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Crisis response information networks

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Abstract

In the past two decades, organizational scholars have focused significant attention on how organizations manage crises. While most of these studies concentrate on crisis prevention, there is a growing emphasis on crisis response. Because information that is critical to crisis response may become outdated as crisis conditions change, crisis response research recognizes that the management of information flows and networks is critical to crisis response. Yet despite its importance, little is known about the various types of crisis information networks and the role of IT in enabling these information networks. Employing concepts from information flow and social network theories, this paper contributes to crisis management research by developing four crisis response information network prototypes. These networks are based on two main dimensions: (1) information flow intensity and (2) network density. We describe how considerations of these two dimensions with supporting case evidence yield four prototypical crisis information response networks: Information Star, Information Pyramid, Information Forest, and Information Black-out. In addition, we examine the role of IT within each information network structure. We conclude with guidelines for managers to deploy appropriate information networks during crisis response and with suggestions for future research related to IT and crisis management.

Keywords: *Crisis Response, Information Networks, Role of IT, Information Flow, Network Density.*

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1. Introduction

The occurrence of several large-scale natural disasters in the past two decades -- e.g., the Severe Acute Respiratory Syndrome pandemic, Hurricane Katrina, Asian Tsunami disasters and the Swine Flu epidemic -- has attracted significant public attention and ignited interest among researchers (Thomas & Fritz, 2006; Weick, 1993; Lin, Zhao, Ismail, & Carley, 2006; Junglas & Ives, 2007; Majchrzak, Jarvenpaa, & Hollingshead, 2007; Billings, Milburn, & Schaalman, 1980; Van de Walle, Van Den Eede, & Muhren, 2009; Mitroff, Pauchant, Finney, & Pearson, 1989; Quarantelli, 2001; Rubin, Amlôt, Page, & Wessely, 2009). While extensive work has focused on preventing crises under the assumption that crises are avoidable (Augustine, 1995; Kash & Darling, 1998; Salmon, 1993), the recognition that poor crisis response can result in a humanitarian catastrophe of far larger magnitude than the damage caused by the original event itself (Junglas & Ives, 2007; Hynes & Prasad, 1997) is leading to a growing body of research emphasizing crisis response (Leidner, Pan, & Pan, 2009; Hiltz, Van de Walle, & Turoff, 2010).

One element of crisis response that is particularly important to large-scale disasters is that of information flow and network management (Housel, El Sawy, & Donovan, 1986). Managing information flows is critical in crisis situations because decision making is bounded by time urgency, and information may become outdated as the crisis conditions change (Majchrzak et al., 2007; Hale, 1997). Furthermore, decision makers face the challenges of information overload; the availability of fewer communication channels; and the omitting, delaying, and filtering of information, and processing of incorrect information during crises by intermediate message-handling units (Nunamaker, Weber, & Chen, 1989; Sniezek, Wilkins, Wadlington, & Baumann, 2002). To cope with crises in an efficient and highly coordinated manner, updated crisis information must be allowed to flow vertically and horizontally among crisis response organizations in a rapid manner (Hale, Dulek, & Hale, 2005).

The aim of this paper is to analyze the different approaches to structuring information networks during crisis response and to investigate the role of IT in these information networks. Drawing upon concepts from information flow and network theory, we use a comparative case study of the responses to four major societal crises to develop four prototypical crisis information response networks. The two main dimensions of our framework are (1) information flow intensity and (2) network density. Our prototypical networks provide a basis for further research into IT and crisis response and allow practitioners to understand the development and use context of the information networks they implement during crisis response.

Our paper is organized as follows: we begin with a review of information flow and network research. We then present our research method and cases. We conduct within-case and cross-case analyses. Our implication focuses on the role of IT in crisis response information networks. Finally, we present some research and practical implications.

2. Theoretical Foundation: Information Flow and Information Networks

Information flow is an important topic in several streams of organizational research, including organization design (Te'eni, 2001), supply chains (Sahin & Robinson, 2002), and social networks. The latter stream of work is particularly relevant to crisis response situations because responding agencies are often not a single organization but multiple organizations with varying degrees of pre-existing relationships. The network of responding agencies must be quickly assembled and coordinated. Social network research distinguishes networks according to the type and level of ties (i.e., individual, organizational, and institutional) comprising the network (Bell & Zaheer, 2007; Suarez, 2005). Existing ties, be they individual, organizational, or institutional, imply a well-established, trust-based relationship (Krovi, Chandra, & Rajagopalan, 2003; Pan & Pan, 2006). The strength of the ties depends on several factors such as the amount of time spent together, the emotional intensity, the intimacy, the reciprocal services associated with the relationship (Granovetter, 1973), the sense of belonging, and the perception of the actor's role importance (Hahn, Moon, & Zhang, 2008; Pan & Pan, 2011). The diffusion of information – e.g., information flow -- is influenced by network ties. The degree to which network ties

influence the information flow depends on whether the ties are strong or weak. Strong ties are likely to promote high quality information transfer between parties and serve as effective conduits of information (Rowley, Behrens, & Krackhardt, 2000; Adler, Goldoftas, & Levine, 1999), especially among formalized networks (Ghoshal, Korine, & Szulanski, 1994; Granovetter, 1973; Levin & Cross, 2004; Pan, Pan, Chen, & Hsieh, 2007; Tan, Pan, & Hackney, 2010). Weak ties, however, may provide access to information only in outer social circles but may provide a large amount of information (Granovetter, 1973). Generally in an organizational setting, it is important to establish strong ties among actors in order to enhance team performance (Gruenfeld, Mannix, Williams, & Neale, 1996) and to establish weak ties in order to promote innovation (Gilsing & Nooteboom, 2005).

In a crisis situation, there is no time for the time-consuming process of developing and nurturing close ties; rather, responders must draw upon their existing ties but also quickly establish new ties. The ties are part of a complex network of responders. For example, in a typical response to a hurricane in the state of Florida, more than 300 responders from 50 different agencies will be activated, each with different specialized expertise (Xia, Becerra-Fernandez, Gudi, & Rocha, 2011). Given the large number of responders and agencies involved, the structural complexity of the response network is very high (Xia et al., 2011). Consequently, one essential element concerning information flow in crisis response is the design of a structure of information flow among agencies that ensures proper flow of information to and from the relevant agencies. We refer to this structure of information flow in crisis response as the crisis response network.

Among the key activities of the crisis response network is to ensure that resources are effectively and efficiently allocated to the affected individuals. In order to properly collect and allocate resources, responders require detailed ground information, detailed information about available resources, and detailed logistics information, as well as information about where responders are located and their access to resources. It is the responsibility of the central responding agency – the agency that oversees the coordination of all other responding agencies – to establish the protocols for collecting, storing, sharing, and distributing information (Pan, Pan & Devadoss, 2005). Traditionally, disaster planners and managers have advocated top-down, centralized command and control during emergency situations (Moynihan, 2008; Rosenthal & Kouzmin, 1997). However, some have argued that the centralized command and control may not be a good model (Lin et al., 2006). Because the detailed information must move at a rapid pace and across a variety of sources, existing information channels and routines are often too slow, disconnected, and inadequate to meet the needs of crisis information flow (Majchrzak et al., 2007). As a result, other forms of crisis response networks may need to be considered in order to improve information flow.

Recent work on information flow in crisis response has focused on the impediments to information flow (Day, Junglas, & Silva, 2009), identifying seven major impediments to the flow of information across a crisis response supply chain network. The seven impediments are data inaccessibility, data inconsistency, inadequate stream of information, low information priority, source identification difficulty, storage media misalignment, and unreliability (Day et. al., 2009). Technology may play a role in overcoming the impediments to information flow. Pivotal in supporting information processing and disseminating activities during crisis response are emergency management information systems (Hiltz et al., 2010) or crisis information systems. To be effective, crisis information systems ought to consider who the participants are, what they aim to achieve, and what the relationships are among them (Jul, 2010; Quarantelli, 2005). Emergency management information systems play an active role in simplifying data and minimizing filtering, supporting feature matching, reducing cognitive overload, directing attention efficiently, reducing confirmation bias, and aiding diagnosis during crisis response (McKinney, 2008; Turoff, Van de Walle, & Hiltz, 2009).

Most of the work on IT in crisis response has focused on the role of IT in coordinating information flow across responders (Leidner et al., 2009; Manoj & Baker, 2007). Less, if any, attention has been paid to the processes of communicating with victims and with the public. Because of the large number of potential stakeholders involved, a primary challenge in crisis response is the process of stakeholder informing (Leidner et al., 2009; Majchrzak et al., 2007). Indeed, the process of resolute informing is a central activity that involves creating new, or modifying existing, communication and information channels to ensure the timeliness of information delivery from multiple sources (U.S. National

Research Council, 2005), the avoidance of information overload (Turoff, Chumer, Walle, & Yao, 2004), and the establishment of accountability with fragmented information across stakeholder groups (Leidner et al., 2009; Marcus & Nichols, 1999; Chen, Sharman, Rao, Upadhyaya, & Cook-Cottone, 2010). Recent work suggests that the public sometimes develops its own informing process during crises, when it is unable to get what it deems as reliable, timely information from the central responding agencies (Day et al., 2009).

The above review of the literature on information flow during crisis response suggests that information flow is an essential element of crisis response and that the effectiveness of the crisis response network will be influenced by the role of the central responding agency, the role of IT in helping coordinate the diverse agencies involved, and the means of communication with stakeholders. Yet the literature is not specific on the different types of crisis response networks or how the network type influences information flow. Our study addresses these issues. Using case studies of the information processes developed during the crisis response activities following four independent crises, our study will uncover different structures of information networks that result in varying degrees and intensity of information flow.

3. Research Approach

We adopted a qualitative research approach with a multiple case design in order to ensure exposure to different forms of crisis information networks. The selection of the cases was guided by the principle of theoretical replication (Yin, 1994). We selected and successfully obtained access to two case sites and carried out extensive primary data collection. Given the limited access to more crisis response case sites, we turned to secondary data collection. We selected cases in extreme situations and polar types in which the process of information flow is "transparently observable" (Pettigrew, 1988). Each of the four cases was contextualized in a large-scale natural disaster setting. The organizations involved in this study were comprised of mostly public-sector organizations with only one being a private, non-profit organization. While all of these cases have similar characteristics to some extent in that they were large-scale natural disasters requiring the involvement of local, regional, and national aid organizations, we sought variation in other characteristics to tease out further compelling evidence. For example, the approaches to crisis response and information management were different across the four cases. Our goal was to expand and generalize theories (analytical generalization) rather than to engage in statistical generalization (Yin, 1994; Myers & Newman, 2007; Pan & Tan, 2011). The four cases we studied were: the Severe Acute Respiratory Syndrome (SARS) crisis in Singapore, the Sri Lanka tsunami crisis, the Cyclone Nargis crisis in Burma, and the Hurricane Katrina crisis in the US. The unit of analysis is "network." The four different networks represented in the four cases are summarized in Table 1 below.

Table 1. A Summary of Four Crisis Response Networks

Data Collection	Information Flow	Name of Crisis	Crisis Response Network	Organizations Involved	Date of Crisis Occurrence
Primary	High intensity and density	Severe Acute Respiratory Syndrome Crisis	Singapore Government Agencies	Singapore's Defence Science Technology Agency, Ministry of Health and 12 other Government agencies	March, 2003
Primary	High intensity, low density	Sri Lanka Tsunami Disaster	Tzu Chi Voluntary Organization, Taiwan and its Overseas Branches	Tzu Chi Taiwan, Malaysia and Host Countries' Voluntary Organizations	December, 2004
Secondary	Low intensity, high density	Cyclone Nagis Crisis	Government of Burma & International Relief Organizations	Burmese Government, Red Cross Organization, and Several Others	May, 2008
Secondary	Low intensity, low density	Hurricane Katrina Crisis	US Government Agencies	City, State of Louisiana and US Federal Government	August, 2005

3.1. Data Collection

Of the four cases analyzed, we conducted primary data collection in two cases and secondary data collection in the other two. For the case of the SARS crisis, field research began in August 2005 at one of the working groups participating in the SARS crisis response, Singapore's Defence Science Technology Agency (DSTA). Altogether, we conducted 16 interviews of senior managers and members of the crisis response team. For the Sri Lankan tsunami crisis, we interviewed key members from Tzu Chi Voluntary Organization (Tzu Chi), a Taiwanese not-for-profit organization that participated in the Sri Lanka tsunami disaster relief mission. Altogether, we conducted 18 face-to-face interviews between April 2005 and January 2006. The interviewees selected for both cases comprised mainly the key members of the crisis response teams. The interviews lasted approximately one to one and a half hours each. Crisis management, information flow, and social network theories guided the design of the interview questions.

These interviewees represent various "voices" (Myers & Newman, 2007). Gathering different perspectives is important for triangulation purpose (Rubin & Rubin, 2005) and to prevent elite bias (Miles & Huberman, 1994). For both cases, the interviews included a variety of questions concerning how crisis information flow was managed during the dire period and the factors that affected the way information was disseminated. We inquired about how updated information was published publicly and the amount of information organizations were collecting and transmitting during the response period. The interviews also included more general questions designed to give interviewees the chance to express their opinions on the crisis response experience (refer to Appendix A for excerpts of interview topic guides). All interviews were tape-recorded and transcribed. Summaries were generated from the transcribed texts.

For the cases of Cyclone Nagis and Hurricane Katrina, we used secondary documentation from a variety of sources as the text to be examined (i.e., major periodicals and information from several governmental and private, not-for-profit organizations' websites that emerged after the disaster events). We were inspired by several previous studies that deemed secondary data effective and useful in explaining vulnerable and sensitive settings (Cowton, 1998; Davidson, Worrell, & Lee, 1994; Barley, Meyer, & Gash, 1988; Church, 2002). Altogether, we identified and studied 37 articles. Refer to appendices B and C for the reference details of some of these articles. We focused our data collection on articles reporting the relief activities carried out by major crisis responders (e.g., Federal Emergency Management Agency; US Department of Health and Human Services; Asean Humanitarian Relief Efforts for Victims of Cyclone Nagis) and other media reports on the two crises (e.g., New York Times; CNN; The Guardian). Media reports and analyses pertaining to responses to both disasters were deemed relevant to our data gathering efforts as they represent a "faithful mirror of reality" (Franzosi, 1995, p. 166). We first identified articles with titles or keywords that included Cyclone Nagis or Hurricane Katrina. After reading the relevant articles, we highlighted the sentences that described the crisis response actions, and the topics that emerged included: what were the response strategies and plans, what actions were taken, and who was involved. On several occasions, we revisited articles we had analyzed previously and provided linkages to other articles if they provided similar reports or analyses (Harris, 2001; Insch, Moore, & Murphy, 1997).

3.2. Data Analysis

We carried out data analysis by recursively iterating between the empirical data, the theoretical lens, and the relevant crisis management literature. The iteration helped to shape our four emerging prototypical crisis response information networks. We continued the iterative process until the state of theoretical saturation was reached, that is, when it was possible to comprehensively explain the findings of the case study, and no additional data needed to be collected or added to improve the developed prototypes (Eisenhardt, 1989). We began our analysis by reading all transcripts and documents and highlighting the descriptions that were related to the crisis information flow management process. Social network theory sensitized us to the importance of information flow but stopped short of indicating the precise characteristics of flow that might be relevant to code. Therefore, we used analytic induction (Taylor & Bogdan, 1998) to uncover new constructs and relationships that could enrich our understanding of the phenomenon and assist our theory building process (Patton, 2002). Analytical induction involved the following steps (Goetz & LeCompte, 1981):

(1) defining phenomenon in a tentative manner, (2) scanning data to identify categories, (3) developing typologies, (4) determining the relationships that exist among categories, and (5) continually refining categories until all are accounted for. Table 2 below summarizes the analytic induction procedures adopted in this study.

Table 2. A Summary of the Analytic Induction Procedures Adopted in this Study

Steps of Analytic Induction		Additional Description	Illustration (where applicable)
1	Defining a phenomenon in a tentative manner	Formulating provisional statements about the phenomenon	Our review of the literature on information flow during crisis response informed the importance of information flow during crisis response and that the effectiveness of the crisis response network will be influenced by several attributes. The literature review provided the tentative theoretical foundation of the phenomenon
2	Scanning data to identify categories	Creating descriptive codes that require little or no inference beyond the data itself (Miles & Huberman, 1994)	We conducted line-by-line coding that helped us to focus on the content of the text in the line and allowed us to develop our coding categories: information flow and direction, and network density
3	Developing typologies	Creating inferential codes that pull together data into smaller and more meaningful units (Punch, 2005)	We analyzed the coding categories in each case and subsequently compared them across the four cases. The analysis led us to derive four crisis network response information structures
4	Determining the relationships that exist among categories	Developing theory or statement that helps in understanding the phenomenon by determining the relationships among the categories	We studied the relationships among the categories and found that the four information network types vary in the amount of information the network is able to process (information intensity), the direction of the flow of the information (top-down vs bottom-up), the overall reach of the information (density), and in the role of the central organizational response agency (refer to Table 5)
5	Continually refining categories and roles until all are accounted for	Data continue to support and substantiate the emerging categories (Holton, 2007)	Our iterative process continued until it was possible to comprehensively explain the four information networks and their structures, and no additional data needed to be collected or added to improve the developed prototypes

To establish the patterns of information flows among the crisis response organizations, we first listed the types of information relevant to the crisis response process (refer to Table 3).

Table 3. Types of Crisis Response Information

Information Element	Crisis Information Content
Personnel Status	Registration of personnel, exact location of personnel, and personnel tracking system. Personnel with first aid and fire rescue experiences
Infrastructure	Location of emergency aid equipment. Details of crisis management system specifications, e.g., hardware and software. Established physical communication networks such as telephone and radio
Crisis Management and Notification	Emergency plans and organization, emergency preparedness practices, and existence of test scenarios. Communications within rescue organizations, such as report lines between rescue leader, assistants, rescue personnel, press, and public administration
Area Access	Geographical information such as infrastructure, one-way streets, blocked access routes, road barriers, parking, and helicopter landing areas

We then developed a list of common themes including information flow speed and network density, which dealt with information handling during the crisis response, and two more general categories involving stakeholders and resources (Refer to Table 4 below). Speed and volume of information were two prominent components of information handling, which we label information intensity. A second information-handling category concerns the direction of information flow. Here we looked for evidence of information flowing top-down or bottom-up. Based upon the data, we added an unexpected flow, in silo, to reflect response networks where information flowed around silos but not across silos. Another theme we found repeatedly was network density -- the concentration of nodes in the crisis response network. We looked for evidence that indicated the concentration of organizations.

Table 4. Excerpts of Coding Categories

Category	Description	Sample Code Category	Excerpts of Transcripts
Stakeholders	Variety of stakeholders involved and affected by crisis response	Main responsibility Authority Hierarchical level	(a) "a nine-member inter-ministry SARS task force was set up with the Home Affairs Minister leading the crisis response operation" (b) "many foreign aid organizations were made to wait anxiously for approval from the Burmese Government to deliver loads of emergency supplies to the cyclone victims"
Resources	Resources deployed during crisis response	Manpower Funding Equipments and vehicles IT expertise Availability of IT infrastructure and applications	(a) "DSTA developed a crisis management system" (b) "Tzu Chi mobilizes and coordinates volunteers arriving from the Taiwan Headquarters, the host countries, and from the neighboring countries" (c) "Humanitarian organizations became wary of handing over millions of dollars' worth of food and equipment to the military government"
Information Flow Intensity	Speed and volume of information diffusion during crisis response	Immediate Delayed Volume Frequency	(a) "the Health Minister of Singapore would provide daily updates of SARS outbreak" (b) "Tzu Chi relief teams would receive instructions and updates of the response progress twice a day" (c) "Large information had to be drawn from hospitals, Ministry of Health, clinics and traditional Chinese medicine practitioners" (d) "the Burmese Government banned information concerning the crisis response situations"
Network Density	Number of intermediate nodes in the information processing channel	Information intermediaries Sources and destinations	(a) "The SARS command center deployed 14 ministries and statutory boards to combat the national crisis"
Direction of Information Flow	The predominant transportation mode for information	Top-down Bottom-up In silos	(a) "Throughout the entire saga, the Junta leaders kept information flow to foreign aid organizations to a minimum" (b) "Bureaucracy slowed the entire relief action and initiative. For example FEMA being part of the Department of Homeland Security became a layer down the hierarchy. All these layers further delayed clear crisis response messages being sent out early"

Coding categories reflect our interpretations of the information flow management process during crisis response. We conducted an initial pilot run for coder training and pilot testing of reliability. During the pilot run, we also refined the coding instrument and procedures. To establish the reliability of the coding, each coder was asked to quote a particular segment of the relevant texts. Coding was conducted independently and without consultation and guidance. We examined the portions of the codings where both coders agreed and measured the inter-coder reliability using Cohen's Kappa

coefficient. Our coefficient score of 0.77 suggests substantial agreement between the two coders, and the result also demonstrates that the categories were clearly defined and could be located in the text with little ambiguity. As the reliability coefficient was high, each coder was subsequently asked to code separate portions of the texts. We sorted relevant interview comments and secondary reports according to the various categories and developed a list of themes within each category (Harris, 2001). The list contained the location of each comment on the transcript, the transcript number, the interview date, any links to other comments, reports, and sources of news coverage. In addition, we looked for evidence in the transcripts that indicated the relativity of our two dimensions. The next step in our analysis was to analyze the information flow and direction, network density, stakeholders, and resources in each case and, subsequently, compare across the four cases. This led us to derive four crisis network response information structures (described in the Within-Case and Cross-Case Analysis Sections). In order to reduce researcher bias, a senior colleague was asked to take part in early analysis of some of the data. The colleague was uninvolved in the fieldwork and was, therefore, unfamiliar with all four cases. The role of this colleague was to bring a different and possibly more objective eye to the evidence and detect any bias in data analysis.

Overall, our findings revealed patterns that conformed to the information flow, network, and crisis management literature in that the importance of information flow activities was underscored in each case, with two providing examples of effective information flow and two providing examples of ineffective information flow. But our findings go beyond the existing work by uncovering four crisis information network approaches that had yet to be explored in existing crisis management literature. The next section presents the background information of the four cases, describes the events that happened, and analyzes how information flows and networks were managed during respective crisis response operations.

4. Case Description and Analysis

4.1. Within-Case Analysis

For each case, we explain the center of the crisis response operations – its major activities as well as how it was organized, the technologies used in support of the center of operations, and the nature of communications with stakeholders. These three categories of analysis, derived from our review of the literature, enable us to understand what information was gathered by whom (e.g., the activities and structure of the center of operations), how the information was gathered and disseminated (the technology in support of the center), and with whom the information was shared (the communication between the center and stakeholders).

4.2. Case 1: SARS Crisis – Singapore Government

The SARS outbreak in March, 2003 was a national health crisis in Singapore. Within two days of being notified of the first several cases of the virus, a nine-member inter-ministry SARS task force was established to coordinate the crisis response operation. The Minister explained the crisis response strategy: “Our national strategy against SARS has three prongs: First, to detect and isolate SARS cases as early as possible. Second, to ring-fence detected or suspected cases, hospitals and clinics and personnel treating SARS cases and adopt robust screening and infection control procedures. Third, to contain the spread of the virus and guard vigilantly against outbreak in the wider community.” Initially, the Ministry of Health used an ad-hoc spreadsheet to maintain a list of infected patients and potential contacts that were required for medical confinement. Within two weeks, a crisis management system was developed to process and distribute information necessary to coordinate various crisis response activities across some 14 government agencies. The information included hospital contact tracing, daily SARS updates, border control, community contact tracing, and the issuance and supervision of home quarantine orders. To develop the case database, information had to be drawn from hospitals, the Ministry of Health, clinics, and traditional Chinese medicine practitioners. The isolation, preventive, and containment measures the government implemented proved highly effective. Although SARS spread rapidly and there was little medical knowledge available on how to treat it, Singapore experienced only 238 cases. Within three months of its first reported cases, Singapore was removed from WHO's list of SARS-affected countries.

4.2.1. Center of Crisis Operations

In responding to SARS, the Singaporean government set up a SARS command center under the direction of the Home Affairs minister supported by 14 government ministries. Various government agencies focused on specific informing issues. For example, the Ministry of Health monitored the spread of SARS and the movements of individuals who had been exposed to SARS. The Ministry of Finance provided the information on Central Provident Fund contributors, which accounts for virtually everyone in the Singapore workforce, thereby enabling individuals to be traced from that single database. The Ministry of National Development conducted a survey to assess the level of public confidence in fighting SARS. The Civil Aviation Authority of Singapore issued directives to airlines and ensured compliance with SARS preventive measures at the airport. The command center received information from these various agencies and then disseminated it to other agencies with little delay.

4.2.2. Technology Support for the Center of Operations

To support SARS command center's response activities, the Defense Science and Technology Agency (DSTA) developed a crisis management system. The system provided applications to track the movement of individuals infected with, or exposed to, SARS. The system captured data on patient information, infection status, and relation to other patients or contacts. The information helped generate a better understanding of the spread of infection. It allowed for the identification and notification of potential people at risk through its linkage to the reference database. The system required data from several agencies, including the Ministry of Health, the Ministry of Education, the Department of Transportation, hospitals, and hospital staff. The agencies worked independently to gather information. For example, the Ministry of Health kept track of individuals who had been served Home Quarantine orders. Quarantined individuals were required to appear on demand before web-based cameras plugged into telephone lines. This allowed the Ministry of Health to monitor the patients' compliance with the quarantine orders. DSTA attempted to add continuous improvements and functionalities to the system that was built over the course of the first two weeks after the first SARS case was identified. The CIO of DSTA commented: "Every night, I would go through the emails exchanged by various heads in the government and incorporate their suggestions into the system. It was an extremely useful communication mechanism."

4.2.3. Communication with Stakeholders

Data from the crisis management system were used to generate reports that provided the command center an accurate update. These updates were provided to the various agency heads, who exchanged information, feedback, and suggestions for further actions. Thus, the crisis management system developed to support the command center became the central tool to establish information flow to and from various agencies. To communicate with the public, the Minister for Health would hold a daily press conference to update the nation on SARS crisis. In communicating with the patients and the general public, the command center relied heavily on media broadcasts. In collaboration with local broadcasting companies, the Ministry of Health launched a free to air channel that focused exclusively on SARS. Apart from the latest updates on SARS, it aired re-runs of programs about SARS, related cable programs from foreign channel partners, and public education spots that gave tips on precautions people could take against SARS. The media acted as a "mediator between the government and the public" to keep the public informed about what the government was doing. Furthermore, the Feedback Unit, a government agency that coordinates public feedback on government policies and measures, gathered feedback from citizens through its online forums. Through these manifold information gathering and dissemination actions, the SARS command center ensured that corrective measures were openly communicated to all stakeholders. Moreover, the command center was able to transcend the political quagmire of multiple agencies, each with a separate agenda, creating "tele-cooperation" through the use of information technology.

4.3. Case 2: Sri Lanka Tsunami Disaster – Tzu Chi Voluntary Organization

Tzu Chi is a Taiwanese-based private, not-for-profit organization that has been involved in many international disaster recovery operations. Known for its rapid mobilization of its volunteers during crisis response, Tzu Chi mobilizes and coordinates volunteers arriving from the Taiwan Headquarters, the host countries, and from neighboring countries. On December 26, 2004, an earthquake struck under the Indian Ocean, 250 kilometers northwest of Indonesia's Island of Sumatra and triggered a tsunami. The tsunami devastated 13 countries' coastlines, leaving more than 280,000 people dead

and millions homeless. Among those countries severely affected was Sri Lanka. More than 35,000 people were killed and 443,000 people lost their homes in Sri Lanka during the tsunami disaster. The overall damage to Sri Lanka was estimated at US $1 billion, with a large proportion of losses concentrated in housing, tourism, fisheries, and transportation. In the aftermath of the tsunami, Tzu Chi lent its support by collecting and assessing the ground information at Sri Lanka. Following this initial situational assessment, Tzu Chi then developed a response plan and set up a relief coordination center in Taiwan.

To support the extensive crisis relief activities in Sri Lanka, Tzu Chi had to raise funds. It called on volunteers worldwide to donate and appeal for donations. Tzu Chi promoted the fundraising campaign and broadcasted updated information about its relief missions at Sri Lanka on its television channel "DaAi TV." Besides television, Tzu Chi also posted daily updates on its website. According to the Sri Lanka Tsunami Operational Director: "Many visitors visited our website and in record numbers. Some even had trouble, for the first 2-3 days, accessing our site." Because of its efforts to establish transparency and accountability in managing the raised funds, Tzu Chi gained credibility from donors and beneficiaries. According to Tzu Chi's Secretary of Information Integration: "We had a policy of updating our website regularly to inform donors how their donations were used, our relief activities, and the resources used for each relief mission. By publishing the information publicly and regularly, it helped to improve our credibility and earn the donors' trusts." Altogether, there were approximately 57,000 volunteers in Taiwan and 27,000 volunteers in 29 countries that helped raise funds. In Taiwan alone, Tzu Chi raised US$14.06 million within two weeks, all of which supported the relief efforts.

4.3.1. Center of Crisis Operations

In the case of the tsunami aftermath in Sri Lanka, personnel in Tzu Chi's headquarters scheduled and coordinated the relief efforts on the ground at Sri Lanka. The partner organizations were dependent on updated crisis information transmitted by Tzu Chi Headquarters. The hierarchy was relatively flat, with headquarters' personnel working directly with response organizations. Information coordination was facilitated by prior relationships formed either in previous joint relief efforts or in annual social meetings. Tzu Chi aggregated ground information provided by Tzu Chi crisis relief teams, who collated information and needs directly from local community and government representatives. According to Tzu Chi's Secretary of Information Integration: "We acted very fast in gathering the ground information and followed the news from local and international media closely. It was crucial to obtain the initial situational information since it would determine the way we prepared for relief missions." The updated crisis information and the directives from headquarters helped the ground operation in many ways. According to the commander: "It helped to ensure efficient supply of required assets to relief missions, and track assets deployed. We also had to move the manpower and high-priority equipment quickly, and establish forward operational storage locations to support our ground operations."

4.3.2. Technology Support for the Center of Operations

The telephone and electronic mail were relied upon as the primary communication technologies to aid communication between the ground operations and the headquarters. Individuals carrying out missions on the ground provided daily information updates. Daily face-to-face meetings were conducted to "summarize the relief activities and account for the progress." The progress was then reported to the Tzu Chi Headquarters through fax and telephone. A large bulletin board was used on site with detailed descriptions of daily operation updates. By consulting the headquarters, decision-makers on the ground received alternative but feasible options for crisis response. In most circumstances, such consultation exercises proved useful since time did not allow for the generation of structurally different alternatives on the ground. Tzu Chi adjusted its operational plans frequently to suit changing circumstances on the ground.

4.3.3. Communication with Stakeholders

Whereas the telephone, fax, and email were the primary communication tools to reach the response agencies, the world-wide web was the main communication tool to reach potential donors and volunteers. Tzu Chi had a policy of updating its website regularly. According to the Secretary of Information Integration: "We had to inform our volunteers and donors of our relief activities, and the resources used for the mission. By publishing the information, it helped to improve our credibility and earn the donors' trusts and volunteers' continued support."

Overall, even though Tzu Chi deployed a less sophisticated set of communication technologies relative to the SARS case in Singapore, it was agile in collecting data and establishing an information flow that enhanced its speed and effectiveness in deploying its resources during disaster response.

4.4. Case 3: Hurricane Katrina - USA

On August 28, 2005, Hurricane Katrina hit the southern coast of the United States with devastating effect, resulting in some 1,800 deaths and more than US$81 billion dollars in damage. In spite of warnings from the National Hurricane Center that Katrina was strengthening to a Category Five storm, the highest level, the Federal Emergency Management Agency's (FEMA) director, Michael Brown, did not order a mandatory evacuation. New Orlean's mayor, Ray Nagin, did declare a state of emergency and ordered voluntary evacuation; however, the order came less than 24 hours before the hurricane struck in the early morning hours of August 28, and many people, especially the very vulnerable, such as those in elderly homes and hospitals, were unable to be evacuated in time.

After Hurricane Katrina struck, the city and state expected federal help in the form of troops to aid in the rescue of survivors. However, the federal government refused to send in the troops until the state formally requested them. The state request was delayed as a result of the state not immediately approving the federal government's relief plan. According to an observer: "Bureaucracy slowed the entire relief action and initiative. For example FEMA being part of the Department of Homeland Security became a layer down the hierarchy. All these layers further delayed clear crisis response messages being sent out early. No layer is a good layer."

The scenes that arguably most shocked the world took place at the Superdome and the convention center, with thousands of people sleeping in the stadium, restroom facilities overflowing, and garbage accumulating. Yet it turned out that neither FEMA's director nor his boss, Homeland Security Secretary Michael Chertoff, knew about the crisis at the convention center until four days after the hurricane had hit Louisiana. Given that the Superdome was the designated shelter for survivors without homes, one might presume that those leading the federal relief effort would have received information about the squalid conditions of the shelters. But according to Chertoff, "The very day that this emerged in the press, I was on a video conference with all the officials, including state and local officials. Strangely none of the state and local officials told me about the convention center." Refugees from the hurricane were eventually transferred to more viable shelters in other cities and states, but the US government endured great criticism for its slow and seemingly disorganized response to the Katrina crisis.

4.4.1. Center of Crisis Operations

In the Katrina crisis, there was lack of clarity at the onset concerning which governing body formed the center of the response effort. Most looked to FEMA as the center of response operations, but the fact that FEMA was embedded within the Department of Homeland Security raised questions about who was actually in charge of the disaster response and which department had jurisdictional authority. In addition, being part of the massive, terrorism-focused Department of Homeland Security, the director of FEMA, Michael Brown, confessed to having underemphasized its role in natural disaster response.

As a result of the confusion concerning what governmental entity was supposed to be coordinating the response effort, there were delays in information processing and transmission. The city, state, and federal governments were not only internally slow to gather information, partly because they might have expected someone else to be gathering the information, they were notoriously ineffective in sharing information with other major entities. In fact, there was no central body overseeing the sharing of information and there was confusion as to who was responsible for what.

4.4.2. Technology Support for the Center of Operations

To make matters worse, Hurricane Katrina crippled most routine telephone and cell phone communication because of line breaks, damage to base transceiver stations, and power failures. The damaged communication infrastructure left many key emergency response personnel with limited means of communicating with one another. In New Orleans, hundreds of police officers were left trying to communicate on two radio channels using a back-up system. However, the back-up system became overwhelmed due to high volume, resulting in delays before their messages could get

through. In addition, telephone lines experienced interruptions or were completely out of service. This combination of overwhelmed back-up systems and interrupted phone lines obstructed the flow of relief information (Piper & Ramos, 2006).

4.4.3. Communication with Stakeholders

Local residents as well as the larger public were highly dependent upon the media for information. But the media could not provide the level of detail that the larger public needed: People wanted to know the whereabouts of their family and friends who had been impacted by the hurricane, but there was no resource to provide this information. In fact, at Red Cross shelters, individuals were registered via a paper process, and there was no central electronic database into which the records were put (Day et al., 2009). In part due to their inability to get relief status information from city officials, some residents took matters into their own hands and created their own websites, providing "safe lists" of who was where, with whom, and in what condition. The safe lists turned out to be more useful than mass media.

Overall, Hurricane Katrina turned out to be an acid test for managing information flow during crisis response. To many, there was information chaos. Instead of a single reporting system to establish a uniform information flow to key decision makers, the chaos appeared to be poorly mapped channels of information flow at local, state, regional, and federal levels.

4.5. Case 4: Cyclone Nargis Crisis - Burma

In May, 2008, Cyclone Nargis hit Burma, resulting in the death of an estimated 100,000 people. In the aftermath of the crisis, many international agencies mobilized to deliver aid to the survivors. However, rather than allowing the foreign relief personnel immediate entry into the country, the Burmese government -- led by a small group of military generals (the Junta) -- insisted on approving the entry of each aid agency and all supplies. As a result, many foreign aid organizations were made to wait anxiously for approval from the Burmese government to deliver loads of emergency supplies to the cyclone victims. The government even labeled those providing information to the foreign media and to Burmese media groups in exile as "saboteurs and destructive elements."

Moreover, Burma's Foreign Ministry said it would welcome foreign aid but not foreign personnel, providing little explanation for this stance. As a consequence, humanitarian organizations became wary of handing over millions of dollars' worth of food and equipment to the government. As one journalist noted, "The information blackout added a further layer of difficulty in getting an accurate picture. The international community received restricted access to the updates in Burma and many hundreds of thousands of Burmese and ethnic minority groups were not getting any assistance." Ultimately, in attempting to control the response effort in such a way as to avoid any challenge to its own authority, the Burmese government stifled information gathering and dissemination efforts, sabotaging well-intentioned aid agencies and denying its people much needed relief.

4.5.1. The Center of Crisis Operations

The Burmese government served as its own crisis response center in the aftermath of Cyclone Nargis. Fearing that a free flow of information might lead to challenges to its power and authority, the government kept tight control over information concerning the crisis. The Junta leaders minimized information flow to foreign aid organizations. It also stymied the information flow to, and from, its own people in order to prevent stories of slow relief and rehabilitation from reaching the foreign media. When the international media began criticizing the Burmese government, it responded by imposing a media ban. "The Burmese government was deeply paranoid and isolated," said Derek Mitchell, Principal Deputy Assistant Secretary of Defense at the Center for Strategic and International Studies. "The prospect of having foreigners in the country they could not control worried them."

4.5.2. Technology Support of the Operations Center

The focus of technology by the Burmese government was less on using technology to support the relief efforts and more on restricting the use of technology to transmit images and information about the disaster to foreigners. As part of the overall media ban, the government cracked down on satellite TV receivers, banned newspaper distribution, and banned the airing of TV and radio programs related to the cyclone. According to an observer, "The government's crackdown on dealers of satellite receivers was an attempt to impose a blackout on the media. The government had also prevented

both foreign and domestic journalists from visiting the worst affected areas in the Irrawaddy delta." With the media blackout, the use of blogs and social media sites for the independent gathering and dissemination of information began to take hold. Nevertheless, the military government made use of its complete control over the country's Internet gateways to partially shut down Internet access with intermittent periods of connectivity and cut off the stream of footage and images of the cyclone's devastation. The military government restricted upload speeds to half the download speeds for Internet subscribers and implemented slowdowns in Internet access speeds. It also relied on pervasive filtering practices to shape sensitive topics and block independent media and news.

4.5.3. Communication with Stakeholders

The strict rules imposed by the Burmese government resulted in a tightly restricted flow of information to stakeholders and a highly controlled downward chain of communication. The lack of open communication frustrated international aid agencies and the Burmese people and certainly slowed down the relief efforts. United Nations Secretary-General Ban Ki-moon registered his "immense frustration" with the pace of relief efforts: "I want to register my deep concern – and immense frustration – at the unacceptably slow response to this grave humanitarian crisis. Unless more aid gets into the country – very quickly – we face an outbreak of infectious diseases that could dwarf today's crisis." Instead of focusing all its efforts on helping cyclone victims, the Burmese government's actions proved to be almost as destructive as the storm.

4.6. Summary

Our within-case analysis suggests that the four centers of crisis relief operations functioned very differently, affecting the way that technology was used to coordinate information flow to and from relief agencies, victims, and the general public. Table 5 summarizes the different approaches to information flow revealed in the within-case analyses. Next, our cross-case analysis will compare and contrast the four approaches to crisis response in terms of information intensity, information direction, and information reach. In so doing, we will abstract the concepts from the within-case analysis and develop a framework of four information network structures.

Table 5. A Summary of the Different Approaches to Information Flow Revealed in the Within Case Analyses

	Role of IT in Crisis Response		
	Communication across Relief Agencies	**Communication with Victims**	**Communication with the Public**
SARS Case	Crisis Management Systems (CMS) to manage flow of info from and to agencies	Video cameras in the homes of the quarantined and telephones	Daily press conferences, media Broadcasts, website
Tsunami Case	Ground info from relief teams sent by phone, email and fax to the center. Large bulletin board used to track info.	Face-to-face (ground workers)	Website updates
Hurricane Katrina Case	Technology silos with little cross-sharing of information	Media coverage, telephone (but highly interrupted and overwhelmed), disaster information and postings on websites	Residents formed their own "safe list" websites to update each other on the location of relatives
Cyclone Nargis Case	Government control over all media with restrictions on what information could be transmitted	Scattered face-to-face meeting with the authorities	Use of blogs and social media sites for the public to share images and information, but these were disallowed as soon as the government became aware of them

5. Cross-case Analysis: Theoretical Synthesis

As depicted in Table 6 below, the four information network types derived from our analysis vary in the amount of information the network is able to process (information intensity), the direction of the flow of the information (top-down vs bottom-up), the overall reach of the information (density), and the role of the central organizational response agency.

Table 6. The Four Crisis Response Network Structures

	Information Intensity (Amount)	Network Density (Reach)	Direction of Information Flow	Role of Central Response Organization
Information Star	High	High	Both top-down and bottom-up	Central Information Hub
Information Pyramid	High	Low	Top-Down	Information Gatekeeper
Information Forest	Low	Low	In silos	There is no central organization
Information Black-out	Low	High	Top-Down	Information Filter

The network structure used by the SARS crisis response center is based on high information flow that reaches many stakeholders with little interference or manipulation (for political or other purposes) and flows in multiple directions, e.g., top-down as well as bottom-up. We label this an information star network. While there is a single focal organization at the center of the response structure, this organization does not filter the information or manipulate the information for political or other reasons; rather, this organization serves as a central hub and repository of information that flows to and from response partners and stakeholders. The response partners and stakeholders are considered crisis peers rather than subordinates.

This star network structure depends upon an emergency management IS (Hiltz et al., 2010) that is greatly facilitated by a flexible and powerful IT infrastructure in the participating agencies (Jul, 2010) as well as by IT know-how and resources in the responding agencies. The SARS command center benefitted from its partnership with DSTA (Defense Science and Technology Agency), an agency that had experience developing applications for the military, partnerships with multiple IT providers, and strong leadership. Gathering the information was not easy, but quality information is essential to the performance of the star network structure. The team had to identify data sources, formats, and security issues associated with the reports contained in the crisis management system. As the CIO of DSTA recounted, “I was told it might be impossible to gather such data, but I approached the CIOs from various public sector agencies anyway, and they agreed to my requests."

Whereas the star network can handle large amounts of information flowing across many agencies, the network structure used by Tzu Chi in Sri Lanka -- which we label the pyramid network -- does not allow for as much information reach. This may largely be a result of a lack of IT skills and resources needed to rapidly build an on-the-spot crisis management system to help manage the information needs. The information pyramid structure characterizes a response approach built around a relatively high information flow but relatively low density and a top-down tendency to information dissemination. In this structure, information is gathered by the central organization (as opposed to by independent agencies, as with the star) and sent to the supporting agencies for whom it is relevant. The pyramid structure eliminates delays caused by bureaucratic structures (Dantas & Seville, 2006) and allows information to be coordinated through a single body and quickly spread to others.

In the pyramid network structure, the central node controls who has access to what information. However, this does not imply political motivations or information tampering; rather, the central node may simply be incapable of passing along information to all the involved stakeholders in an efficient manner and, thus, must exercise restraint. In fact, in crisis response situations involving agencies and stakeholders who depend largely on personal information channels rather than IT-based

communication channels, one might expect that the information pyramid is one of few viable options. Indeed, the effectiveness of this type of network depends upon the strength of the social relationships between the focal organization and its partners (Ghoshal et al., 1994). For example, although lacking in IT support and skills, the Tzu Chi was able to compensate with the close ties that it had developed with partner organizations during previous humanitarian missions. These previous joint missions helped Tzu Chi's relief volunteers gain an understanding of humanitarian principles and the missions of other humanitarian agencies. As such, strong ties between Tzu Chi and its partners enabled the pyramid structure to succeed and helped compensate for the lack of systems to help in tracking and placement of aid supplies. This is consistent with existing literature that suggests strong ties are likely to promote high-quality information transfer between parties and serve as effective conduits of information (Rowley et al., 2000).

In cases of a pre-existing strong relationships, the focal organization has strong influence over its partner organizations. Moreover, the partner organizations trust the information coming from the focal organization. The focal organization performs the role of a central information aggregator, combining information from its distributed partners. Unlike the information star that relies heavily upon IT to channel information, the information pyramid network usually consists of an association of people who share common beliefs bonded by altruism, self-interest in helping, and loyalty to an association.

The third type of information network structure we observed can be called the forest information network. Like the pyramid, the forest has low information density, but in this case, the low density is not because strong existing relationships enable the handling of the crisis with a lower information flow (as in the case of the pyramid structure) but because poor existing relationships prevent high information flow across agencies that neither know each other well nor trust each other. The Hurricane Katrina crisis response provides an example of a forest information network. The city, state, and federal governments can each be viewed as a separate tree in the forest. Because the agencies do not have close working relationships, there was a tendency to put in place a tight structure in order to create a sense of order. However, this leads to adverse effects: tight command structures only work in emergency situations when there is a very clear, legitimate, and trusted central command organization. But because of disagreement as to which agency should be the central command organization, no central command organization emerges or has legitimacy. Prior studies contend that in such situations, a loosening, rather than tightening, of the command structure is preferable (Lin et al., 2006).

In the information forest network, the structure can be seen as different entities having separate trees of communication with little communication across the trees. Missing in the information forest is a central organization that coordinates the flow of information throughout the response effort. The lack of a central organization might result from ill-defined response roles, from lack of credibility in the de facto central organization, or from disagreement about which should be the central organization. In such a network, information flow and density, while potentially high in a given entity, remain low in the larger network because of lack of coordination across major response entities. Disconnections between organizations form structural holes (Ahuja, 2000): Parties on either side of a structural hole circulate different flows of information with little or no information exchange between the two parties (Walker, Kogut, & Shan, 1997). Common characteristics for this type of information network include formal consultation, deliberation, and complex accountability procedures for information transferred across entities. As such, organizational flexibility is compromised and crisis information is filtered through multiple layers. Ultimately this structure incurs delays in information processing time, information filtering, and information accessibility (Matheson & Tarjan, 1998).

The last form of information network we observed is characterized by information manipulation, intentional blockage, and deceit. We refer to this as an information black-out network. The case of the Cyclone Nargis crisis illustrates this type of network. The black-out information network differs from both the information star and information pyramid networks in that the black-out has low information intensity: Little information is gathered and even less is distributed. Moreover, the central organization serves as an information filter -- not just deciding upon who sees what, but actively manipulating the information to serve its purposes. Unfortunately, this central organization may not act with the interest of the major crisis stakeholders in mind but rather acts out of concern for its own power. So while little information is effectively gathered and much is concealed from stakeholders, the information that is shared has a wide

reach in order to buttress the central organization's base of power. And unlike the star and pyramid networks in which the central organization viewed the stakeholders as peers in the response, in the black-out information network, the central organization is an authoritarian information filter to the extent that many stakeholders are afraid to gather or share information. Consequently, information flows between the focal and the partner organizations are minimized and, sometimes, non-existent.

While the black-out model may be adopted for political reasons, the inability for critical information to flow between partner organizations may cause operations to fail (Matheson & Tarjan, 1998). With the media blackout, many residents may attempt to use blogs and social media sites for information dissemination. However, as seen in the case of Cyclone Nargis in Burma, a military government may utilize its control over the country's Internet gateways to disable access to the Internet or to allow only intermittent periods of connectivity. Overall, the black-out model reduces the ability to scan the environment for new information and may increase the uncertainty and ambiguity of major stakeholders (Staw, Sandelands, & Dutton, 1981).

6. Implications

Our research has several implications for the role of IT in crisis response. Of the four information network structures, the star network has the greatest reach and is capable of processing the largest amount of information. This is in large part because the star network is enabled by a central, trusted crisis response organization and the crisis response organizers are able to rapidly improvise with IT (Kamoche, Cunha, & Cunha, 2003). For the star information network structure to work effectively and efficiently, the central response organizer must either have, or partner with, an agency that has a strong IT infrastructure, strong IT development skills, and partnerships with IT vendors. This IT agency must, in turn, be allowed to supervise all the information needs of the stakeholders involved in crisis response. Without such centralization and organization, the star information network is likely to degenerate into little more than un-actionable information and information overload. The finding is consistent with Turoff et al.'s (2009) scale of group communication commitment that calls for full-scale collaboration on disaster management and response among crisis response organizations so as to generate real-time, effective disaster response decisions. The network's ability to improvise in IT deployment hinges on its technical structure and social structure (Kamoche et al., 2003). The technical structure refers to the knowledge, skills, and abilities related to the techno-structural aspects of deploying IT. The social structure refers to the behavioral norms and communicative codes that regulate coordination and collective action in a given context. The star network structure suggests improvisation is an effective means of achieving agility in IT deployment, especially when confronted with resource constraints or time pressures.

The role of IT in the pyramid structure is primarily for communication support among pre-existing partners. In fact, crisis response organizers can move from a pyramid structure to a star structure by investing time and resources in building a flexible IT infrastructure. This presupposes that the organizers have slack time between crises and slack resources.

In the case of the forest information structure, IT is more of an inhibitor of effective crisis response than an enabler. Because there is no trusted, central crisis response organizer (as with the star and pyramid structures) and a lack of previous, close-working relationships among the agencies responding (as with the pyramid structure), the different IT infrastructures of the different responding agencies form a boundary. Current research is examining the best ways to integrate incompatible systems during extreme events, such as a crisis (Chen, Sharman, Chakravarti, Rao, & Upadhyaya, 2008). It is possible that integration tools will be able to alleviate some of the bottlenecks implicit in the forest structure (Chen et al., 2008). Aside from integration tools, pre-crisis simulations might help government and humanitarian agencies learn to better coordinate.

Last, the role of IT in the black-out information structure is largely as a saboteur: Social media and mobile technology can help disseminate information to stakeholders in spite of a central organizing body that either is incompetent or purposely tries to withhold information. In fact, Turoff et al. (2009, p. 379) also point out that "online forums have allowed people to transcend geographical distances that normally constrain the reach of helping efforts, to share information and coordinate citizen-led efforts." In this case, only the grassroots efforts of those close to the crisis could help gather and distribute

crisis-related information. This also entails improvising with IT, but on an individual rather than organizational level. The success of improvising with IT on an individual level, though, would depend on creativity, personality factors, cognitive factors, domain-relevant skills, and background factors (Magni, Proserpio, & Provera, 2006).

Our paper makes several theoretical contributions. First, there is limited research that examines organizations' response strategies during crises (Lin et al., 2006). This article addresses this very important issue and contributes to the growing crisis response research. Second, we extend crisis management research by integrating concepts from information flow and network research. Our reviews of the theories and crisis management research suggest that a reconceptualization of crisis management is needed from an information flows perspective (Hale et al., 2005; Majchrzak et al., 2007). In this article, we offer a new perspective on examining how information is managed during crisis response. The prototypes we proposed offer a starting point for developing and coordinating different types of crisis information networks during crisis response. We believe the prototypical cases have the potential to explain crisis response phenomenon. Third, our study helps extend the nascent stream of research on IS in crisis response by looking at crisis response situations in which information flowed smoothly and crisis situations in which information flow was impeded. Whereas Day et al. (2009) identify the impediments to information flow during crisis response, our research presents evidence that information can flow effectively given the proper information network structures. Future research is needed to help understand why certain network structures are chosen and whether they can be modified mid-response. Fourth, our paper provides compelling evidence of the central role of IS resources in crisis responses. IS figure prominently as an asset (the IT infrastructure), a capability (development skills), and a transforming activity (resolute informing). While we concur with previous research about the important role played by IT infrastructure, IT know-how and resources (Turoff et al., 2004; Turoff et al., 2009) and in establishing a trusting relationship based on previous IT collaborative projects (Pan et al., 2005), our finding of the ability of response organizations to rapidly improvise with IT that has an impact on information flow during crisis response is refreshing and adds value to the IS literature.

Our study offers researchers a specific agenda for future research: particularly, to validate the four crisis response network structures in other crisis response contexts. Organizational scholars could reassess past crisis information management scenarios and try to fit the cases in one of the four information structures. They could even consider exploring new forms of crisis information networks. Another research direction could be to engage in a longitudinal study to understand if and how crisis information networks evolve over time. Such investigations may allow researchers to pinpoint factors that shape the evolution at different stages of crisis response. In this study, we emphasize the information flows within a crisis response network. Future research could expand the levels of analysis by including the individual level. An understanding of the communication among individuals may offer new perspectives on crisis information network structures. Given the important role played by IT and the time sensitive and ambiguous nature of crisis settings, possible further research hinges on the notion of improvisation with IT that impacts the information network structure. In particular, future research may explore how such improvisation may be conducted at both individual and organizational levels.

While researchers theorize about crisis management, managers have a much more practical consideration. In every crisis response situation, organizations can consider developing and coordinating their information flows and networks based on one of the four types we proposed in this study. Below we provide a guide (refer to Table 7) for managers who may want to set up an information flow pattern and network for their organizations during crisis response.

7. Conclusion

In this paper, we developed a framework of four crisis information networks by drawing upon social network and information flow theories. By understanding the dynamics of information flow and network structures, organizations can better manage information flows during crisis response. Our findings are based upon four crisis response cases. Our analysis revealed and derived four forms of information networks -- information star, information pyramid, information forest, and information black-out -- with various levels of information intensity and network density. By having a sound

information network structure (i.e., high network density and information intensity or low network density and high information intensity), organizations can distribute efficient crisis information. Our main contribution lies in conducting an exploratory study using an information network perspective to examine how information flows and networks are managed during crisis response.

Table 7. A Step-by-Step Guide for Setting up Information Flow Network during Crisis Response

Step 1: *Locate Crisis Management Expertise*. First step requires that managers locate the relevant crisis management expertise. It may be someone who has at least designed a crisis management plan or was personally involved in a crisis response operation. The person must be familiar with operating in a crisis response context and preferably has some links to other crisis relief organizations. In other words, organizations should identify potential leaders to lead the crisis response team.
Step 2: *Make an Initial Assessment*. Second step requires the organization to assess its situated network structure. Particularly, whether the organization is a focal organization or partner organization? And which other organizations are involved? Having established the actors, the organization should consider its levels of network density and information intensity. A word of caution is that managers must keep a look out for changes in the network form, since the structure may evolve as time passes. Therefore, situated assessments may have to be performed at a later stage again.
Step 3: *Understand Organizational Factors that may Affect the Network Structure*. Step 3 requires that organizations assess the organizational factors that may shape crisis information networks. Here, managers examine whether the organization is connected to other partner organizations and if yes, to what extent? And what is the level of inter-organizational trust established between response organizations? Does the organization single-handedly process and control the information inflows or is there more than one information gatekeeper? Find out whether the organization owns sufficient IT resources and capabilities. Evaluate the information network's IT readiness and the connectivity between organizations. If the IT readiness is high, the organization may consider leveraging on IT to distribute crisis information. Finally, examine the relative power positions within the network. Who has the real power? By considering the power relationships, organizations may devise an appropriate information flow strategy taking into account the power imbalances.
Step 4: *Select an Information Network Structure*. This step requires organizations to select an information network prototype suitable for them. While there may not always be a clear-cut case, organizations should select the most probable quadrants to which they belong. Once the quadrant is established, the organization may proceed to implement the respective information flow strategy. For example, if the information star approach is selected, the organization should align its crisis management plan with its information systems strategy by leveraging its advanced information infrastructure and applications to collect, process, store, and distribute crisis information efficiently.
Step 5: *Migrate the Network*. Finally, the information forest and black-out organizations should consider migrating to the quadrants of information star or information pyramid eventually if they are not already there. The reason is that these two quadrants provide an efficient flow of crisis information. For example, if the organization is located in the black-out quadrant and wishes to relocate, managers should identify and assess the inherent structural holes and broker for improved relationships between organizations to establish adequate communication links.

The results should be viewed within the context of the study's limitations. First, of the four case data collected in this study, two were gathered based on secondary documentation. As such, there may be the presence of interpretation bias. While this bias may be a shortcoming in this paper, it must be noted here that our results are in line with findings from existing crisis management studies. This suggests the generalizability of our findings and observations to theory and their usefulness for theory-building. Furthermore, to substantiate the reasons why more crisis response cases were not studied, it is generally known that crisis situations may involve loss of lives and valuables, and are sensitive topics, making it difficult for researchers to obtain case access. Second, it should be noted that Tzu Chi's efforts in response to the Sri Lanka Tsunami crisis might have been affected by the fact that it was not central to the network of agencies coordinated by the Sri Lankan government, unlike our other three cases, which all reflected responses by the governments of the countries affected. Despite the limitations, we believe our study will appeal to organizations in both the public and private sectors that are directly involved in handling emergency situations. By understanding how information flows may be best managed during crisis response and how information systems can enable or constrain information network structures, crisis-response organizations will be better able to manage the flow of crisis information.

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Appendices

Appendix A. Excerpts of Interview Topic Guides

Case of SARS Crisis

- Organizational and departmental characteristics (e.g. number of people, number of departments and formal organizations).
- Describe the crisis management protocols and practices in the government agencies.
- Please provide the background information of the crisis response efforts (who initiated the response, its objective, who was involved, the response scope?).
- How did you identify your stakeholders? Understand stakeholders' varying perceptions toward the crisis response. Identify the differences in the opinion towards crisis response.
- Did the response teams have adequate access to organizational resources? What resources were provided? How were existing resources deployed to support this? Were there new resources deployed?
- How were crisis response groups organized? How group members were selected?
- Did the agencies develop any capabilities from utilizing the resources? Were the capabilities and resources leveraged to fulfill the objective of crisis response?
- When handling crisis response initiative, how were processes, personnel deployment and rescue services formulated? How did the response agencies acquire related crisis response knowledge? Was information technology leveraged? What role did the information technology play in crisis response? How did the response agencies win stakeholders' trust?
- What factors were taken into consideration when selecting various information technology applications and tools? What were the challenges faced during system set up and deployment? How was coordination with software vendors and users achieved in terms of communication and the understanding of requirements and system compatibility?
- How did Singapore handle and respond to any extraordinary and unexpected situations that caused disruptions to crisis response? What were the challenges faced when integrating various information systems?
- During crisis response, which portion did you consider to be the most difficult? How were the problems resolved? During initial phase of crisis response, did the coordination proceed well? How were problems resolved?
- How did the agencies store and transfer crisis related information during crisis response? Were the information collection, exchange and processing processes effective?
- How did the agencies store and transfer any knowledge created during crisis response?
- How were the relationships between the agencies, and between the agencies and other NGOs? How did they cooperate with one another in the crisis relief activities?

Case of Tzu Chi

- Have you ever joined any overseas relief project? Which is most impressive one to you and why?
- What do you think are the main reasons that Tzu Chi has been participating in overseas relief actively since 1990?
- Does Tzu Chi have overseas relief manuals?
- How does Tzu Chi establish relationship with overseas countries? How does Tzu Chi gain local trust? How does Tzu Chi respond to local government?
- What are the relationships between Tzu Chi and other Non-governmental organizations?
- What is the level of corporation in international relief activities?
- Have you participated in the Sri Lanka Tsunami Relief Project? What were your responsibilities (i.e., domestic affairs, overseas affairs, logistics, and ground force)?
- How to exchange information between ground team and Taiwan Headquarters?
- Was Tzu Chi effective in information collection, exchange and processing? Why?
- How did Tzu Chi train the relief project group members?
- How to select personnel to join the relief project group? How to select the leader
- How was Tzu Chi able to react to disaster so quickly?
- What were the areas for improvement in the Sri Lanka Relief Project?

Appendix B. Excerpts of Data Sources related to Hurricane Katrina Crisis Response

Government Websites

US Department of Homeland Security, Federal Emergency Management Agency. http://www.FEMA.gov/.

Ready. http://www.ready.gov/.

US Department of Health and Human Services. http://www.hhs.gov/disasters/emergency/naturaldisasters/hurricanes/katrina/index.html.

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Appendix C. Excerpts of Data Sources related to Cyclone Nagis Crisis Response

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