORK

Coordination can broadly be defined as the "act of working together harmoniously" (Malone and Crowston 1990), and it is therefore central to work in organizations (Abraham and Reddy 2008). In proposing their coordination theory, Malone and Crowston (1990) described how effective coordination is invisible—it is poor coordination that becomes apparent and that we can observe. Coordination has been studied in various contexts in the literature, for example in hospital settings (Abraham and Reddy 2008), in geographically distributed research and development teams (Hinds and McGrath 2006), and in families (Leshed et al., 2014). Coordination in emergency management deals with specific challenges to information sharing according to the nature of emergency response. Characteristics, complexities, and obstacles in information sharing during emergency response have been extensively studied by Information Systems for Crisis Response and Management (ISCRAM) scholars and examined from various points of view (Barr et al., 2011; Gryszkiewicz and Chen 2010; Hellingrath and Widera 2011; Maitland et al., 2009; Scholl and Carnes 2017; Wikberg et al., 2017). Maitland et al. (2009) considered and compared information management barriers and information technology issues and identified their similarities and differences and requirements for resolving them. Gryszkiewicz and Chen (2010) proposed design requirements for information sharing in crisis management through semi-structured interviews with emergency managers in Sweden. Scholl and Carnes (2017) identified managerial challenges experienced by emergency responders and participants in the 2014 Oso/State Route 530 landslide disaster.

Non-routine events such as large-scale disasters are synonymous with uncertainty, and characterized by their complexity, the need for information, and the speed at which decisions need to be made (Allen et al., 2014).

Mendonça et al. (2007) suggest several key characteristics of disaster management: First, the incidents occur relatively rarely, which limits the opportunities for training. Second, time constraints during an event leads to the convergence of planning and execution. Third, there is uncertainty as the evolution of the situation is unpredictable. Fourth, there is a need to manage interdependencies within a wide range of physical and social systems. And fifth, multiple decision-makers, groups, and organizations will need to come together and negotiate while also responding to the event. Such large-scale events necessitate collaboration and coordination among multiple organizations because integrated information must be available in a timely fashion (Reuter et al., 2015).

At such times, organizations, each with their own distinct mission, culture, and working practices and which work far more independently on a daily basis, are expected and required to collaborate and coordinate, share information, and align under a common command structure. Although a mechanism such as the ICS provides such a structure and is in fact mandated in the U.S., other scholars point to the fallacy of applying a military-style structure in response to an incident, feeling that such an approach overlooks the need for collaboration, cooperation, and transparency by numerous organizations with different cultures and structures (Mendonça et al., 2007).

Empirical studies into coordination and information sharing during disaster response have tended to focus on technological challenges, giving less attention to the organizational aspects or coordination and information-sharing practices and policies. Such studies highlight technical issues that enable or inhibit coordination and information sharing, viewing technology as the solution (Allen et al., 2014; Maitland et al., 2009; Reddy et al., 2009). There has been a recent trend to investigate the organizational and social aspects of disaster response (Bharosa et al., 2010; Ley et al., 2014; Reuter et al., 2015). Nevertheless, the refinement of collaborative and coordination practices that are facilitated by information technologies is often overlooked in favor of the development of new or additional information technologies to support the collaborative processes (Allen et al., 2014).

Through observations of first responder exercises, Manoj and Baker (2007) identified three categories of communication challenges in emergency response: (1) technological—the challenges faced by the rapid deployment of interoperable communication networks after a disaster; (2) sociological—the challenges of obtaining and sharing information among ephemeral groups that are brought together in unfamiliar settings and times of uncertainty; and (3) organizational—challenges that arise due to the changes in management and decision-making frameworks that occur during a disaster. Although Manoj and Baker's work (2007) specifically examined the barriers to communication during disaster response, the technological and organizational categories provide a useful lens through which to look at interoperability and barriers to information sharing during non-routine operations and disaster response.

Technological Approaches

In the aftermath of the September 11, 2001, attacks in New York, the 9/11 Commission emphasized the importance of integrated, all-source information, and pointed out the U.S. failure to "connect the dots." This led to a focus on numerous technological approaches, such as: more and varied sensors to gather data, communication devices and networks to move that data, common operating pictures and visual analytics systems to help make sense of that data, dispatch systems to mobilize based on the situational awareness, and asset request and tracking systems to support the mobilization. The hope was that a single "killer app" incorporating all these capabilities would be used by all the relevant agencies, putting everyone on the same page in support of collaborative effort. (*Virtual USA* was an example of the Department of Homeland Security attempting such an effort.) In recent years, federal stakeholders have accepted that, for reasons that are often not technical in nature, it is unlikely that all relevant agencies and partners will adopt a single application, no matter how effective. This has led to the latest technological challenge—a distributed architecture that focuses on technical interoperability in order to link sensors, share data, and allow each partner agency to use whatever application they desire to make use of that data.

Technological approaches like these have been prevalent in the literature on improving EOC communication. For example, Dawes et al. (2004) focus on critical infrastructure damage after 9/11, and Graves (2002) explores the increased complexity of information technology and the need to integrate these technologies and devise contingencies for them in the face of disasters (Brooks et al., 2013). Similarly, Militello et al. (2007) view collaboration infrastructure to support post-disaster practices from the perspective of keeping technology functional, pointing out that updating shared displays are some of the first tasks to be neglected—particularly if the systems are not used outside of disaster response operations.

Organizational and Process Approaches

During disaster response, the ICS framework alters the day-to-day working practices of government agencies and organizations in the profit and non-profit sectors. It has long been established that "every emergency is local" (Dynes et al., 1972) and the ICS is often initially activated at the lowest geographical, organizational, and jurisdictional level. However, since the majority of the funding for large-scale disasters comes from the federal government, tensions between local and federal participants may inhibit information sharing and require state-level participants to mediate tensions while also dealing with the local aspects of the emergency (Brooks et al., 2013).

Haselkorn et al. (2014, 2015) and Timmons (2007) found that at the individual level, first responders tend to revert to their normal information-sharing practices during times of crisis rather than modify their practices to align with the crisis response framework (i.e., ICS) (Brooks et al., 2013). This "normal" sharing is often described as "informal" communication—relying on personal contacts and existing trust relationships—as opposed to formal communication coming through the predesignated command structure and mediated by government information systems. In Norway, which adopts an equivalent structure to ICS, Rimstad et al. (2014) studied the information flows during the response to the 2011 terrorist attacks in Oslo and on the island of Utoya. Despite the formal organizational structure imposed by the ICS equivalent, important information was also obtained through personal social networking between responders. Similar informal communications were observed by Bharosa et al. (2010) with personal phone calls among Dutch responders facilitating information flows during a crisis response exercise. Schraagen et al. (2010) examined information sharing during crisis management and compared rapidity and accuracy of information sharing between hierarchical and network team organizations through a control experiment (Altay and Labonte 2014). They concluded that network teams were faster, more accurate, and shared more information in difficult scenarios.

Organizational challenges also arise when the plans laid out in emergency response documents are not sufficient or suitable to deal with a specific situation that may arise post-disaster. For example, through analysis of multiple emergency response exercises, Brooks et al. (2013) found that emergency managers were often repairing disrupted organizational routines by bridging unforeseen gaps in the emergency response plans. Here we can draw parallels with Suchman's *Plans and Situated Actions* (Suchman 1987, 2006) whereby there is a difference between the plans that are made in advance and the actions that are required *in situ* at a particular time—although the plans and processes exist, the situations are dynamic and reliant upon interdependence between heterogeneous organizations. Consequently, it is impossible to plan for all contingencies and a degree of ongoing improvisation is necessary (Reuter et al., 2015). The value of emergency response planning is the thought that goes into it, but plans cannot guide a specific action during a specific event—preparedness is best achieved through practice of the plans and their contingencies (Dawes et al., 2004). Mendonça et al. (2007) view improvisation from the technological perspective, using the term *emergent interoperability* to describe the information technologies that need to be "mixed and matched" to support the accomplishment of disaster response tasks by individuals who are part of various organizations each with their own distinct practices and adhocracies.

This background information and our own work identify many obstacles to information sharing associated with human, technological, organizational, and process issues. The Cascadia Rising exercise provided us with the opportunity to directly observe the obstacles to information sharing. Then, using a qualitative analysis approach, we unpacked the symptoms that we observed and identified the etiology of the issues, allowing us to suggest improvements to coordination and information sharing during disaster response.

METHODS

Data Collection

Supporting Researchers in Multiple Roles

The decision to study a multi-state, multi-actor, multi-location, large-scale exercise brought several opportunities and challenges. Our research design had to: (1) be unobtrusive by allowing our researchers to perform within the exercise as observers and evaluators—pre-defined accepted roles within such exercises; (2) obtain rich text and contextual data that would support post-event analysis useful to a diverse group of faculty and research scientists; and (3) capture work and information sharing across multiple sites. With strong support from the Washington State exercise team,[1] our researchers were included on the exercise evaluation team, attended exercise training sessions, and were embedded at a number of key state and local sites. To prepare for the pre-defined role of observer/evaluator, research team members without prior emergency management

[1] Special thanks to Ed Taylor, State Exercise Program Manager, and Jason McMillan, Kitsap County Operations Coordinator.

experience were required to meet minimum qualifications set by FEMA, illustrating a basic knowledge of emergency management. All observers completed the 100, 200, and 300-level ICS online training, and attended a day-long training at the SEOC. In this way, our team was able to contribute to the state's After-Action Report (AAR), the mechanism for sharing lessons learned across the emergency management community.

Fieldnote Jotting Through Slack

We used *Slack*, a communication and messaging tool popular with small and medium sized companies (Benner 2017), for capturing real-time observations and for more general coordination among field observers. Slack "channels," visually distinct conversation threads, were set up prior to the exercise for each location with a team member.

One experienced field researcher trained in ethnographic field work was deployed to Kitsap County. In the course of the exercise where many people were working on computers, she found it was unobtrusive to make fieldnote jottings on her computer as events unfolded (Emerson et al., 1996). It was then easy to paste fieldnote jottings into the Slack channel for her county at brief and regular intervals. This had two unexpected advantages. First, Slack has searchable archiving features built in, making it relatively easy to work with the data repository. Second, researchers at multiple sites—and from multiple disciplines—were able follow data collection in near real time. In several instances this led to tracking and follow-up clarification (i.e., better documentation) as information moved (or not) across exercise sites. Importantly, it also led to data collection of more depth and more diverse topics, as remote researchers with different interests requested follow-up information on events as they occurred.

Qualitative Analysis Approach

The qualitative analysis reported here focused on the Slack-recorded observations from the one trained field researcher at the *Kitsap County EOC*. Prior to coding of these observations all names of emergency response personnel participating in the exercise were anonymized to protect their identities. While Slack is an online tool its security program is aligned with ISO 27000, AICPA Trust Service Principles, and NIST standards. All data in transit and at rest is encrypted and only trained students and faculty were granted access to Slack channels related to the Cascadia Rising Exercise. A research group of graduate and undergraduate students met weekly for two quarters (20 weeks) to learn and then conduct the process of qualitative data analysis using the Kitsap EOC observations. To better understand the observations of the activities at the county EOC, all class participants completed the 100-level ICS online training. A team of four—one undergraduate student, two graduate students, and one university research scientist—was selected to form the coding team. The analysis of the Kitsap field notes began with an initial reading of the observations, as recorded, to familiarize the four analysts with the substance of the data, understand the flow of communication and information sharing activity within the Kitsap County EOC, and begin to identify recurring themes (Strauss and Corbin 2008). The four analysts worked individually and then jointly on close readings of the observations to identify text blocks representing incidents of information sharing or other coordination activities performed by the exercise participants. This allowed the researchers to reduce the data to only those portions of text related to the exercise, which facilitated the coding process described below.

The team began the exploratory, open-coding analysis by iteratively going through data, asking questions, and making comparisons to develop a common understanding of the observations and to identify the emerging themes (Strauss and Corbin 2008). The first theme to develop resulted from asking the question, "what happened?" In other words, "what is the effect or manifestation of the information sharing barrier that was observed?" Merriam-Webster defines an effect as "something that inevitably follows an antecedent (such as a cause or agent). Similarly, asking questions, such as "how" or "why" the effect occurred was used to determine the cause or source of the observed effect. One way to think about the cause-effect relationship between the information sharing breakdowns is to consider the genotype-phenotype relationship (Hollnagel & Marsden, 1996). The effect, like the phenotype, is observable; while the genotype, like the cause, can only be inferred. In this analysis, we first identified the observable barriers of information sharing breakdowns as "effect", then during the iterative, open-coding analysis, we divided the effect theme into seven different categories (see Table 1). When developing the categories for the "cause" theme, we found that while potential causes of information sharing breakdowns are different from the observable (effect) resulting from information sharing breakdowns, we could use the same categories. Accordingly, the cause/source theme used the same codebook, but this time it was used to infer possible causes behind the observed barriers. In some cases, cause and effect were coded similarly which means the observed barrier (effect) was caused from similar category. For example, Observation #11 ("*Planning GIS is trying to create a damage map, but there is a technical issue due to a recent update.*") was coded by computational mechanism issue as effect, while more investigation showed that the source of this observation is computational mechanism issue too. The above process occurred over several weeks, with all team members refining and agreeing upon the codes to be used in the analysis for classifying causes and effects of barriers to information sharing.

Qualitative Analysis Tool

To support the closed coding (using the coding scheme), one of the analysts designed and created programmed Excel spreadsheets, named Code Wizard, to support collaborative qualitative coding (Ganji et al. 2018). Code Wizard consists of two main spreadsheets: one for individual coding performed by coders individually and independently, and one for aggregating coded data for team discussion meetings. Code Wizard, which was evolved during the study, provided the following benefits: (1) minimized training for coders to perform collaborative coding; (2) allowed the team to easily modify, remove, or add a selected barrier; (3) enabled real-time changes during discussion sessions; (4) provided insights into the reasons behind coders' disagreements to be discussed in weekly discussion meetings; and (5) accelerated the agreement level of coded issues by assigning different colors to the categories, allowing the agreement to be easily visualized (See more details in Ganji et al. 2018). Figure 1 presents a sample of the spreadsheet used by each of the analysts.

	Time/ Date	Unit of Analysis	Link to Source	Categories	
				Cause	Effect
1	10:08 6/7/16	It is not clear if the information is from a citizen or someone else.	go to	Paper Mechanism Issue	Source Breakdown
2	10:08 6/7/16	The agency that the information is coming from is not on the form.	go to	Paper Mechanism Issue	Source Breakdown
3	10:08 6/7/16	I ask about this and the player shows me other written forms that similarly require a lot of guessing because the way they are filled out is vague.	go to	Content Breakdown	Content Breakdown
4	10:20 6/7/16	One of the planning team goes to track down who handed off two confusing paper information forms. Guesses are made based on pen color and handwriting as to who to talk to.	go to	Source Breakdown	Content Breakdown

Figure 1. Qualitative Analysis Tool (individual spreadsheet) Used by Each Analyst to Code the Data

Once all four analysts coded the Slack data, results were merged into one spreadsheet showing the codes assigned by each analyst (see Figure 2). The merged spreadsheet was also designed to calculate Fleiss' kappa (Fleiss et al., 1969) as a statistical index for evaluating the inter-rater reliability coefficient of investigated text data. Using this merged spreadsheet, the coding team met weekly to review and discuss coding choices, allowing analysts to ask questions, make comparisons, and iterate until they achieved an inter-rater reliability of $\kappa = 0.80$[2]. The team conducted coding data in two steps. First, the analysts coded data for the effect theme in three rounds of coding to meet the acceptable inter-rater reliability threshold. Second, two rounds of coding were performed similarly to identify types of causes/sources to achieve our threshold. The themes that emerged from our analysis are detailed below and include excerpts of the observations to illustrate findings.

[2] Although there is no general agreement on a minimum Fleiss' kappa value for a strong consensus, exceeding 0.8 is widely considered as "almost perfect agreement" in the literature [14].

	Time	Unit of Analysis	Help? Codebook / Link to Source	Coder 1 Primary	Coder 2 Primary	Coder 3 Primary	Coder 4 Primary	Agreement (Pi)
1	10:08 6/7/16	It is not clear if the information is from a citizen or someone else.	go to	SB	SB	SB	SB	1.00
2	10:08 6/7/16	The agency that the information is coming from is not on the form.	go to	CT	SB	SB	CT	0.33
3	10:08 6/7/16	I ask about this and the player shows me other written forms that similarly require a lot of guessing because the way they are filled out is vague.	go to	CT	CT	CT	CT	1.00
4	10:20 6/7/16	One of the planning team goes to track down who handed off two confusing paper information forms. Guesses are made based on pen color and handwriting as to who to talk to.	go to	CT	CT	PM	PM	0.50
5	10:20 6/7/16	Another confusing message doesn't have a log number from the message center, so it was not routed through the center. So, the planning players are unsure who to go back and get information from.	go to	CT	CT	PM	SB	0.17

Figure 2. Qualitative Analysis Tool (merged spreadsheet) Used to Discuss Coding Choices by all Analysts and Achieve Agreement

RESULTS

Our analysis revealed that observations recorded during two days of the Cascadia Rising regional disaster exercise at Kitsap County represented 45 issues or breakdowns in cooperation and information sharing. Further analysis found that these issues could be coded using seven categories for both effect (i.e., how the issue manifested) and cause (i.e., the source of the issue). See Table 1 for the seven categories used to code the issues as causes and effects.

Category	Definition
Computational Mechanism Issue (CM)	Perhaps poorly designed computer-based form or system
Content Breakdown (CT)	Unclear or incomplete content; missing information
Coordination Breakdown (CD)	Individuals/groups knew the process, but process did not work, or they did not follow it
Interoperability (IO)	Systems do not work well together, may occur when two systems have two different standards
Paper Mechanism Issue (PM)	Paper form not working, perhaps due to poor design or missing information
Source Breakdown (SB)	Source not identified; whenever we think something went wrong regardless of paper or system
Unclear Process (UP)	People unsure how to do things due to unclear or undocumented process including the lack of training

Table 1: Classification System and Definitions developed to identify cause-effect relationships of information sharing

breakdowns

Almost half of all obstacles to information sharing were coded as manifesting as either computer system issues (13) or coordination issues (9), while coordination issues (10) and unclear processes (12) were coded as the actual cause of almost half of all information-sharing breakdowns. Very few breakdowns manifested as issues with paper mechanisms (1), while content (2) and information source issues (2) caused very few breakdowns.

Table 2 shows those observations manifesting as computational mechanisms issues[3]. Unclear processes were the cause of four of these 13 issues. Upon first reading, these issues may appear to be caused solely by a technical issue. For example, Observation #14 includes several mentions of technology (e.g., "multiple systems", "GIS", and "Adobe PDF viewer"). However, looking beyond these surface detail and examining additional text that preceded and followed Observation #14, the coders classified the cause as an "unclear process," explaining that if exercise participants understood how and which systems to use, the inability to coordinate and share information may have been overcome. Similarly, for Observations #15, #16, and #19, participants are having difficulty with the system designed to record damages on a regional map. While one may infer the cause as a computational mechanism issue, the analysis team explained that had the process been more clearly conveyed they would not need to spend valuable time trouble-shooting the system to determine if the feature worked correctly, hence they classified the cause as "unclear process."

Three of the manifestations of computer system mechanisms were classified as caused by issues of interoperability. Observation #13, #22, and #45 describe issues related to the inability of systems to share data across disparate systems. In the case of Observation #13, both versions of WebEOC had the ability to track events and resources, but a standard definition of "significant event" was not available. As a result, an event that was tracked in one version of WebEOC could not be tracked in a different version WebEOC.

Only one time, was an issue with "coordination" identified as the cause of a "computational mechanism" manifestation (see Observation #33 in Table 2). In this case, functionality which was expected to be available by the start of the exercise, was not implemented. Throughout the exercise it because apparent that tracking all issues, assign a priority, and sort on the priority was a function that would provide great value to the resource scheduling team.

Finally, five of the 18 manifestations of "computational mechanism" issues were also classified as caused by "computational mechanism" issues. Various technical issues are explicitly called out in the observation, and a thorough reading of the Slack jottings surrounding these issues, resulted in the analysis team agreeing that these issues were caused by a failure of technology.

#	*Observation*	*Cause*
11	Planning GIS is trying to create a damage map, but there is a technical issue due to a recent update.	Computational Mechanism Issue
13	The Deputy PIO is working on an internal communication issue. The PIOs would like to use WebEOC to communicate with each other internally. That functionality has not been implemented for Kitsap County in the same way it works at Camp Murray. These PIOs want to track things in WebEOC that don't quite qualify as "significant events" but may be bits of information that they would get information requests about.	Interoperability
14	Looks like multiple systems are in play for the road damage. Original maps are created in GIS. Trying to get the details without being too pushy. Seems some edits are also being made in an Adobe PDF viewer. Though, the player I spoke with said, "It's not doing what I want it to do.	Unclear Process
15	I've been looking at the Public Works trying to do rapid mark up on PDFs of maps. It doesn't seem to be working.	Unclear Process
16	A National Guard player is at the smart screen loading a map. He is attempting to edit the map which is a PDF by drawing over it with a stylus. "It's not doing what I want it to do."	Unclear Process
17	He will also convert it to a JPG so it can be shared.	Computational Mechanism Issue
18	There is a problem with editing the map in the PDF viewer. If you change the	Computational

[3] In order to fully understand an observation, the analysis team often referred back to Slack jottings that both preceded and followed the observations shown in the table.

	map view, the edits above it will be off.	Mechanism Issue
19	[participant] from county public works and a National Guard player are troubleshooting the map on the smart screen. They are looking up the smart screen manual on [participant] phone. It seems that the smart screen should support easy and fast markup of the map so that Public Works can quickly get out information to crews of where damage is. The national guard player is going through several permutations, but none of them seem to work. For rapid assessments and documentation, it seems this system needs some reworking.	Unclear Process
22	Kitsap assessment tool has a web-based tool to upload a situation report. The web app is partially broken. A recent ArcGIS system update broke the ability to talk directly to the damage assessment collection tool. One of the National Guard players: The EOC GIS displays are all different, no standard.	Interoperability
26	Message forms are coming in, but it can't be brought in to the GIS tool. Data is being put into the GIS system by hand.	Computational Mechanism Issue
27	Can't download data from the web app. A CERT volunteer and the GIS planner continue to work on fixing the system.	Computational Mechanism Issue
33	The WebEOC functionality they were looking for (logging lower priority information) probably won't be implemented during the exercise.	Coordination Breakdown
45	The web-based tool is pre-loaded with important locations such as drug stores, food stores and fire stations throughout the county. It is designed to work with their GIS, though there was a hiccup with that yesterday.	Interoperability

Table 2: Observations manifesting as Computational Mechanism Breakdowns and their causes as identified by the coding analysis team.

Table 3 represents the nine observations that manifested as coordination breakdowns. Seven of these nine issues were also caused by coordination breakdowns. Observation #9 is the description of the process where the county commissioner, officially declares a "state of emergency." This declaration is required in order for other tasks to be completed, thus many people are idle due to the breakdown in coordination. The two interoperability causes identified in Table 3, Observation #29 and #34, are related to operational and technical interoperatbility issues, respectively.

#	*Observation*	*Cause*
9	This declaration could be made locally by the county commissioner, but so far that has not happened. The commissioner is inaccessible which is delaying the declaration. This is delaying some of things that need to occur.	Coordination Breakdown
12	Several stickers are beings added retroactively to the map.	Coordination Breakdown
25	Too few GIS workstations here.	Coordination Breakdown
28	We have a very incomplete [picture] of what the damage is in the county.	Coordination Breakdown
29	ACCs and Police Departments are overwhelmed.	Interoperability
30	Plans are not solidified on commodities for citizens.	Coordination Breakdown
34	Damage assessment, some blips some parts still not talking to each other.	Interoperability
35	The message center is not operational today.	Coordination Breakdown
36	Still use the message forms. Deliver them where they need to go.	Coordination Breakdown

Table 3: Observations manifesting as Coordination Breakdowns and their causes as identified by the coding analysis team.

To summarize, a qualitative analysis, grounded in the data, revealed that breakdowns in information sharing among people and agencies had many symptoms and many causes, and they were not always aligned. Two-thirds of barriers that manifested themselves as computer systems issues were not caused by computer systems issues, and a third caused by unclear processes manifested as computer systems issues. In the following section we discuss what results like this one mean for improving collaborative management of disasters.

DISCUSSION

In this qualitative investigation of the response to a large-scale regional disaster, focused on the activities of a county EOC, we sought to identify the cause-effect relationships that made it difficult to achieve desired information sharing. Specifically, we identified the observable effects of information sharing breakdowns and then inferred possible causes of these breakdowns, using the classification system described above. While not all may agree with the particular classifications, we believe that the qualitative coding methodology and the analysis tool used here contributes to the knowledge regarding the causes of breakdowns in complex socio-technical crisis management systems.

According to the *Cascadia Rising Disaster Exercise After Action Report* (FEMA 2016), a long history of regional coordination and collaboration led to overall successes during the exercise, improving situational awareness and decision-making capabilities and bridging gaps in communications and problem-solving. Still, as we observed at the county-level EOC and as was acknowledged in the AAR, there were significant obstacles to information sharing and coordination. In fact, the general conclusion of the Cascadia Rising After Action Review was that we as a regional community are not prepared for a disaster of this magnitude. But where should we focus our investments and energies to become better prepared?

This study suggests that in a crisis information sharing environment, computer systems are more likely to manifest a problem than they are to be the cause of it. Results indicate that although the effect of an obstacle to information sharing or coordination may be related to a computer system or software, the cause of the problem is more often than not due to other factors. Computer issues were as likely to be caused by unclear processes as technical issues. Some of these issues could be attributed to individuals' lack of training with such systems, exacerbated by the infrequency of using computer systems that are designed for or being adapted for use during disaster response. Overall, obstacles to collaborative work that appear to be related to computational issues are generally attributable to non-technical causes. This indicates the danger in attempting to improve collaborative management of disasters by enhancing technological capabilities. Interestingly, when we discussed this conclusion with disaster practitioners, their general reaction was, "That's not surprising. We knew that." Yet the investment in technical fixes to crisis collaborative systems continues to be considerable.

Coordination issues in support of collaborative work could be attributed to various factors. The extent of the Cascadia Rising exercise scenario meant that the state had to call upon federal and military assistance in order to respond to the disaster. Consequently, there were individuals who were working together for the first time and unfamiliar with operational procedures involving these new players. Such challenges are common in disaster response due to different organizational cultures and distinct individual and coordinative work practices Ley et al., 2014). The shared ICS structure is designed to overcome some of these challenges, but in many cases did not achieve this, either because several jurisdictions used modified versions of the ICS—which is acceptable but can lead to problems with coordination (Lee et al., 2011)—or because ICS is more effective as a going-in position than as a playbook to manage unexpected challenges. Our results indicated that coordination breakdowns were common, about 1 in 5 of all obstacles whether viewed as cause or effect. Coordination issues were the most significant cause of missing content. This missing information meant that necessary collaborative work was delayed or could not be completed.

Interoperability issues, viewed not just as machine issues, were also significant. There are many levels of interoperability, from technical levels that link networks and data to mission-centric operational and policy levels of interoperability (Haselkorn et al., 2016). While prior studies of disaster systems have focused on "lower-level" technological interoperability problems of data sharing and networking, we took a broad definition of "system" and included "higher-level" interoperability such as conflicting policies or misaligned practices. From this perspective, interoperability was a prevalent cause (1 in 5) but not as prevalent an effect (about 1 in 10). As the literature suggests, response emergency managers, faced with interoperability issues, improvise and devise low-tech workarounds to support information sharing (Brooks et al., 2013). During Cascadia Rising we also saw evidence of this. For example, as response teams were trying to find geographic information system (GIS) data, they discovered that there was no data clearinghouse that could be used across organizations. This led responders to improvise—reaching out to regional workers they had connections with and finding suitable data. They then, however, struggled mightily with integrating this data into a useful situational picture.

More than a quarter of all information breakdowns we observed were categorized as being caused by an unclear process. Supporting this, the AAR found that almost all jurisdictions reported a lack of understanding of the resource request process, finding that in some cases the personnel had not received adequate training required to make and track resource requests (FEMA 2016). Like the improvisation described above, this further speaks to the fact that resources should be allocated to support how people actually work—informally based on past shared experiences and trust relationships—rather than on new technology that changes, and constraints work processes. Unclear processes were the single biggest cause of obstacles to information sharing in support of collaborative crisis work. Introducing new technology that impacts how people work is likely to make this problem worse, not better.

CONCLUSION

State-of-the-art human centered design methods are based on the perspective that technology is a tool in support of accomplishing human missions and meeting human needs. Without an alignment of human issues such as shared missions, policies, and operational concepts, no amount of technology can achieve effective collaborative work. Operational professionals such as those working heroically to minimize the destructive impact of earthquakes and other hazards know this intimately. This study found information-sharing obstacles associated with computer systems to be the single most **visible effect** during a major crisis exercise, but they were far from the most significant **underlying cause**. This evidence, in support of what practitioners already know from experience, argues for a shift in how we invest in our collaborative crisis management "systems."

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