This paper investigates a previously overlooked phenomenon in crisis response information systems; namely, inclusive crisis infrastructure. By expanding the well-acknowledged infrastructure concept with alternatives to understand the nature and scope of inclusive crisis infrastructures, this paper contributes to closing the gap between theory and practice by raising some research questions critical to studying inclusive crisis infrastructures. The emerging literature on crisis response information systems suggests that external sourcing of information increasingly influences crisis response operations. To contribute to this discourse, the paper draws on Pipek and Wulf’s (2009) definition of work infrastructures and Palen and Liu’s (2007) conceptualization of peer-to-peer communications to develop a better understanding of the crisis response arena as a whole. In doing so, this paper goes beyond the emphasis on event-based technologies that currently dominate the crisis response information systems literature and instead argues why crisis infrastructures need to be both inward-looking and accommodating to technological and social outcomes parallel to formal response contexts. The novel conceptualization captures the fact that the crisis context contains collections of collective IT artifacts that are not aligned or related but that are, for autonomy reasons, interlinked to crisis organizations’ current IT infrastructure and may be of great value to such organizations if infrastructure capability options are considered.

**Keywords:** Social Media, Crisis Response, Crisis Infrastructure, Inclusivity, Information Systems, IT Infrastructure.

Jan Recker was the Senior Editor for this paper.
INTRODUCTION

Social media have pioneered new ways of communicating during and after rescue and relief operations following disasters (Palen and Vieweg 2008). Social media are:

- web-based services that allow individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system (Boyd and Ellison 2007, p. 1).

Several studies of major disaster events have demonstrated the value of these technologies to members of the public directly or indirectly affected by the event (Munro 2012). However, this finding is rarely mirrored in the traditional crisis response (CR) systems research because of the assumption that an effective crisis infrastructure is based on institutionalized procedures for preparing for and activating crisis responses (Landgren and Nulden 2007; Pan et al. 2012; Turoff et al. 2004). While the infrastructure concept has been defined as framing inextricably related artifacts, entities, heterogeneity, surrounding objects, and information services into the situated use of information systems (Bygstad et al. 2010; Cordella 2006; De Marco and Sorrentino 2007; Hanseth and Lundberg 2001; Hanseth and Lyytinen 2004; Hanseth and Lyytinen 2010), the crisis response discipline endures with inward-looking arguments explicitly addressing the critical role of information technology that supports crisis responders in their collaborative tasks (Carver and Turoff 2007; Jennex and Raman 2011; Turoff et al. 2011; Van de Walle and Turoff 2008). The difficulty with inward-looking arguments can be traced to information processing, contingency, task-technology fit, and resource-based perspectives, which have been the dominant informing elements in IS research attempting to explain information technology use during crisis events (Constantinides and Barrett 2012).

A common strategy for rediscovering the foundation and scope of crisis response has been to consider ways to efficiently provide timely and accurate information to all relevant individuals in the course of a crisis response (Murhen et al. 2008; Turoff et al. 2004). To that end, Pan et al. (2012) suggest that the structures of information networks provide valuable insight into the crisis response practice, and their approach emphasizes information flow and network density as core tenets of the resulting four prototypical crisis response network types presented in their case study research. However, this and similar approaches in the literature do not fully recognize the influence that IT used by external individuals, such as members of the public, has on established crisis infrastructures. Previous research in which scholars have investigated the scope of crisis response operations is limited to assumptions about socio-technical routine practices, such as coordination of tasks (Constantinides and Barrett 2012), response information networks (Pan et al. 2012), commitment and capacity to act (Mendonça and Wallace 2007), expectations from actions (Weick 1988), and inter-organizational information processing (Comfort et al. 2001). While such assumptions are valuable for understanding actability during crisis events, their contribution to a broader understanding of information systems in crisis responses is limited.

To develop a better understanding of the crisis response infrastructure put forward in this paper, one must recognize that “the point of entry to the practical and theoretical space of concerns is in considering how ICT is changing this arena” (Sutton et al. 2008, p. 278). The essence of this change is the placement of emphasis on the value of new online technologies and the way in which they interplay with the highly structured response practice. These

CONTRIBUTION

This conceptual paper provides IS researchers and practitioners interested in crisis response with a discussion of the interplay between two domains: traditional crisis infrastructure and external sourcing of information via social media technologies. The paper takes an information infrastructure perspective to articulate five capability-oriented research questions that are central to better understand how these domains interlink. An extensive literature review is presented to argue for and formulate the questions. The research questions illustrate the need for formal crisis response agencies to acknowledge its interconnectedness with external information sources. As the literature on social media technologies note, these two domains are converging because of new pathways to share information. On the other hand, the literature in crisis response underscores and promotes ways to warrant the efficacy of command and control structures in formal response agencies. A class of problems in crisis response found in previous research (e.g. the Haiti earthquake case) serves as a base to show some critical capabilities essential to understanding new affordances of emerging social media technologies into traditional information infrastructures. Theoretically, the paper contributes with new knowledge about how to go beyond the dominant crisis event and task-technology fit perspectives in crisis response research by illustrating the concept of inclusive crisis infrastructures.
technologies enable online socially convergent activities that have the merits of being collectively resourceful, self-policing, and information generative (Ada et al. 2010; Hughes et al. 2008; Sutton et al. 2008). As Palen and Liu (2007) argue, online activities carried out by members of the public during crisis situations are an emerging form of society-scale, computer-supported cooperative activity that "supports the need for communities to be able to improvise response under uncertain and dynamic conditions" (p. 733). The idea thus developed and elaborated on in this paper is that, although crisis organizations depend on the traditional building blocks for successful crisis response, they also need to accommodate external instances, such as new information pathways, that parallel ongoing crisis response, which implies that social media technology and crisis response are co-adaptive (i.e., they constitute a crisis infrastructure in which a number of heterogeneous socio-technical relationships create distinct interaction patterns) (Hanseth and Lundberg 2001).

The paper synthesizes and analyzes the mainstream crisis response information systems literature, information systems infrastructures, and the recent findings in social media technology literatures that centers on online crisis communications, and argues for the notion of inclusivity. Inclusivity refers to a collection of interlinked IT artifacts and resourceful activities that constitute inclusive crisis infrastructures, which is distinct from viewing infrastructures as assemblages of IT artifacts (Henningsson and Hanseth 2011) because inclusivity is not necessarily a product of integrated and related components, nor does the collection of artifacts interact with and influence each other as Henningsson and Henriksen (2011) argue; instead, it interlinks the traditional crisis response infrastructure components and the increasing sourcing of information via fragmentary social media technologies. The inclusive crisis infrastructures are thus best described as autonomous entities sharing information via collective IT artifacts to provide rescue and relief capability without interfering with operational efforts.

By using insights from capability-building approaches in crisis response information systems research (Harraold 2011; Jennex 2007) and specifically extending the research of IT capabilities initiated by Pipek and Wulf (2009) and Palen and Liu (2007), this research proposes a set of capability-oriented research questions. The research questions illustrate the nature of the emergent information pathways that occur as a consequence of interlinking formal response organizations and socially convergent online activities.

The paper is structured as follows. The paper first provide a research background to highlight the type of real-world problems that exist in connection with crisis response information systems. It then overviews the crisis response literature to provide a basis for the discussion of inclusive crisis infrastructures. The next two sections outline the characteristics of crisis infrastructures and highlight the growing external influence of social media technology on the crisis response arena. The fifth section articulates five research questions appropriate for the study of inclusive crisis infrastructures. The paper concludes by suggesting the research implications for future research and the crisis response practice.

THE CRISIS INFRASTRUCTURE CHALLENGE

A major earthquake struck Haiti on January 12, 2010, and inflicted devastation on one of the poorest nations in the world. Many international crisis response organizations embarked on rescue operations alongside volunteer organizations. While many specific rescue operations were successful, the UN reported that their overall strategy failed during its implementation. John Holmes, Chief of the U.N. Office for the Coordination of Humanitarian Affairs, explained this in the Washington Post on February 17, 2010:

I was disappointed to find that despite my calls for the global cluster lead agencies to strengthen their cluster coordination capacity on the ground, very little progress has been made in this critical area. This lack of capacity has meant that several clusters have yet to establish a concise overview of needs and develop coherent response plans, strategies and gap analyses. This is beginning to show and is leading others to doubt our ability to deliver.

Four months later, a panel of responders and researchers discussed the inability to coordinate resources in Haiti at the 7th Conference on Information Systems for Crisis Response and Management (ISCRAM) in Seattle. They created the following list of problems with the information systems practice as part of a broader narrative of the disaster by official and non-governmental organizations:

- Teams were unaware of resources coming into Port-au-Prince during the first few days of the emergency response.

- Definitions of information flow in and between teams did not exist. Different information systems were used.

- Standard operating procedures were not outlined before the event, which meant that actions were defined in real time during relief efforts.
Members of the international public used a variety of social media technologies to inform the masses of the response’s progress.

Scenarios such as these are common in crisis situations worldwide and continue to cause significant challenges to the effective performance of crisis organizations (Comfort 1999; Harrald 2006; Munro 2012; Weick 1988; Weick 2010; Zook et al. 2010). The information systems practice above is thus represent a class of problems that crisis organizations have to deal with in the course of disaster events (Sein et al. 2011). For example, Yin et al. (2012) found in their study of social networking activities during the Christchurch earthquake in New Zealand in 2010 that situation awareness information reported in tweets and blogs was not visible to crisis response teams. Similarly, Kaewkitipong et al. (2012) confirm the class of problems found from the Haiti case in their study of the 2011 Thailand flooding disaster. For example, it was not clear to formal response agencies how to exploit the benefits of social media because of the preference of one-way communication modes.

For the agencies responsible for coordinating and communicating progress during the Haiti earthquake, the problems outlined above imposed great challenges when compiling information from dispersed teams to distribute an overall situational picture of the rescue progress. Response and relief organizations thus developed incompatible information system practices during the relief effort. For example, while some teams used printed products, such as spreadsheets, to organize efforts, others used a mixture of email and verbal communications to coordinate their work. At the same time, people published numerous texts, photos, and videos about their personal experiences during the earthquake on social media sites (Huiji et al. 2011). As Heinzelman and Waters (2010) note, during the course of the response, relief actors failed to aggregate and prioritize data from outside sources, which made it difficult to benefit from valuable information coming from the Haitian community. Accordingly, the Haiti disaster clearly shows that the crisis response consisted of two distinct social network contexts with different capabilities, one having its roots in the traditional crisis response system and another that exists on the premise of peer-to-peer online information sharing and knowledge production.

INWARD-LOOKING ARGUMENTS IN THE CRISIS RESPONSE LITERATURE

To review the literature in crisis response requires a framework to classify previous work. Scholars such as Constantinides and Barrett (2012), Harrald (2011), and Weick (2010) assert that is important to understand the theoretical assumptions that form the basis of crisis response approaches. Such understanding allows researchers to recognize how the crisis response goes through different phases and hence indicate the reasons behind scenarios such as those that caused incompatible information systems practices during the Haiti disaster. Inward-looking arguments are associated with a greater understanding and responsiveness to disaster events (Turoff et al. 2004). This is important for response capability, which refers to the critical goals that must be achieved, the critical decisions that must be made, and the acquisition of relevant situational information in the course of crisis response (Harrald 2011; Jennex 2007). Thus, response capability enables crisis teams to respond to the unexpected under extreme conditions, the ability to manage organizational change and transition to subsequent phases, and use of tools that support sense-making and decision needs (Harrald 2006). Because most crisis response approaches have been grounded in information processing, task-technology fit, and resource-based perspectives, three distinctive inward-looking arguments for crisis response are evident in the crisis management, crisis enactment, and crisis technology literature of the past two decades. The first argument suggests that routine behavior has a determinate impact on crisis response capability. The second argument, crisis response as exception handling, recognizes the link between crisis response actions and information technology. The third argument, technology-centric CR-IS, positions information technology at the center of crisis response with reference to its capability to coordinate resourceful crisis activities. The arguments are discussed below.

Crisis response capability

Pan et al. (2012) assert that the formal crisis response network is a social network that involves a mixture of cross-boundary socio-technical communications to manage undefined situations, which are often high-pressure situations that involve rescuing people and saving lives (Nunamaker et al. 1989; Turoff 2002). This study has led to the viewing of crisis response as a collaborative advocacy of inter-related individuals, groups, and organizations, with different backgrounds and levels of expertise, that operates in emergencies (Mendonça et al. 2007). Research on this view is based on the idea that cognition defines the capacity to recognize the degree of risk to crisis exposure and execute the behavioral activities necessary to meet response objectives (Mendonça and Wallace 2004). The well-acknowledged view of crisis response as “comprising the ability to lead an adaptive creative management team when faced with the unexpected” (Harrald 2011, p. 5) means that, with adequate cognitive ability, crisis response is effective, interdependencies between the social and technical systems are less problematic, and a common operational picture of needs and resources is enabled among responders (Comfort and Haase 2006). The
importance of cognitive capability lies in the fact that the relevance of successful crisis response falls into situations where systemic interdependencies exist (Jul 2010) and ultimately define any crisis organization's capacity to act.

Scholars, emphasizing the need to maintain an open and adaptive crisis response system structure, have examined systemic interdependencies (Comfort 2007; Harrald 2011). Unexpected situations stress organizational discipline and the organizational structure because procedures may be forced to change as emergencies evolve. Thus, there are two central issues concerning crisis response effectiveness; namely, the response system boundary and the design of information infrastructures to meet the demands of ever-changing response environments. However, Harrald (2011) argues that crisis management tends to separate the formal response organization from the potential support that spontaneous volunteers and community members can provide, which means that response plans, in their creation, exclude non-routine behaviors and self-organization by members of the public in response to emergent needs. The already complex dependency structure of response systems, including enacted crisis coordination (Shen and Shaw 2004), is thus expanded by information exchange between affiliated and non-affiliated individuals (Landgren and Nulden 2007).

The information infrastructure design perspective suggests that decision-makers under stress require systems that can quickly find and display information relevant to the mental models they use to assess and adjust their actions in rapidly changing environments (Comfort 2007; Mendonça et al. 2007; Turoff et al. 2004). According to Comfort (2007), the purpose of any system’s design is to develop a “common knowledgebase” to support collective actions to reduce risk. Comfort (2007) suggests that “the collective capacity of a community to act to reduce risk can be increased through timely information search, exchange, and feedback processes that create an inter-organizational learning system across jurisdictions and sectors” (p. 197). To this end, Jennex (2007) writes that crisis organizations require knowledge management-based response systems that “perform correct actions and which facilitate communications between various responding groups and managers” (p. 1). Similarly, Turoff et al. (2004) argue for certain information infrastructure design premises that mirror the need for improvisation during response. Their argument is that emergencies can evolve to be concerns beyond the jurisdiction of local agencies. This particular vein of crisis infrastructure research is similar to Pipek and Wulf's (2009) conceptualization of the work infrastructure as attributes, such as interconnectedness and complexity, standardization, and (in)visibility, that are at the core of response routines.

Overall, the literature on collective adhocracy suggests that response operations are likely to include both centralized and distributed operations (Mendonça et al. 2007). Systemic interdependencies are thus sensitive to situations where predefined coordination, decision-making, improvisation, adaptability, and creativity have proven valuable for effective problem solving during emergencies (Comfort 1999; Harrald 2006). The collaborative adhocracy position can be criticized for ignoring varying perceptions of the usefulness and ease-of-use of the information and communication tools used in crisis situations. More specifically, the collaborative adhocracy position can be criticized for ignoring the need of developing capacity for lifelong individual and group learning (Harrald 2011). The vast majority of studies based on this perspective advocate decentralizing information technology practices to enable improvisation and creativity during responses. In sharp contrast, other studies suggest that institutionalized response plans must be reinforced, which makes it difficult to theorize how responders and managers interact with information technology by collectively exploring their cognitive abilities.

**CR-IS as exception handling**

Enacted sense-making and technology enactment are discussed below to explain why exception handling appears in the crisis response literature.

The literature describes crisis response enactment as the assurance that responders interpret and follow prescribed action procedures of exceptional and disruptive events using response plans and information technology (Murhen et al. 2008). Consequently, crisis response performance largely depends on individuals’ cognitive abilities to interpret and make sense of any new situation (Weick 2010). Enacted sense-making can be traced back to the 1960s and 1970s and the theoretical advancement in organizational behavior that acknowledged variants of structuralism in which human actions are observed as the result of embedded structural conditions (Hermann 1963; Powers 1973; Salancik 1977; Staw 1980). The first fully developed application of enactment in crisis-related situations is Weick (1988). This seminal work views enactment through cognitive processes, including commitment, capacity, and expectations in crisis situations, and assumes that enactment involves a process, enactment, and a product (an enacted environment). Furthermore, scholars agree that actions devoted to sense-making are essential for achieving a successful response. For example, Murhen et al. (2008) argue that the disruptive nature of emergencies calls for a deeper understanding of sense-making properties to process the often ad-hoc-oriented information flows during a response. Murhen et al. (2008) write that information practices in extreme events are viewed as a “repository of best practices” (p. 318) and that this view is an oversimplification, which is an impediment to the reflection of any given course of action.
Following the early focus on enactment, in which cognitive conditions defined actions, subsequent research began to reassess the assumptions to include social agency variants. Weick (2010) explores, in considerable detail, the social dimension of enactment and presents an ambitious attempt to clarify the ground on which emergencies may be explored. In Weick’s (2010) own words, “enactment is central in descriptive language and considered as just one of seven properties of sense-making, the other six being social context, identity, retrospect, reliance on cues, ongoing experience, and updated plausibility” (p. 544). Mailis and Sonenshein (2010) investigate affective processes in sense-making and argue that enactment is inherently embodied in it. They build their argument on cognitive processes (Weick 1988) and consider those as a collection of “shared meanings”, which would support better understanding of interrelated perspectives among those affected by a crisis event (Geyer-Schulz et al. 2010). They further incorporate human emotions in their view on embodiment because “crisis situations are typically characterized by intense negative emotions such as anxiety and fear” (p. 566). This expansion of the definition of enactment can add further understanding of how responders psychologically react to hazardous events, which makes crisis response more the result of an experience than of singular events (Roux-Dufort 2007).

In the second line of research, the literature on technology enactment under turbulent conditions suggests that information systems should support communication, data gathering and analysis, and decision-making (Harrald 2006; Turoff et al. 2010). A considerable body of research acknowledges that technological opportunities are turned into technological realities entangled with organizational environments (Van de Walle and Turoff 2008). This line of research on crisis information system practices that seek to reconcile the technology patterns inherited in the dyadic interaction between crisis management and crisis operations is called knowledge management (KM) (Chen et al. 2008; Jennex 2007; Yates and Paquette). Lee and Bui (2000) suggest that, to enact the crisis environment, crisis organizations should develop knowledge-based templates that are both descriptive and normative, and crisis organizations should make tasks in a given crisis descriptive accounts from which organizations can derive normative actionable templates. As templates could be embedded in information/action flows in various phases of crisis management, a body of scenarios and cases can be formed to advise enactment in future events. Central to the KM perspective is the notion that KM-based systems depend on the interface and quality of the knowledge stored and retrieved from the systems (Jennex 2007). Researchers working from this perspective focus on “decision-making processes” (Muhren et al. 2010; Xu et al. 2009), “knowledge acquisition” (Muhren et al. 2009), and “modeling information flow” (Zimin et al. 2011). In the scope of crisis response, researchers following the knowledge management perspective typically seek to explain how information sharing leverages the knowledge of crisis organizations (Jennex and Raman 2011) so it can be utilized across organizational barriers (Österlund 2008).

The exception handling perspective has been criticized for defining crises as abnormal and disruptive events that foster a black-box attitude toward information processing (Murhen et al. 2008). Exceptions inevitably draw attention to the “triggering events” that unleash the disaster and the immense need for event-based information. Researchers who analyze information processing argue that knowledge informs enactment, regardless of the human or technical agency involvement (Jennex and Raman 2011). However, one problem with this view is how uncritically information-processing perspectives have been used to suggest various knowledge management system solutions to resolve the issue of learning from previous response operations. Most research efforts in this direction stress the increasing demand of such systems but say little about the knowledge distribution in a large network of response actors.

**Technology-centric CR-IS**

The third conceptual position of inward-looking arguments assumes that information technology is the core resource of crisis organizations and, as such, impacts planning routines, decision-making, and individual responders’ performance (Muhren et al. 2010; Turoff et al. 2004). Orlikowski (2007) defines the foundation of this position as a perspective taking “a functional and instrumental approach, assuming that technology is largely exogenous, homogeneous, predictable, and stable, and performing as intended and designed across time and place” (p. 1437). Many case studies involving information technology use in a crisis response use these features as organizing themes to understand local interpretations of information technology in crisis response (Landgren and Nulden 2007). These studies argue that crisis organizations look toward technology use during the actual response and seek ways to assess how technology would provide adequate emergency management toolboxes. For example, different geographical information system applications are valuable to first-line responders coordinating efforts during events (Yuan and Detlor 2005) and enable run-time decision-making (Zenger and Smith 2003–). The second avenue of research on this perspective primarily views technology as the execution of crisis management routines. In particular, research underscores the importance of having information technology that supports resource allocation decisions to minimize social and economic impacts (Dantas and Seville 2006). Almost unanimously, scholars and emergency management practitioners have expressed their observation that information technology significantly increases coordination efficiency during response efforts. Using information technology, local crisis organizations become equipped to bridge with regional authorities to activate accommodating response frameworks and practices. The source of technology centricism is thus posited to influence the likelihood that a certain mode of information technology-based coordination succeeds. Information technology-based coordination modes can be categorized into

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Volume 14  Issue 4  Article 3
three main groups: (1) single integrated enterprise-like systems, (2) multiple-agency decision support, and (3) technical and organizational interoperability.

Integrated systems typically span emergency planning, routines used during execution and recovery, and training to make crisis operations work in practice (Meissner et al. 2002; Turoff et al. 2004). As such, integrated systems can be used productively in crisis organizations because they build on well-adapted event scenarios developed based on prior experiences. As infrastructure scholars would argue (Henningsson and Hanseth 2011):

*when the installed base becomes larger and more stable, its capacities to interact with other components are extended and open up new spaces for new add-ons and more integration with other systems – the more it is becoming a powerful structure which may support new and more powerful control systems* (p. 16).

The ability to coordinate response tasks thus depends largely on the extent to which organization members can use a stable installed base to build and maintain viable understandings of the response systems to which they belong.

To align decision protocols in a cross-organizational setting, a natural scenario would include the use of inter-organizational information systems. The literature argues that the technical capacity to exchange timely and accurate information between multiple participants increases the organizational capacity to solve shared problems that require action at the local, regional, national, and international levels (Comfort et al. 2001). Such a capacity requires an effective infrastructure to enable dissemination of information originating from multiple agencies (Dantas and Seville 2006). However, if infrastructures halt, the coordination outcomes may manifest differently during the timespan of crisis events. As Comfort (2007) writes:

*this condition creates asymmetry in the information processes, whereby jurisdictions and organizations with higher levels of responsibility and authority transmit orders to lower levels without requesting or listening to feedback from field operations personnel or organizations outside the formal chain of command* (p. 192).

Information technology-based coordination may also originate from interactions between technology and emergency routines (Harrald 2006). In their study of the crisis response during Hurricane Katrina, Comfort and Haase (2006) demonstrate that fragile communication infrastructures severely hampered the coordination of emergency routine performance. The concept of interoperability has explained the effects of uncertainty on emergency response. Unlike ordinary organizational interoperability issues, where incompatibility between technical systems consumes most resources, the emergency response arena must operate even if the technical systems fail. One typical effect in such a scenario is the potential risk of misinterpreting decisions while coordinating response actions (Chen et al. 2008).

The technology-centric position in crisis response focuses on IT-based coordination of interdependencies between IT-enabled activity nodes (Comfort 2007). This position largely rests on the view that people use IT to complete various operations when performing a task (Mathieson and Keil 1998). Thus, the task-technology fit (TTF) perspective has influenced most research studying the role of information technology in crisis response. The information technology in use is thus observed as a function of coordinated actions that enhance situational awareness and facilitate authoritative decision making (Constantinides and Barrett 2012). Critical voices argue that TTF models take a decidedly rational approach by assuming that users choose to use IT that provides benefits, such as improved job performance, regardless of their attitudes toward IT (Dishaw and Strong 1999). Germonprez and Zigurs (2009) argue that research efforts tend to focus on deterministically matching technology to the task being performed. This prescriptive approach treats the user as a recipient of a defined task and technology, rather than an active player who can modify technology in the use context. In short, the design of IT is linear and assumes a strong relationship between tasks and technologies (Harrald 2011). On the basis of the above discussion, the crisis infrastructures typically include an array of information technologies (Figure 1) arranged to gain the quickest possible overview of any disaster event (Jennex 2007).
Figure 1. Crisis response information infrastructure (visual adaptation of Jennex, 2007)

Table 1 highlights the practice, assumptions, and some remaining capability challenges following from the existing perspectives in the literature of crisis response information systems. The overall weakness associated with current understandings of crisis response information systems is the exclusive attention toward the crisis event. This view has stimulated researchers to prescribe how actions should be performed in practice instead of seeking understanding of alternative information system perspectives. The conceptual positions, crisis response capability, crisis as exception handling, and technology centric CR-information systems have manifested inward-looking crisis infrastructures that exclude valuable inflow of peer-produced knowledge and thus reinforce separation between formal and non-formal response systems. Given the predominance of crisis event-focused research, this conceptual research contributes to the IS literature on crisis response by providing an expanded view of crisis infrastructures.

THEORETICAL FOUNDATION

Infrastructures are commonly viewed as structures of shared, open, heterogeneous, and evolving socio-technical systems of information technology capabilities (Hanseth and Lyttinen 2010). However, definitions of an infrastructure do not include any conceptualizations of what occurs in the outer social circles of any crisis (Pan et al. 2012) because the basic assumptions concern its core elements (namely, standards, strategies for developing standards, and design strategies) (see Hanseth and Lyttinen (2010) for a detailed review). This literature stream has specifically asked how users reshape a new infrastructure during its use (Hanseth and Lundberg 2001). The central argument is that systems must be observed as part of larger infrastructures, and the strategies for developing these infrastruc-

<table>
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<tr>
<th>Perspective</th>
<th>Practice</th>
<th>Assumption</th>
<th>Source</th>
<th>Capability challenges</th>
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<tbody>
<tr>
<td>Crisis response capability</td>
<td>crisis response is viewed as collaborative advocacy</td>
<td>the ability exists to lead an adaptive creative management team when faced with the unexpected</td>
<td>(Harrald 2011; Mendonça and Wallace 2007)</td>
<td>supporting individual and group learning (Harrald 2011; Jennex 2007)</td>
</tr>
<tr>
<td>CR-IS as exception handling</td>
<td>information practices associated with extreme events are conceived as a repository of best practices</td>
<td>responders interpret and follow prescribed action procedures for exceptional and disruptive events using response plans and information technology</td>
<td>(Jennex 2007; Murhen et al. 2008; Weick 1995)</td>
<td>Supporting integration of emergent groups interrelated perspectives into response efforts (Harrald 2011; Jennex 2007)</td>
</tr>
<tr>
<td>Technology-centric CR-IS</td>
<td>the combination of various types of information technology impacts planning routines, decision making, and the performance of individual responders</td>
<td>information technology is the core resource used by crisis organizations</td>
<td>(Jennex 2007; Mathieson and Keil 1998; Meissner et al. 2002; Turoff et al. 2004)</td>
<td>Understanding the new technical capabilities of Web 2.0 applications (Harrald 2011; Jennex 2007)</td>
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</table>
tures must be implemented in the context of strategies for developing the infrastructures in which the systems become incorporated (Hanseth 2002). The fundamental assumption is that the information infrastructure, commonly considered the background for organizational activities, does not exist unless included in the action that occurs when IT infrastructures are considered in their deployment (Cordella 2006). In contrast to the rediscovery of infrastructure features, Pipek and Wulf's (2009) work brings forward emergent capabilities during IS usage that become integrated in work environments. According to Pipek and Wulf's (2009) observation of the work infrastructure, capability is defined as “the entirety of devices, tools, technologies, standards, conventions, and protocols on which the individual worker or the collective rely to carry out the tasks and achieve the goals assigned to them” (p. 455). Moreover, Pipek and Wulf (2009) distinguish their idea of infrastructures from classical infrastructures (e.g., Star & Ruhleder, 1996) by emphasizing the necessity of also discussing scale and temporal issues with regard to infrastructures. Infrastructures can be, for instance, global/local and have shorter or longer lifetimes. This brief discussion of infrastructure research and the comprehensive literature review clearly indicate that crisis infrastructures are instances of the class infrastructure (Table 2).

<table>
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<tr>
<th>Feature</th>
<th>Class: infrastructure</th>
<th>Instance: crisis infrastructure</th>
</tr>
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<tbody>
<tr>
<td>Shared</td>
<td>Primarily companies within the sector (including their employees), but also customer and suppliers</td>
<td>Rescue organizations within the sector, but also external aid agencies</td>
</tr>
<tr>
<td>Evolving</td>
<td>By exchanging new types of information among the users and by involving more organizations</td>
<td>By integrating and introducing new IT capabilities</td>
</tr>
<tr>
<td>Heterogeneous</td>
<td>Multiplicity of, e.g., competing and overlapping sub-infrastructures, standards, and service providers</td>
<td>Multiplicity of, e.g., applications and sub-infrastructures, response teams, and response routines</td>
</tr>
<tr>
<td>Installed base</td>
<td>All current integrated services, their users and developers, and the practices they are supporting and embedding</td>
<td>All current applications and their users and developers, as well as the rescue and relief practices they are supporting and embedding</td>
</tr>
</tbody>
</table>

According to Pipek and Wulf (2009), the work infrastructure contains elements that are interconnected by virtue of their functionality and utility or by the shared interest of users. These elements are not stabilized by design but are embedded into ongoing open-ended crisis actions, and they allow the reinterpretation and modification of technology over time (Cordella 2006). Two assumptions lie at the core of Pipek and Wulf’s (2009) analysis that define the work infrastructure as an emergent process embodying capability:

1. **Versatility**: The infrastructure can be used for many purposes in many work environments, and its success can be partly attributed to its ability to combine multiple purposes into one technology or tool, even across spatial, professional, and organizational boundaries that previously could only be spanned using multiple tools.

2. **Reflexivity**: Information systems as work infrastructures can be observed as reflexive in two ways. First, the designers’ IS work environments are part of the same global infrastructure as those of the users. Second, all improvements to the global infrastructure are developed within that infrastructure.

These characteristics are relevant to the crisis infrastructure concept in that they point to design and use aspects; however, more importantly, they also reflect open-ended situated enactment (i.e., the ability to make assessments and act accordingly) (Mendonça and Wallace 2004). As Boudreau and Robey’s (2005) study of technology enactment demonstrates, “as users enact technologies in response to their local experiences and needs, significant organizational changes may result over time” (p. 4). In the enduring information practices in Haiti, versatility and reflexivity afford new ways of understanding information technology and organizing responses. Along this line of thought, Pipek and Wulf (2009) discuss organizing design. There is no real controversy regarding this difference of focus because both instances aim to produce desirable outcomes from actions. There is, however, great tension between the willingness to adopt new technologies and the immense need to maintain managerial control in response organizations. For example, consider potential changes in information sharing in any new multi-agency setting. Harrald (2011) argues that a typical response starts with a predefined, closed organization structure, and unexpected events occur as the response evolves, which may force the response organization to change its procedures. Local enactment inevitably gives rise to adaptations, demonstrated by inter-organizational systems under differing technical, organizational, and cultural conditions (Comfort and Kapucu 2006). A particular issue that causes variation in crisis systems, as Comfort and Kapucu (2006) further argue, is the difficulty in accepting new
Social media and crisis communications

Social media technology has recently received increased attention in crisis management and disaster response studies. Social media technology, including Twitter and Facebook, are used to disseminate public information during crisis events and are considered important sources through which the international public can report personal knowledge of events. Palen and Vieweg (2008) characterize features of online activity during crisis events and conclude that social networking using social media technology fosters social creativity and collective intelligence. This type of collective behavior has, according to Palen and Vieweg (2008), demonstrated how social media technology encourages people in crisis situations to help others and offer support in the outer circles of disasters. Shklovski et al. (2010) view social media technology as a community resource with which people attempt to make sense of their shattered worlds, such as in the aftermath of Hurricane Katrina, using digital connections to bridge time and space. Shklovski et al. (2010) conclude that the search and redistribution of information resulted in people creating or discovering online spaces that became virtual instantiations of the damaged and broken physical environments, which facilitated a sense of belonging.

The occurrence of several large-scale disasters (e.g., Hurricane Katrina and 9/11) has motivated researchers to study how members of the public, in setting up temporary organization and improvising rescue and relief efforts, function as “first responders” (Mendonça and Wallace 2004). Case research shows that it is challenging for response organizations to incorporate publicly created data into crisis routines because formal response organizations need to maintain managerial control and ensure reliability and trust in postings and content (Jennex and Raman 2011). However, research along the social media course has shown the benefit of setting up so-called back-channels (Sutton et al. 2008) in the formal response organization to create a computer-mediated alliance with members of the public (Palen and Vieweg 2008). Sutton et al. (2008) suggest that the real change in the crisis arena is in how social media technology creates a new behavior that, in turn, rearranges the roles in crisis response. Palen and Liu (2007) characterize this change by noting communication challenges in the alliance between formal response organizations and members of the public. Focusing on the increasing IT-enabled citizen participation in crises, they propose three modes of communication (p. 733):

- Communication between members of the public affected by the crisis: Citizen communication can create new opportunities for creating new, temporary organizations that help with informal response efforts.
- Communication between members of the public affected by the crisis and those outside it: This communicative pathway facilitates the use of social media technology during crisis events. During disasters, online media are used to stimulate the engagement of grassroots organizations in relief efforts.
- Communication between the official information officer function and members of the public: This information pathway will shift from the one-way depiction to the two-way depiction of information exchange. This pathway will arise out of the need for an organizational destination for the data that citizens collect at disaster scenes.

These communication modes exploit the relevance of social media technology as collaboration and communication tools during crises and in the post-impact crisis responses (Shklovski et al. 2010; Sutton 2010). The power of these communication modes lies mainly in the collective capability of gathering information from disaster events and displaying data for relief efforts.

Building collective infrastructure capability

This section provides a structured basis for discussing inclusive crisis infrastructure in the light of infrastructure capability. Infrastructure capability is relevant for bridging inward-looking crisis response organizations with online crisis communications. Any inward-looking initiative of crisis organizations is guided by an idea of versatility and reflexivity. In discussions regarding inclusive crisis infrastructures, this idea has to be associated with online crisis
communications. Thus, Pipek and Wulf's (2009) notion of global/local infrastructures is a relevant framework for incorporating Palen and Liu's (2007) argument about online crisis communications and the further discussion advocating the necessity for the two automonies to share information via collective IT artifacts.

Building on the concept of capability, several researchers (Mendonça and Wallace 2007; Turoff et al. 2004; Weick 2010) have extended the applicability of capability analysis to crisis management research and the investigation of ad-hoc collaborations, enacted sensemaking, and technology centrum. The concept of capability is thus a multifaceted notion covering broad issues in IT design and use and human actions. Several empirical studies have shown that IT capability analysis can be used to determine how different actors make sense of information technology and how they interact with the technology during crisis response operations (Carver and Turoff 2007; Jennex 2007; Jennex and Raman 2011; Turoff et al. 2011; Van de Walle and Turoff 2008). In addition to the dominance of inward-looking perspectives (local infrastructures) of crisis response information systems, research on online activities has recently emerged that seeks to articulate a parallel trajectory of IT use (global infrastructures) and how it can influence the traditional crisis response practice (Ada et al. 2010; Hughes et al. 2008; Palen and Liu 2007; Sutton et al. 2008).

When investigating the building of collective capability from the information infrastructure class horizon, it seems natural to consider the inclusive crisis infrastructures as entities comprising inextricably interlinked artifacts in contrast to related artifacts. Interlinked artifacts are those that are used in collective settings, supporting the exchange of formalized elements (i.e., data and data structures), and that still maintain distinct social behavior. A significant characteristic of interlinking artifacts is the absence of interference with the structures of the participating systems and the limitation of their interdependence. The challenge in realizing this attribute is analytical and lies in recognizing that “an infrastructure is the embodiment of standards, so that other tools or infrastructures can interconnect in a standardized way” (Cordella 2006, p. 9). For the inclusive crisis infrastructure, and hence the inclusivity to materialize and interlink the traditional response system with the online community, three indispensable conditions for supporting the infrastructure capability building process are that: 1) primary language should be used in messages, 2) messages should be written such they can be processed by everyone, and 3) messages should refer to well-known concepts. The traditional crisis response system already recognizes these conditions due to its experience in actions performed during responses, and this knowledge now has to be enmeshed with knowledge of online technologists.

The knowledge base in these two communities maintains information about the current state of any crisis and information about desirable outcomes of rescue and relief efforts. Reasons for the interplay between these communities are apparent, but one may think that the formalization of exchange requires some special arrangements in the installed base. In fact, technologies such as Web 2.0 applications do not build on complex integration schemes, which is convenient for displaying large sections of text. Text in the form of sentences is the primary language that both communities can process because sentences refer to well-known concepts in the context of any crisis. A simple example is these tweets that members of the public tweeted as the earthquake in Haiti progressed: “the hospital in Jacmel also seriously damaged and turning people away”¹ and “We are mobilizing resources and preparing plans to bring medical assistance to areas that have been hardest hit”.

Although the traditional response system and the online community interpret tweets such as these differently because rules and regulations control rescue actions and because sourcing of information is a primary concern for online communities, they serve both communities by providing invaluable knowledge. Within the crisis infrastructure, this type of information can be used, for example, to make tactical decisions about rescue effort prioritization. For groups of people directly or indirectly affected by a crisis, this information provides relief in knowing that others are providing remedies. Accordingly, this paper outlines five research questions that research should address in order to understand different information pathways between local and global infrastructures. This set of research questions is a natural outcome of capabilities that are captured by the term “inclusive crisis infrastructures”, which the next section explains.

**INCLUSIVE CRISIS INFRASTRUCTURES**

Two central concerns of the inclusive crisis infrastructure are supporting inter-organizational response interactions and interfacing with members of the public. According to the crisis information system context, blurred boundaries between crisis response agencies and the public/collective are distinct if the level of analysis shifts in recognition of these concerns (Comfort and Kapucu 2006). To that end, a critical issue is how the commonly excluded outsiders to a crisis event can serve as useful crisis response resources. The growth in social media use in relation to ongoing

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crises has developed into a community of practice in parallel with the formation of formal response agencies. As the Haiti earthquake rescue operations progressed, social media websites provided information about the actual conditions, which relieved stress among relatives of potential victims. Conversely, social media technology may constitute a valuable resource for crisis organizations because they can benefit from gaining access to information on individuals' last known locations or structuring missing person data. The selected approach takes the stance that inclusive crisis infrastructure is relevant in sensitive situations where dynamics exist in translating, technology, and learning between opposing ideologies (see, e.g., Braa 2002). Given the traditional response system approach (i.e., acting by centralized means; e.g., plans and policies), tension exists between crisis responders and social media technologists because they hold different values and attitudes toward information quality. In some situations, responders will need high-quality information, whereas in other situations, adequate data will be sufficient. To remedy this situation, it is appropriate to assume that reliability in this relationship could be provided by refocusing strategies for crisis response information systems to constructively contribute to the inclusive crisis infrastructure (Cordella 2006; Hanseth and Lundberg 2001). Following Pipek and Wulf's (2009) research on information infrastructures, the first capability constructs of inclusive crisis infrastructures include the core elements, versatility, and reflexivity, which underscores the relevance of crisis response as crisis response capability, exception handling, and technology centric.

Versatility
When crisis response is seen as an inward-oriented process, action and learning from action are central to the crisis response practice (Harra 2011). Given that the information practice associated with crisis response is highly heterogeneous in nature (Murhen et al. 2008), the information technology used in such circumstances is based on the different meanings assigned to it and the different ways in which responders engage with it (Orlikowski 2007). Problems related to action and learning in the Haiti case are found in the situated uncertainty in which technology use and non-use provided teams with insight regarding what particular activities should be prioritized. Pipek and Wulf (2009) discuss the need to distinguish activity spheres by work practice for the infrastructure to contribute to goal achievement, which can be accomplished, the authors argue, by ensuring that all creative activities contribute to someone else's work practice. When organizational procedures require infrastructure changes, a critical issue is maintaining a common view of the particular work object (Jonsson et al. 2009). Lessons learned from performing rescue actions may thus serve as input to the strategic changing of work practices. Such a positive feedback loop consequently reshapes the collaborative infrastructure (Hanseth 2002) as a result of considering action as an outcome rather than a stable organizational foundation (Cordella 2006). Thus, the following research question arises:

RQ1. What are the alternative representations to support diverse action and learning styles of inclusive crisis infrastructure?

Reflexivity
Developments in crisis work practices in which sophisticated information technologies increasingly enable responders to both improvise and be rationally decisive represent the core of IT-based responses (Turoff et al. 2004). In the crisis response information systems literature, there is undoubtedly an excess of rational-based approaches to designing crisis information technology, influenced by Simon's well-known rational decision schemata that sought to explain task-technology performance (March et al. 1958). Interestingly, recent research has stressed the intuitive dimension of crisis response. To this end, sense-making (Weick 1995) has been suggested as a foundation for IT design because of its constructs that extend beyond rationalistic decision-making schemes (Murhen et al. 2008). The participatory design approach has identified needs in the situated medical work context to help workers imagine and explore changes in future practice (Kristensen et al. 2006). The actor-network theory has also informed research concerning which concept knowledge networks have used for accommodating behavioral aspects, collective actions, and cognition as bases for socio-technical CR-IS design (Harnesk and Lindström 2011). These are examples of design approaches that specifically meet the infrastructural aspects, including interconnectedness and complexity, layer approach and standardization, and (in-)visibility, that Pipek and Wulf (2009) consider relevant challenges for infrastructure design. With regard to problems in information flow definitions for boundary-crossing activities during the initial stage of the Haiti earthquake, the reflexivity aspect ensures information transparency between rescue teams. At its core, reflexivity concerns the reciprocal processes of interpreting and interacting with particular artifacts over time. The technology-centric perspective of crisis response information systems has influenced the deployment of different technologies into the crisis infrastructure, calling them pivotal for supporting the interrelatedness of response action perspectives. This type of support fails because it builds on functionalities that standardize organizational actions instead of recognizing recursive dynamic interactions between technology and people (Cordella 2006). Recognizing these contextually bounded conditions implies a shift in the analysis from the information processing position to the processes that produce knowledge to understand the effects of decisions and the foundations of selected information flow models (Harra 2011). Accordingly, it is relevant to ask the following research question:
RQ2. What is required of technology developers to step outside linear models of the task-technology fit perspective and other similar approaches?

Online crisis communication
For the practice of crisis response to acknowledge external informational sources, a relevant question to ask is whether people affected by a disaster are prepared and willing to help others in relief efforts (Harrauld 2011). When and if these people are willing, they will be able to set up an IT-based temporary organization and omit any self-concerns. This organization does not necessarily engage in information sharing with the traditional response system but rather prioritizes communications in the temporary organization. In this regard, the organization has the characteristic of an IT-based ad-hoc network organization, rather than a physical organization, in that it functions using online communication. Thus, online crisis communications represent the third process constructed for inclusive crisis infrastructures. In recent research addressing interrelated perspectives, this type of organization falls into the notion of crowdsourcing (Geyer-Schulz et al. 2010). Munro (2012) argues that people engage in micro-tasking activities in the sense that they can use a platform (e.g., Google Person Finder) to create or update Person Finder records from unstructured reports. One instance of micro-tasking activities during the Haiti earthquake included the initiation of translation-enabled communications between Creole-speaking people and English-speaking responders by establishing a phone number (“4636”) used for sending text messages in Haiti. Approximately 2000 “digital volunteers” collaborated on an online micro-tasking platform to translate texts and identify missing people. For the micro-tasking platform to work, its services must be able to integrate with a message infrastructure, regardless of the message type, and be available to the entire temporary organization. To that end, it is appropriate to ask the following question:

RQ3. How can the interrelatedness of perspectives among those directly affected by a disaster be supported?

The premise including external actors relates strongly to Suchman (2002) argument that “awards should be given not for discrete decontextualized artifacts, but for the collective achievement of new, more productive interactions among devices, and more powerful integrations across devices and between devices and the settings of their use” (p. 99). In this regard, Sutton et al. (2008) demonstrate how IT changes the crisis response arena because technology and society are co-adaptive when producing new types of behavior in the traditional crisis response roles. As several studies of rescue and relief efforts in Haiti demonstrate (Munro 2012), the sourcing of information from external groups and individuals to the formal response system is a key issue associated with connecting the inward- and outward-looking perspectives. The many different platforms that were used to aid in relief actions in Haiti have one important feature in common: they build on peer production of information to fill any blank spaces in the extensive flow of information during rescue and relief operations. For example, Web 2.0 technologies provided online mapping and new interaction channels between physically distant places (Huiji et al. 2011). A description of the Haiti sourcing scenario starts off with a call on Twitter to set up an SMS gateway to report incidents, which then gets translated and geo-tagged on a map to support the decision-making of aid agencies regarding recourse allocation (Zook et al. 2010). People were actually saved from death as a result of geo-tags by being able to send texts saying, “I’m buried under the rubble, but I’m still alive” (Zook et al. 2010, p. 23). This scenario demonstrates that both alternative and mainstream organizations can use social media technology to support a legitimization process in the larger arena of crisis response (Sutton et al. 2008). To that end, Harrauld (2011) argues for the need to shift the focus from the traditional response approach to a practice that recognizes inflow of knowledge from members of the public. Answering the following research question may provide insights into the scope of inclusive crisis infrastructures:

RQ4. How can the knowledge of external groups and individuals benefit inward-looking crisis agencies?

Crisis response and information systems are, to a great extent, perceived as a black box by those individuals not directly involved in rescue operations. However, response may be perceived as a black box even by insiders, which is primarily a cognitive issue that derives from the problem of concretizing the course of response (Weick 2010). In Haiti, this issue was obvious to responders developing an awareness of available recourses and defining how standard operating procedures could be carried out under extremely difficult circumstances. Aside from this operative side of crisis response relationships, members of the public are increasingly active during crisis events, which is not a relationship without problems because responders may observe interference in situations where citizens see active support. In many ways, this situation resembles traditional understandings of role relationships in systems design, in which designers produce artifacts and users consume these products as planned consequences of technology adoption. This conception is underscored by the well-acknowledged view that resources needed for response are always given a priori and that any social structures in which these resources are deployed can be predefined (Burnell et al. 2004; Chen et al. 2008; Jennex 2008; Muhren et al. 2009; Richardson 1994; Roux-Dufort...
2007; Turoff et al. 2004; Van de Walle and Turoff 2008). However, the conception of information technology as a stable entity is outdated because the modern information society is asking for flexible technologies, particularly in dynamic crisis environments (Harra 2011; Jennex 2007). Thus, research into crisis infrastructures should emphasize the study of interactions rather than relationships to facilitate understanding of the relational interplay between technology and people (Cordella 2006; Orlikowski 2007; Jonsson, 2009; Intra and Hayes 2011). For example, interplay is situated activity, which evolves as new actors become involved and are faced with disaster situations (Palen and Vieweg 2008). To connect formal response organizations and members of the public, a construct functioning by virtue of strategically formalizing interplay could facilitate societal involvement in crisis response. According to Harra 2011, the central problem in formalizing societal involvement is that sharing information may be restricted to a closed organizational emergency system. Information restriction may, for instance, hinder automated report summarization of tweets, and texts visualized on social media websites is one way to facilitate large-scale information posting (Huiji et al. 2011).

RQ5. What are the generative mechanisms necessary to orchestrate knowledge sharing in the inclusive crisis infrastructure?

DISCUSSION AND IMPLICATIONS

This paper assumes that the crisis response practice may be both inward- and outward-looking by virtue of interlinked information infrastructures. Versatility, reflexivity, social media, and crisis communications can stimulate a constructive assessment of inclusive crisis infrastructures and create an even stronger association among crisis managers, crisis responders, members of the public, and information technology. In doing so, this paper develops the idea of inclusivity, which refers to a collection of interlinked IT artifacts and resourceful activities that constitute inclusive crisis infrastructures. The inclusive crisis infrastructures illustrate the interplay between crisis organizational properties, responders and members of the public, and information technology in use in that they combine collective IT artifacts and resourceful activities, which may be characterized and labeled inclusivity. This view stands in sharp contrast to information processing-grounded studies that have lead to the development of stable crisis infrastructures instead of the articulation of information practices as results of occurrences that “have no real beginning and no real end; envisage constraints and objectives tending to change continuously en cours de route; are characterized by changing staff composition; and are running the risk of fluctuating morale and motivation” (Murhen et al. 2008, p. 317, emphasis in original). Inclusivity thus represents a frame for understanding interlinking infrastructure capabilities.

Implication for theory

Inclusivity combines the views on capability provided by Pipek and Wulf (2009) and Palen and Liu (2007) with the argument that these views are autonomous and can interlink in the course of any crisis (i.e. accounting for what goes on in the outer circles of the crisis) (Pan et al. 2012). The interlinking mechanism is the language easily understood by crisis response organizations and members of the public. When inclusivity is understood, response organizations and online technologists develop a functional computer-mediated alliance for sharing information on any crisis event and its progress. Inclusivity is nothing short of a logical cultivation of the traditional crisis infrastructure because our collective understanding of crises is no longer shaped exclusively by the “experts” (crisis responders) (Zook et al. 2010). The cultivation of a broader understanding of the crisis response context involves recognizing that the inclusive crisis infrastructure contains elements that are, as Orlikowski and Iacono (2001) note regarding theorization of the IT artifact, “always embedded in some time, place, discourse, and community” (p. 131). Orlikowski and Iacono further develop the argument that the form and function of the IT artifact manifests interaction patterns in a certain context. Constructive social online interactions, regardless of the modes of communication, and inward perspectives of crisis response all share a common idea of knowledge creation that is embedded in canonical ensembles of crisis response. Collective IT artifacts, such as Web 2.0 technologies (e.g., Facebook, Twitter, Youtube, and Google Maps) all support the idea with inclusivity. Opposed to other crisis infrastructure architectures, which are all inward-looking approaches, inclusivity puts online peer-produced knowledge at the center. For instance, collective IT artifacts enables the forming of relationship between individual and collective needs that features learning, instruction, guidance, and access to local information that may otherwise be inaccessible. With respect to the disaster in Haiti, a perspective of inclusivity focus on understanding crisis response as a powerful socio-technical infrastructure performed in practice. Looking at the socio-technical infrastructure and using the notions of social media (Boyd and Ellison, 2007), work infrastructure (Pipek and Wulf, 2009), and crisis communications (Palen and Liu, 2007) results in a broader description of the crisis context. It is a description of communication and information sharing practices that makes inclusivity a salient feature of crisis infrastructures. At the class level, inclusivity attributes particular technologies and particular capabilities to crisis response actors and online technologists through particular instances of collective IT artifacts. As such, inclusivity characterizes the necessary conditions for interlinking the traditional crisis response technologies and emerging online technologies to combine new affordances into existing infrastructures.
Implication for empirical research

Online interaction as a communication mode has been discussed in the literature on alliances and crowdsourcing, which are examples of temporary organizations where collective IT artifacts exist. The literature almost unanimously echoes the widening scene of crisis response in which social media technology has become a primary concern. The five research questions stated above bridge different areas of the literature and offer a path for the systematic analysis of collective IT artifacts in the crisis context. For example, what information-sharing pathway is appropriate under any turbulent and dynamic crisis conditions? Questions 1 and 2 suggest that the traditional work infrastructure in crisis organizations should seek ways to internalize knowledge about relief and aid efforts produced by online technologists. Questions 3-5 suggest that self-organizing groups formed during crises develop communication patterns that have the power to influence and advise official responders to direct their efforts to critical scenes of any disaster. Looking at these research questions from the viewpoint of inclusivity means that the issues highlighted in the Haiti narrative are possible to address systematically. Interlinked features, such as online tweets, are anticipated to aid in aggregation and distribution of information about incoming resources, preparation of standard operating procedures, and supplement determinate CR-IS platforms. It is thus likely that feasible information practices will emerge from better understanding of interlinked infrastructure capabilities.

As suggested by, for example, Jennex (2007), the crisis information infrastructure holds a central position in the crisis response associated with a set of institutionalized information practices. Permanent crisis response staff can describe and explain how information technologies leverage capabilities, such as decision-making and creation of situational awareness (Muhren et al. 2010). In addition to research that use case study methodology and action research methodology to develop IT artifacts to improve crisis information practices the action design research methodology, Sein et al. (2011) provides a promising outlook for further studies in the area. Action design research methodology is specifically tailored toward advancement in IT artifact design and improvement of organizational processes. It is an iterative approach that builds on assumptions about the existing class of problems and instantiations of IT artifacts (c.f. the Haiti case), which are evaluated with regards to the identified research problems in any organizational process context.

With regard to research questions 3-5, it is relevant to ask whether action design research methodology is appropriate for the study how self-organizing groups interlink with traditional crisis response structure. The self-organizing groups appear as a consequence of the willingness among members of the public to aid in different crisis relief operations. This context is populated by anonymous individuals that form a crowd, which can effectively source information to other interested and knowledgeable participants of the crowd. Action design research methodology can be used as an overall research design for studying crowdsourcing although with no organizations involved. For example, by drawing on some general principles that are the result of previous action design research projects, IT artifacts can be designed and deployed to a crowd context. To harness the feedback on IT artifact usage from crowd participants, researchers may use traditional case study methodology or surveys. In fact, several previous studies of online activities including social media technology have used surveys in different forms to capture the knowledge of online self-organizing groups.

Implication for evaluation

A challenge for the crisis infrastructure research community is to determine how the inclusive crisis infrastructure can be evaluated. Any epistemological evaluation approach would have to combine two different methods to analyze interlinked information infrastructures. Because the formal crisis response network has its roots in the information processing perspective, evaluating the inclusive crisis infrastructure will show how design choices reflect the fundamental hypothesis of effective response activities. The evaluation thus follows a variance logic that explains changes in the IT artifacts because designers are often restrained by organizational patterns that reinforce development varieties, assuming full control over IT specifications (Hanseth and Lytinen 2010). With regard to the informal online communication network, designers can only have control over the meta-artifact (e.g., Web 2.0 technology), and members of the public carry out actions and activities using a large number of IT artifacts to collectively unfold emergent crisis information. In this context, evaluators must address a priori designed artifacts and criteria set by online technologists in a fuzzy environment, such as the crowdsourcing community (Harnesk and Thapa 2013).

Evaluators of the inclusive crisis infrastructure should also consider the fact that it is the infrastructure as such, and not the software applications running on it, that should be evaluated. Because IT infrastructures typically are invisible to both designers and end users, evaluators should be attentive to the capabilities that interlinking technologies of local and global infrastructures afford. When the inclusive crisis infrastructure is seen as powerful socio-technical relationship, it is no longer relevant only to evaluate the usefulness or usability of single technologies. This conceptual research instead suggests that evaluation should focus on the affordances of combined technologies and what generative effects that emerge from such socio-technical relationship. That is, generative effects meaning...
how crisis responders can extend their knowledge with peer-to-peer produced knowledge and how members of the public can even more effectively form online alliances to inform others about response progress. One approach to evaluation is to investigate how the seemingly static architectural requirements of local infrastructures (Jennex 2007) interlink with the dynamic and flexible architecture of global infrastructures. A natural scenario is that new technologies will be added over time to the architecture of the global infrastructure. The present paper exemplifies this scenario by using text classification technology, which can be captured and visualized by means of features of global infrastructures (Yin et al. 2012). It is thus important to recognize that inclusive crisis infrastructures produce outcomes that may exhibit emergent features of numerous local and global actions (e.g., use, interpretation), which can only be anticipated by reference to the process of connecting new technologies to local and global infrastructures.

CONCLUDING REMARKS

This paper investigates a previously overlooked phenomenon in crisis response information systems; namely, inclusive crisis infrastructure. By expanding the well-acknowledged infrastructure concept with alternatives to understand the nature and scope of inclusive crisis infrastructures, this paper contributes to closing the gap between theory and practice, which results from the exclusive focus on crisis events. Established crisis response information system perspectives are inward-looking and aim for resource efficiency, attributes that do not warrant consideration of information sharing, and knowledge production outside response routines. The proposed infrastructure expansion is subject to a socio-technical theory incorporating three main factors: (1) versatility, (2) reflexivity, and (3) online crisis communications. The notion of inclusivity provides a way to handle the challenge of maintaining the benefits that a wider scope of crisis information sharing can generate in the interactive crisis response context.

The interplay between interlinked crisis infrastructures could have been discussed at the micro-level, where, for example, information misfit occurs as a consequence of non-integrated IT artifacts. In doing so, this study would have aligned itself with mainstream crisis literature and continued to have an explicit IT focus on the disaster event, although this is still important because crisis response depends heavily on sophisticated information technologies for effective response. However, such a focus actually limits the broader understanding of the contextual position associated with IT artifacts. At the same time, a decision to design or re-design the traditional crisis infrastructure may be dictated by internal organizational features, which risks paying less attention to external information sources. The plan for further elaboration of this pathway is the development of interlinking mechanisms of the inclusive crisis infrastructure, which includes, for example, what implications these mechanisms generates for inclusion and exclusion (i.e., sustaining inward-looking perspectives or not).

This study will hopefully stimulate further research by providing a fundamental proposition for the nature and scope of inclusive crisis infrastructures. Several questions are left unresolved, but the present paper suggests some research questions that should be addressed to successfully develop inclusive crisis infrastructures. This avenue concerns, for example, the assessment of which of the many Web 2.0 technology platforms emergency agencies should interlink with. Crowdsourced translation, filtering techniques, and the categorization of data (Huji et al. 2011) are examples of technical mechanisms that qualify as collective IT artifacts in the inclusive crisis infrastructure. Methodologically, action design, and particularly action design research, could be used to explain the functionality of inclusive crisis infrastructures. In particular, the problem of understanding the behavior of external information sources in relation to traditional response systems needs further investigation because the primary concern for both instances is action with intentional outcome.

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ISSN: 1532-3416