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Research Article

Information Flow Impediments in Disaster Relief Supply Chains*

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Abstract

Supply Chain Management (SCM) is seldom more difficult than during disaster relief efforts. As supply chains quickly form in response to a disaster, a slow information flow presents a major hindrance to coordinating the allocation of resources necessary for disaster relief efforts. This paper identifies impediments to the flow of information through supply chains following large scale and catastrophic disasters. Given the scarce body of literature on this subject, a grounded theory case study was conducted to examine an extreme case. The study concentrates on the efforts of multiple organizations and individuals that provided relief in the aftermath of Hurricane Katrina, which battered the Gulf Coast of the southeastern United States in late 2005. Data was gathered from diverse sources, including government agencies, profit and non-profit organizations, and individuals, during and after the disaster. Based on our data analysis, we not only identify information flow impediments (i.e., inaccessibility, inconsistent data and information formats, inadequate stream of information, low information priority, source identification difficulty, storage media misalignment, unreliability, and unwillingness), but also identify likely sources of these impediments, and examine their consequences to organizations' disaster recovery efforts. Our findings suggest some potential design principles for devising solutions capable of reducing or alleviating the impact of information flow impediments in future disasters.

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Information Flow Impediments in Disaster Relief Supply Chains

1. Introduction

When Hurricane Katrina made landfall near New Orleans on August 29, 2005, it brought winds of 140 mph and near-record storm surges. Communities along the Gulf Coast of the USA from southeast Louisiana to Alabama were devastated, but more damage was to come. On August 31, Katrina's strong storm surges, winds, and continued rainfall in New Orleans began to break the city's levees. Much of New Orleans quickly became uninhabitable, as 80 percent of the city and portions of neighboring parishes flooded. Flooding in most areas did not recede for weeks. In the end, nearly 1,700 people died, and unparalleled masses of people evacuated to neighboring cities and states (U.S. House of Representatives, 2006). Houston, Texas, took in an estimated 250,000 evacuees and managed what is considered to be the largest shelter operation in U.S. history. In just one location alone—the Reliant Complex, which includes the old Astrodome—Houston city services and volunteers provided food, housing, and medical care to a total of 24,300 evacuees during the height of sheltering operations. Over several weeks, roughly 60,000 volunteers helped distribute over USD 7 million in donated goods and services (Harris County Joint Information Center, 2006). The remaining 225,000 evacuees in Houston were scattered throughout the city in other Red Cross shelters, hotels, informal shelters, and private households of family, friends, or kind strangers who opened their homes.

Despite attempts by organizations and various levels of government to organize Katrina response and recovery efforts effectively, documented results show that the efforts to provide help where needed were often inefficient. Poorly coordinated supply chain efforts, for example, led to USD 900 million in manufactured homes and 110 million pounds of ice (60 percent of what was ordered) going unused by the Federal Emergency Management Agency (FEMA) while many suffered in desperate need of housing and relief from the heat (U.S. House of Representatives, 2006).

The formation of supply chains following large-scale catastrophic disasters such as Hurricane Katrina is a complex undertaking. Disaster-driven supply chains form an incident organization, a "temporary configuration of otherwise disparate resources" (Smith and Dowell, 2000, p. 1154). Within these impromptu structures that attempt to save lives and restore communities, the need for successful supply chain management is unparalleled. Supply chain management theories built in non-disaster environments have shown that the coordination of resource flows, and their related costs, can be improved by leveraging information flows (Cachon and Fisher, 2000; Lee and Whang, 1999).[1] However, fostering information flows among a large collection of previously unrelated organizations in a post-disaster environment is fraught with difficulty just when the right resources truly need to get to the right place at the right time.

The objective of our research therefore, is to study *information flows in the management of the disaster relief supply chains that formed following Hurricane Katrina*. We accomplish this by investigating a single, critical instance case, or so-called extreme case (Yin, 2002). This approach takes advantage of a rich, yet rare, occurrence of a situation that has not received significant research attention in the SCM and IS fields. We have chosen to apply grounded theory due to the absence of a strong theoretical background on disaster relief in the existing SCM and IS literature. As the massive information breakdowns and supply chain disarray in Hurricane Katrina's wake demonstrated, adequate response and recovery following large-scale catastrophic disasters remains an elusive goal (McEntire, 1999, 2002; Stephenson, 2005; Wise, 2006). Studying these post-Katrina phenomena will help researchers recognize the limitations of the current literature in both the SCM and IS fields when encountering a disaster environment. With our study, we empirically contribute to an under-researched area and propose theoretical categories of information flow impediments in disaster relief supply chain management. System developers may particularly benefit from our proposed design principles when formulating solutions to reduce and even overcome existing information flow impediments in future disasters.

[1] We are not suggesting that information flows are the only problem for coordinating supply chains during emergencies; however, as the literature shows, it is a major factor (Cachon and Fisher, 2000; Lee and Whang, 1999).

The paper is structured as follows. First, we provide some background on both non-disaster (henceforth, "normal") and disaster relief supply chain research. Second, we discuss our extreme case study research approach in more detail. Third, we present our results, which consist of theoretical propositions concerning the impediments to information flows that we identified, their possible causes, and the observed reaction strategies. Fourth, we propose a set of design principles that future researchers can subject to empirical testing. Moreover, we reflect on the unpredictable nature of disaster situations and highlight the relevance of improvised human action to solve problems not considered in existing information systems. We conclude by reflecting on the relevance of our study and others that may concentrate on this area.

2. Background on Supply Chains in Disasters

The formation or reformation of supply chains following large-scale and catastrophic disasters such as Hurricane Katrina is a complex undertaking. Established and impromptu organizations and government agencies, attempting to work together, in some cases for the first time, quickly must provide goods and services that help save lives, provide comfort, and even restore entire communities. A supply chain supported by systems that support the flow of information is an important factor in disaster relief efforts.

Supply chain management literature places considerable emphasis on the relationship between information flows and the responsiveness or efficiency of resource flows (Sahin and Robinson, 2002; Chen, 2003). It has long been known that inter-firm management of resource flows and their related costs are greatly improved by leveraging proper information from supply chain partners to make better decisions when managing variability and uncertainty (Forrester, 1958; Lee, Padmanabhan, and Whang, 1997; Cachon and Fisher, 2000; Lewis and Talayevsky, 2004). However, this relationship has not been specifically investigated within the context of disaster relief where both uncertainty and variability greatly exceed that found in normal supply chain environments.

Supply chain management in normal environments often focuses on value production within a single firm for its own benefit or that of its owners (see Kouvelis, Chambers, and Wang, 2006 for a recent literature survey). Yet, when a major disaster adversely impacts lives and communities, individuals and organizations often give of their own resources to ensure the overall system adequately serves those in dire need (Thomas and Fritz, 2006). Managing disaster relief supply chains, then, may present challenges that are somewhat different from managing normal industry supply chains, as they require different information flows for different purposes.

Despite both its intriguing uniqueness and its distinct importance to society, research on disaster relief supply chains is scarce (exceptions are: Beamon and Kotleba, 2006; Denning, 2006; Van Wassenhove 2006; Oloruntoba and Gray, 2006; Ödzamar et al., 2004; Tomasini and Van Wassenhove, 2004). The research that does exist helps characterize how these supply chains differ from their normal industry counterparts; however, it does not explicitly examine the flow of information between supply chain partners. Nonetheless, when this literature is examined, we find that three primary themes emerge concerning the unique aspects inherent to disaster relief supply chains that underscore their need for and difficulty with fostering adequate information flows: *urgent responsiveness, extreme uncertainty, and a short supply chain life-cycle*.

Disaster relief supply chains require unparalleled levels of *urgent responsiveness* when compared to their normal industry counterparts. The overarching disaster relief supply chain performance criterion during the response phase is primarily responsiveness, and efficiency is secondary. The public shows little tolerance for "penny-pinching" when lives are threatened or people remain uprooted from their homes (Kelly, 1995). Additionally, minimizing the impact of a disaster often means saving lives, preserving property, and quickly restoring both social and economic foundations. For example, Van Wassenhove (2006) examines the difficulties of managing humanitarian aid supply chains and notes that the pressure of time is not just a matter of money, but can mean the difference between life and death. Similarly, Ödzamar et al. (2004) recognize the need to distribute relief aid rapidly in their creation of an integrated emergency planning and response decision support system. Therefore, the

managing of supply chains under these circumstances will depend greatly on having relevant and timely information.

In addition to time and public pressures, disaster relief supply chains operate under *extreme uncertainty*. Beamon and Kotleba (2006), for example, investigate inventory management strategies applied in emergency relief operations in southern Sudan and note the unique irregularities in size, timing, and location of relief item demand patterns. Tomasini and Van Wassenhove (2004, p. 437) point out that disaster relief functions are unique from normal industries in requiring a supply chain to be "designed and deployed immediately with limited information about resources available, needs in the field, quantities required, and a large amount of suppliers (who make unpredictable contributions)." Similarly, Van Wassenhove (2006) discusses how crucial information for designing normal industry supply chains, such as time, place, type of product, quantity, and potential supply sources may not be known when participating organizations are forming new disaster relief supply chains. Even after relief efforts begin to stabilize, post-disaster environments may remain so large and dynamic that no single organization can independently create and maintain comprehensive information concerning the overall relief effort.

Disaster relief supply chains also have very *short life-cycles*. Oloruntoba and Gray (2006) specifically mention the short and unstable existence of humanitarian aid supply chains when contrasting them to normal industry. That is, normal supply chains often evolve supplier-buyer relationships over decades as they refine policies and processes to improve their competitive positions. Investments are often made to increase resource-flow efficiency by formalizing and automating information flows within these slowly-changing organizational networks. As Denning (2006) points out, however, disaster relief supply chains hastily evolve new networks of relationships within days or even hours. Inter-organizational policies and processes are rapidly created and modified with little time to formalize or automate associated information flows before relief efforts subside in a matter of only months. Furthermore, once relief efforts end, participating organizations have little incentive to continue maintaining or refining the policies, processes, relationships, and information flows established for their response to the disaster.

Since both lives and community livelihoods are at stake, there is certainly a need for improving the responsive flow of resources among organizations participating in disaster relief supply chains. Supply chain management research asserts that variability and uncertainty can be better managed by improving information flows, but has not explicitly considered how to foster these information flows in disaster relief environments or how instrumental they could be in improving relief effort performance. In practice, several information systems have been implemented with just that goal and still, adequate system performance in disaster relief supply chains remains elusive (McEntire, 1999, 2002; Stephenson, 2005; Wise, 2006). It is likely that fostering information flows in a context of urgent responsiveness, extreme uncertainty, and short supply chain life-cycles presents considerable difficulties (Manoj and Baker, 2007). Therefore, we seek to contribute empirically to information-related supply chain knowledge by providing a case study of information flows in Hurricane Katrina relief efforts. Theoretically, our research contributes a set of propositions regarding information flow impediments that exist during disaster relief efforts. We examine how these propositions can serve as a foundation for designing information systems that enhance disaster relief supply chain performance.

3. Research Method

As the phenomenon being studied represents a complex, yet rare, occurrence of a disaster situation that has not received significant theoretical research attention in the IS or SCM fields, we chose a qualitative approach. Qualitative methods have the advantage of supporting a constant comparative analysis while providing the flexibility for investigating aspects of a phenomenon that may not be completely identifiable at the outset of the inquiry (Boudreau and Robey, 2005; Eisenhardt, 1989; Klein and Myers, 1999). A large-scale disaster such as Hurricane Katrina represents exactly this—a situation of extreme and unique conditions, the effects of which are deemed to be incisive while somewhat erratic. Therefore, we chose a single, critical instance case, or so-called extreme case (Yin, 2002), in order to explore the impact of information flow impediments on the effectiveness of supply

chain management in disasters. Methodologically, we relied upon a grounded theory approach due to the absence of a strong theoretical backdrop in the disaster management literature (Glaser and Strauss, 1967; Strauss and Corbin, 1990). Grounded theory provides researchers with the opportunity to think outside the confines of existing schemas while providing guidelines to approach the nature of a phenomenon in a structured way. Though rarely applied in the IS and SCM fields, as compared to other disciplines such as health management, grounded theory has proven its usefulness through some studies (e.g., Galal, 2001; Schroeder et al., 2008; Urquhart, 1997; Urquhart, 2000).

3.1. Data Collection

The nature of the study required us to select interviewees that had been exposed to and had first-hand experience of the disaster's aftermath in terms of information and supply chain management. Simultaneously, the phenomenon obliged us to strive for a broad and comprehensive spectrum of experiences, capturing disaster perspectives of both demand and supply. On the demand (or receiving) side, we were granted access to interview employees of a large defense contractor and a local university in the New Orleans area. On the supply (or relief-providing) side, we gained permission to interview a government Emergency Operations Center, a faith-based organization, chapters of the American Red Cross in both Louisiana and Texas, and four volunteers who were not employed by any organization, but were selected based on their varied experiences with providing relief services. Even though the organizations and individuals selected were not all directly linked to one another, they were related indirectly through the broader disaster relief supply chain network. We summarize the background of each organization's relief efforts in the appendix.

Within each organization, we chose interviewees who had interfaced between the strategic and operational level of the organization to capture the consonance (or dissonance) between plans and their implementation. We were able to obtain interviews with at least two individuals from each organization, with the exception of the local university. Table 1 provides a summary of the interviews conducted.

Table 1: Post-Katrina Data Collection

	Site Selection	Interview Data	Archival Data
Relief-receiving organizations (demand)	University of New Orleans (UNO)	1 interview	Online press releases
	Large Defense Contractor	8 interviews	Organization press releases
Relief-providing organizations (supply)	American Red Cross	2 interviews	Online press releases
	Interfaith Ministries (IM) for Greater Houston	2 interviews	Online press releases
	Harris County Office of Homeland Security and Emergency Management (OHSEM)	2 interviews	Online press releases
	Spontaneous, unaffiliated volunteers	4 interviews	Personal blogs

Data collection began in November 2005 as Hurricane Katrina relief efforts began stabilizing. Interestingly, study participants displayed high motivation to contribute to our study, despite—or perhaps because of—the severe and extraordinary nature of the situation. Interviews were semi-structured and lasted an average of 40 minutes each. As an opening question in each interview, we asked participants to recap the context and facts surrounding their experiences with Hurricane Katrina. Next, we asked interviewees open-ended questions that allowed them to provide their own perspectives of the event. If we perceived any ambiguity concerning an interviewee's statements, follow-up questions were asked to ascertain the appropriate context and attain better understanding.

In closing, we asked interviewees to comment on any episodes that were still prevalent in their minds, but had not been mentioned yet. We recorded and transcribed all interviews.

3.2. Data Analysis

We analyzed our data using the Strauss and Corbin (1990) coding paradigm, consisting of open, axial, and selective coding, as it provided a thorough and structured approach for examining the phenomenon of interest. It should be mentioned that we used the coding scheme as a general guideline to make sense of our data while remaining alert for emerging themes. We found the coding helpful for identifying impediments to information flows, their context, their possible origins, and their consequences. The specific data analysis steps formed a spiral rather than a sequence, described as follows.

The transcripts of the interviews were subjected to open coding. Open coding is concerned with identifying and naming the dimensions of the phenomena through the emergence of concepts or codes. We analyzed interviews on a line-by-line basis and fractured them into codes that summarized our interpretation of the data. Then, through comparative analysis across interviews and with regard to similarities and differences, we grouped codes together and formed, where applicable, more abstract categories or themes.

Axial coding was applied to match codes into the categories of the coding paradigm. Categories of axial coding are schematically summarized in Table 2. This part of the analysis required us to pay close attention to linking categories and subcategories while keeping the coding paradigm in mind. Knowing that some researchers have criticized the coding paradigm due to its tendency to force data into a pre-fabricated form (Glaser, 1992), we made certain to apply it as a guide instead of as a dogmatic principle by closely concentrating on emerging themes. We found that the coding paradigm and its categories fit the overall nature of our data very well—with one exception. Considering the number of organizations and the variety of diverse incidents that took place in the disaster situation, we soon realized that the category of intervening conditions was too broadly defined for our purposes. Therefore, we had to segment this category into multiple pieces, each signifying a different information flow impediment and its respective action/interaction strategies (as indicated in Figure 1).

Table 2: Axial Coding Dimensions from Strauss and Corbin (1990)

Dimensions	Definition
Causal Conditions	Causal conditions represent a set of events or happenings that influence the phenomena (p. 131), such as rules, regulations, beliefs, values, etc.
Phenomenon	Addresses the question: What is going on here? (p. 130)
Contextual Conditions	Contextual conditions represent a specific set of conditions (patterns of conditions) that intersect dimensionally at the time and place to create the set of circumstances or problems to which persons respond through actions/interactions. (p. 132)
Intervening Conditions	Conditions that alter or mitigate the impact of causal conditions; they are unexpected events or factors that result in certain behavior or action/interaction strategies associated with the phenomena. (p. 131)
Actions/Interaction Strategies	Purposeful and deliberate acts that are taken to resolve a problem by individuals or groups to issues, problems, happenings or events that arise under those conditions, and in so doing, shaping the phenomenon in some way. (p. 128, 133)
Consequences	Outcomes of actions/interactions, representing what happens as a result of those actions/interactions or the failure of persons or groups to respond to situations by actions/interactions, which constitutes an important finding in and of itself. (p. 128)

In a last step, and using selective coding, we solidified the model to form theoretical propositions that provided a coherent picture of the phenomena observed. We accomplished this by cross-validating it not only against interview data but also against archival data. In a few instances, when we felt that an interpreted theme might not be tied directly to the accumulated data, we contacted the interviewees to comment on and clarify these issues. Overall, we finalized the analysis by reaching the status of "theoretical saturation" (Eisenhardt, 1989). Our selective coding allowed us to develop a theoretical framework that classifies information flow impediments and identifies strategies that were used to respond to them. During this phase, we also went a step further to identify possible technical solutions that might support the observed reaction strategies to each impediment (as will be discussed later in the Discussion and Table 3).

Figure 1 provides the comprehensive model summary of our data analysis based on the Strauss and Corbin (1990) coding paradigm. Due to our research objective of identifying information flow impediments, however, we will focus on specific parts of the model only for the discussion of our findings, i.e., the phenomenon, the intervening conditions, and the action/interaction strategies.

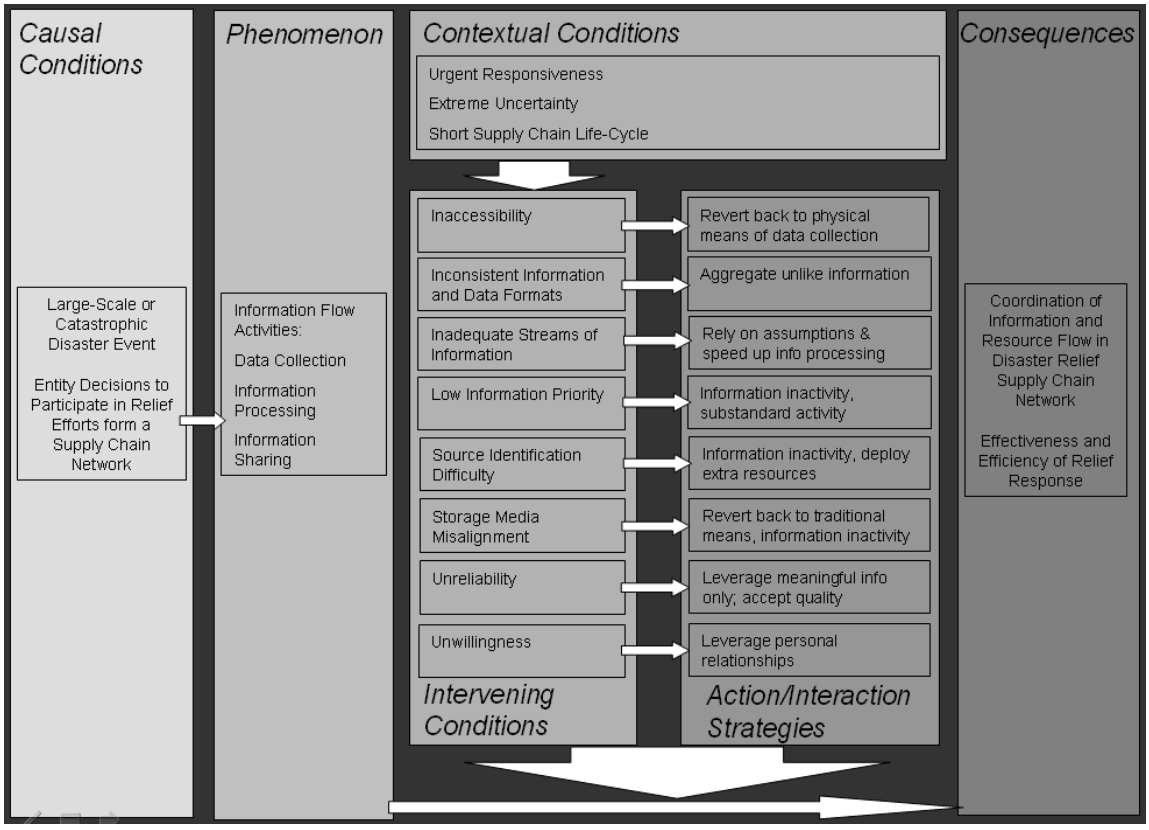

Figure 1: Coding Analysis of the Phenomenon based on Strauss and Corbin (1990)

4. Results

In this section we present the results of our study. It is divided into two parts. First, we concentrate on three distinct activities (i.e., collection, sharing, and processing) that we found contributed to the inter-organizational flow of information in the Hurricane Katrina disaster relief supply chain. The second part of the section focuses on eight specific issues that impeded the aforementioned activities.

4.1. Information Flow Activities and Their Impact on Resource Flows

Organizations were found to be carrying out data collection, information processing, and information

sharing activities in an effort to improve either their own performance or that of the overall incident organization. The following quotes from a senior director of emergency services at the American Red Cross provides illustrations of the three information flow activities and how they are related.

> *"During disaster assessment, when we actually go in and record what (houses) are destroyed and what is damaged after disaster, there's a form to fill out […] On this form you record if it's destroyed, major, or minor, what kind of damage. They call it a street sheet, one sheet per street. […] Then you bring all those sheets back and they have to be consolidated into a larger sheet so we know what kind of disaster it is. […] Whenever there's a disaster anywhere in the state, (the state emergency operations center will) initiate conference calls. Two a day, usually at 10 and 3. […] You have local decision makers, majors, judges, etc. […] It's all about information sharing."*

First, the recording of house damage is a *data collection* activity as it results in a collection of facts and figures concerning how many, and how badly, houses are damaged on each street in a disaster affected location. The Red Cross then performs *information processing* by aggregating the data to provide valuable input information for several decisions that directly impact the flow of resources in the disaster relief supply chain (e.g., whether to open more shelters, the predicted duration of relief operations, how much food and water to bring in). In this quote, *Information sharing* occurs through conference calls. The Red Cross communicates data collected about damage at specific sites, or processed information about aggregate damage, or even its resource-related plans for opening shelters, keeping them open, and providing food and water; in addition, the Red Cross can obtain valuable data and information from other organizations that it can process to support future decisions.

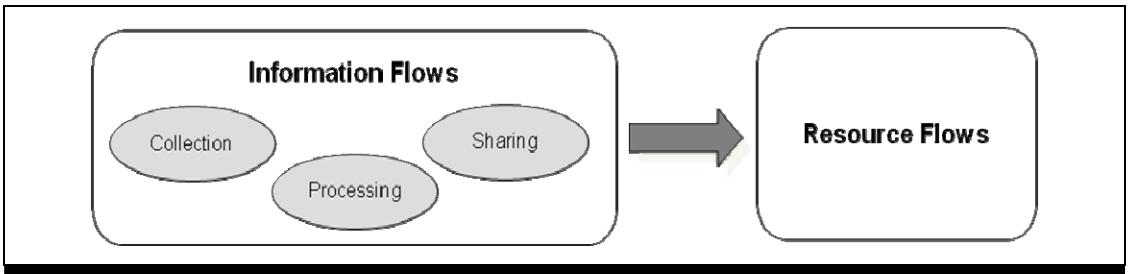

Figure 2: Observed Information Flow Activities and their Impact on Resource Flows

We found many activities of collection, processing, and sharing that impacted resource flows. In the following quote, a Red Cross senior director reflected on the difficulties of managing resources at the Reliant Complex shelter and how impediments to the activity of sharing information ultimately impacted their own inventory management efforts. Notice how the supplier organizations, in lieu of continued information sharing, re-processed stale information about need when making decisions concerning inter-organizational resource flow.

> *"There was a disconnect on resources cause you didn't always have the right amount of resources at the right time at the right place. […] Initially you didn't have enough resources, but then once the flow starts […] then that flow keeps coming in. […] We had truckloads of cots that were brought into Houston that were […] never opened. (We) had to contract with warehouses to take excess donated goods because we were overwhelmed. […] There were trade-offs being made. You're taking a lot of resources away from what you could be doing with that money and manpower and you're using it to manage donated goods. […] If you don't end up communicating your needs effectively then whoever's sending you the resources is going to continue sending you the resources and after a while you're caught saying 'don't send anymore!'" (Senior Director Emergency Services, American Red Cross)*

Yet this overabundance of resources did not exist throughout organizations across the entire disaster relief supply chain. The next excerpt discusses how most offices in a rural area of Louisiana had insufficient resources to provide for relief client needs while the Red Cross shelters, after obtaining communications capabilities, were overwhelmed.

> *"I found (a) communications truck with technology. I knocked on the window, and he asked if he could help anybody, and I said 'hey, come with me!' It was a full truck, full communications, I had internet, I had telephone. It basically ran the base (of local Red Cross) operations for several weeks. […] Most people couldn't get through a phone system. The lines were waiting at every office that you could think of. People were looking for assistance. And then you had (Red Cross) shelters that got bombarded with assistance because people just want to help, so there was too much clothes, too much food. It sounds strange that our shelters had too much, but there was too much assistance there." (Community Recovery Manager, American Red Cross)*

The two quotes above are among those that show the impact of information flows on the flow of resources (see Figure 2). Both excerpts illustrate how impediments in the information flow left organizations struggling to direct and receive appropriate resources. First, when locations experiencing relief client demand were not known to suppliers, no resources were sent. After demand locations were known, a lack of current information led suppliers to believe that they were helping to satisfy additional downstream demand by continuing to send more resources that, in fact, were not needed. In general, when the flow of information was impeded, resource flows created underserved pockets of demand at several locations while others, such as the Red Cross shelters above, were overburdened with inventory management. In the next subsection, we discuss in detail our findings regarding information flow impediments.

4.2. Information Flow Impediments

After analyzing the data, we found that eight theoretical categories of information flow impediments emerged: (1) inaccessibility, (2) inconsistent data and information formats, (3) inadequate stream of information, (4) low information priority, (5) source identification difficulty, (6) storage media misalignment, (7) unreliability, and (8) unwillingness. Each of these impediments corresponds to what qualitative researchers call an analytical generalization, which consists of inductively formulating theoretical concepts or categories (Yin, 2002; Lee and Baskerville, 2003). Thus, these theoretical categories are presented in the form of analytical generalizations and we provide a definition below for each of these analytical generalizations along with relevant examples from our interviews. When not evident within a quote, we also provide a summary discussion of the action strategies organizations carried out in response to each impediment. We do not claim that this set of impediments is exhaustive, as further research may expand the definitions or add more. Moreover, we acknowledge that they may even overlap. Indeed, some of the episodes portrayed in this paper could be used as examples for more than one information flow impediment. Due to the interpretive nature of the study, however, they are vindicated, we argue, as they offer conceptual and explanatory power. We depict the relationships between impediments and general reaction strategies in Figure 1.

(1) Inaccessibility

Inaccessibility refers to the inability to obtain data or information that is known or assumed to exist. Often, we found this was due to physical constraints. A local defense contractor, for example, wanted an initial damage assessment of its facilities. Unfortunately, with communication lines down, roads inaccessible, and entire parishes closed off, accessing information about the status of its facilities turned out to be challenging.

> *"We had no eyes or ears on the ground; we had no communication in or out." (CIO of a local defense contractor)*

For this defense contractor, the inaccessibility of the facility via normal remote communications methods led to use of an alternate means of collecting the information we desired. One of the firm's employees, a colonel in the Army Reserves, was able to inspect the damage visually and report back:

> *"(The colonel) said: I'll go. I got a rucksack, I can last several days […] just get me down there somehow. […] We send him down there and that night he called us with that satellite phone. He told us what we are dealing with. The data center is gone, the walls are gone, there are a few people around, it's devastated, it's even worse than the pictures on the news." (CIO of a local defense contractor)*

In another example, the Harris County Office of Homeland Security and Emergency Management (OHSEM) learned that some of the parishes in Louisiana had emptied their jails and put prisoners onto buses heading toward Houston. OHSEM then attempted to obtain information from Louisiana's correctional facilities. The following passage describes the inability of Louisiana correctional facilities to provide data about prison inmates evacuated on buses following the New Orleans levee breaks.

> *"They had no records of who they sent to us, because the computer systems all went under water." (Administrative Coordinator for the Harris County Office of Homeland Security and Emergency Management)*

As a reactive strategy, people sought an alternate source of similar information.

> *"So, we had our DPS contact the Louisiana state troopers to […] get a copy of their sexual offender list." (Administrative Coordinator for the Harris County Office of Homeland Security and Emergency Management)*

Thus, inaccessibility can arise not only when emergency workers face situations for which their information systems are unprepared, but also when they cannot access sources of information. In such cases, emergency workers may seek alternate sources or revert to methods that pre-date the modern age of information processing, such as sending a human messenger for physical inspection.

(2) Inconsistent Data and Information Formats

Inconsistent information and data formats exist when multiple sources of similar data or information cannot be compared or aggregated due to having different dimensional or field definitions. This impediment regularly occurred after an *Inaccessibility* impediment had been solved, but it also refers to situations in which the received information differed greatly from other sources of related data. As an illustration, consider how American Red Cross relief workers in Louisiana attempted to ascertain shelter occupancy based on information from several different sources.

> *"The numbers were really a myth. You talk to emergency operations, the director of the parish, and what he would tell you was what was requested. The numbers were very different compared to what our staff would be coming in with." (Community Recovery Manager, American Red Cross)*

Attempting to reconcile numbers based on different measurements proved difficult. For example, when attempting to ascertain the number of relief clients that were currently residing at a shelter, information about resource requests, registrations, inventory usage, and other sources was not consistent. "Playing it safe" (i.e., aggregating these numbers by taking the highest one) was a common strategy applied to ensure that adequate resources would be available no matter which source was most accurate.

> *"So you basically took the combination of all the information resources and you would take the highest number because you wanted to be safe." (Community Recovery Manager, American Red Cross)*

Another example of inconsistent information appeared in the midst of Katrina relief efforts when Hurricane Rita spurred an evacuation from the Houston area. Some media sources reported that hundreds were dying of heat exhaustion on the evacuation routes.

> *"Because of (media reports), we mobilized various county and city resources to go up and down the lines of cars handing out water. According to the Red Cross, all needs were being met. The police were telling us 'it's hot but no one's dying'. The medical services said they transported 40 people." (Administrative Coordinator, Harris County Office of Homeland Security and Emergency Management)*

Although the information was inconsistent, it provided indications to help determine that the media reports of heat exhaustion deaths were untrue. Aggregating dissimilar information proved to be more appropriate as a base for decision making than having no input information at all.

(3) Inadequate Stream of Information (Shortage/Overload)

An inadequate stream of information occurs when there is too little or too much data or information available to an organization. Organizations capable of dealing with large amounts of information, such as Harris County OHSEM, generally desired more information so they could integrate it into their view of the rapidly shifting environment. When asked how valuable additional information about demand and supply/relief capacity would be, the Administrative Coordinator of the Harris County OHSEM jokingly replied: *"Yes!"* Harris County OHSEM responded to a perceived shortage of information by simply improvising based on whatever they did have. That is, they were able to continue their operations by making assumptions and estimates that allowed them to remain flexible. It is important to note that an inadequate information stream, especially too little information, can result from the existence of the other information flow impediments, but it may also arise from the extreme uncertainty and urgent responsiveness inherent in the disaster environment itself.

In contrast to too little information, the Red Cross had to deal with too much information—more specifically with overwhelming amounts of data in the form of shelter registrations on paper. In addition to being used for registration, these paper forms provided important data when trying to find and reunite missing and separated family members.

> *"The Red Cross shelter registration process […] was tied completely to paper. […] At that point there was so much paper data. […] Being able to track people–finding them–that was a hard piece. We found out that as much effort as we put into shelter registration and being able to find people, it is woefully inadequate for what is needed in a mass evacuation like a Katrina evacuation." (Senior Director Emergency Services, American Red Cross)*

As the Red Cross encountered overwhelming quantities of paper registrations, they reacted by putting more effort into finding missing family members. Unfortunately, due to the sheer volume of registrations, they found the additional effort to still be inadequate.

The difference between having too much and too little information appeared to depend on the function of the organization. Organizations attempting to allocate resources to many organizations, such as Harris County OHSEM, often wanted more information, while organizations dealing directly with relief clients, such as the Red Cross, often had difficulty managing the information they received. The example of Harris County OHSEM points out the need for employees to be ready to make decisions based on very little information, while the Red Cross example highlights the need to integrate disjunctive data formats into automatable procedures when dealing with shelter registrations.

(4) Low Information Priority

Low information priority is the failure to place appropriate precedence on information flow activities. Given the humanitarian imperative of the tasks necessary following disasters, the collecting, processing, and sharing of information may not be a top priority for managers, workers, or volunteers. For example, central authorities, such as Harris County OHSEM, did not receive enough information—not only because of inaccessibility, but also because officers providing help could not dedicate time to data collection activities. The following quote illustrates a common sentiment among the front-line disaster relief providers who were often the only ones with access to important demand data.

> *"It's not that we don't want to share (information), but finding the time. […] I do not have time to share. Is it important to (help others) capture information or provide help?" (Community Recovery Manager, American Red Cross)*

In this case, low information priority resulted in inactivity with respect to collecting, processing, and sharing information.

> *"For 15 days, there was no time. You were exhausted. It just didn't happen." (Community Recovery Manager, American Red Cross)*

In contrast, the local defense contractor continued information activities, but altered its priority on normal information processes for decision making.

> *"It boiled down to making decisions quickly. Large corporations can easily find themselves going into analysis paralysis in their normal operations. Most of that went out the window as*

we worked to solve problems at what we soon were calling 'hurricane spee.d'" (Group Director of IT Solutions at a local defense contractor)

Even relief clients themselves placed low priority on information activities.

"(Relief clients) don't see the importance of leaving a trail of where they've been. Unless they have relatives…" (Senior Director Emergency Services, Red Cross)

Overall, reactions to low information priority ranged from information inactivity to proceeding with decisions based on substandard information.

(5) Source Identification Difficulty

Source identification difficulty occurs when an organization does not know where to obtain the data or information that it wants. Source identification difficulty is similar to inaccessibility; however, while the latter involves the absence of channels, the former refers to not knowing where the required information is. An illustration of source identification difficulty is the experience of Interfaith Ministries (IM) when working with several faith-based congregations that were eager to find out how they could contribute to the disaster relief efforts.

"Nobody knew who to call, where to go. […] the underlying assumption in disaster (planning) is that people know what their roles and responsibilities are; but a lot of people will wait, and then (ask) 'why did this not happen?' 'I was waiting for you to do it, and I didn't know I was responsible for it.'" (Manager, Office of Disaster Preparedness, Interfaith Ministries)

Not knowing where to get the needed information led to an action strategy of inactivity. That is, since the parties involved did not know where to get information about what their roles and responsibilities were, they remained inactive while others were waiting for them to do something.

This type of information flow impediment can also be illustrated by the difficulty experienced when locating or identifying relief clients. As many volunteer organizations rapidly transformed into shelters, no formal documentation was kept about these events. As a result, the Red Cross continued to find Katrina relief clients sheltered in smaller community churches that were not a part of the formal relief efforts even a month after the disaster.

"We would find people sheltered even after Katrina had passed 4 or 5 weeks later that we didn't know about." (Community Recovery Manager, American Red Cross)

As a reaction, the Red Cross initiated extra efforts to obtain data concerning the whereabouts of sheltered relief clients.

"I actually took two trained volunteers that helped on a daily basis and I put them out in the community with one of our response teams to go church to church […] to find out if there are people sheltered in this community." (Community Recovery Manager, American Red Cross)

Thus, source identification difficulty refers not only to the need for collected information that already exists, which may even be available in information systems, but also to the need for collecting new information for the first time. This raises an interesting question regarding how an organization experiencing source identification difficulty can even know whether the information it needs has already been collected by another organization and whether it is accessible. The reactions to this type of impediment involved waiting and the deployment of extra resources. Overall, we found that this impediment rendered a deep sense of uneasiness among those working in the organizations.

(6) Storage Media Misalignment

Storage media misalignment occurs when characteristics of the chosen recording or storage media inherently inhibit efficient information flow activities. For example, it could refer to the gathering of information on paper, which makes it unsuitable for electronic processing. This occurs as the initial data gathering takes place in the field at a time when formal computerized systems are typically not available, or paper data collection is faster than various electronic means of data collection. Consider the data collection problems that surfaced during and after registration in the Reliant Complex mega shelters in Houston.

> *"The problem is inputting the data is slower than writing. […] (For) almost all military operations, the actual real time operation is done on paper because the technology can't keep up with us yet. Now, the technology is fabulous for tracking assets, the technology is fabulous for tracking your actions for accountability, but when you're in that decision making mode, when you're issuing those orders…technology is not there yet." (Administrative Coordinator for the Harris County Office of Homeland Security and Emergency Management)*

At the same time, however, problems were encountered by the Red Cross as they processed registrations on paper at the Reliant Center mega shelters. The following two discussions show that although paper may be better for data collection activities, newer information technologies hold important advantages when processing and sharing information.

> *"(The Red Cross) kept (taking shelter registrations on paper) and then they had to stack the papers. 'How many people ya'll got' was the question. 'Well, we have this many on this sheet. How many we got on this piece of paper?'" (Administrative Coordinator for the Harris County Office of Homeland Security and Emergency Management)*

The action strategy taken after the realization of storage media misalignment was to convert the paper-based data storage to a computerized database.

> *"(Eventually,) we had volunteers with computers all over the city taking chunks of paper trying to put all that data into computers. That was very laborious, trying to put all that into the computer database." (Senior Director Emergency Services, American Red Cross)*

Other action strategies included expending more effort on handling the data each time it was needed and, more commonly, simply not using the available data. Storage media misalignment is related to low information priority, as the need to act makes relief workers register data on paper rather than wait for electronic devices. Response strategies to this impediment included information inactivity and dedicating extra resources to processing data. By information inactivity, we mean that the organization decided to stop processing data. Overall, this information impediment suggests the need for information systems that can easily capture data in electronic formats more suitable for processing activities.

(7) Unreliability

Unreliability refers to an organization's low level of confidence in data or information it possesses. This not only refers to information organizations actually receive, but also to information they send. Interfaith Ministries (IM), for example, in its intermediary role between government and faith-based organizations, was approached by many congregations in hopes that it could provide the most current and reliable information.

> *"We had a lot of people having us to be (their information resource), but we didn't have the database to really say I feel confident enough for you to go. […] And that ticked a lot of people off, because you didn't know for sure, knowing that it wasn't reliable and timely." (Manager, Office of Disaster Preparedness, Interfaith Ministries)*

Nevertheless, organizations often kept the most meaningful part of the information while still doubting the details. This was a situation experienced by the Red Cross:

> *"All the data was self-reported, so there was no verification. You ask for identification, a driver's license or picture ID. It has an address and a picture so there's some verification there, but so many people came to shelters with no identification whatsoever. They had to wade through water […] lots of people lost their wallets. […] (But the data) was good to a point, because you knew that person survived the evacuation, they survived the disaster, and they were at a Red Cross shelter at some point. So we knew who was alive." (Senior Director Emergency Services, American Red Cross)*

Interfaith Ministries' reaction to the unreliability of information was to discourage faith-based organizations from getting involved if it was not clear they were needed. In this way, they simplified their efforts by reducing the number of organizations involved. In contrast, the Red Cross simply

accepted the unreliability of the data they possessed and used it wherever it could provide value. Thus, unreliability is an information impediment that prevails across different organizations and refers not to the accessibility, format, or amount of information, but to its quality. We found that this is something organizations deal with simplifying and by keeping the most important meaning conveyed.

(8) Unwillingness

Unwillingness occurs when one organization decides not to transfer data or information to another organization. This category is closely related to inaccessibility; however, the non-availability of information does not depend on something physical as inaccessibility does, but rather on constraints of regulatory law or even personal preference. Continuing a previous example, when Harris County OHSEM was informed that parishes in Louisiana had emptied their jails onto buses that were heading toward Houston, Harris County requested sexual offender lists from the State of Louisiana. Unfortunately, state laws precluded this information from being shared.

> *"Well, it didn't happen; state law. They couldn't give (sexual offender lists) to anybody […] It's not like in Texas where you put their names and all up." (Administrative Coordinator for the Harris County Office of Homeland Security and Emergency Management)*

As a reactive strategy, Harris County OSHEM responded to this unwillingness, and more from the American Red Cross, by obtaining the information without permission.

> *So, what we did is, we hacked into their system and downloaded the list. […] Now we wanted to combine this information with the registration information that the Red Cross had captured electronically already by that time. Well, the Red Cross told us we can't get that information. […] it is their policy, it said, at a national level. So no problem, we hacked their system as well and did a quick cross reference." (Administrative Coordinator for the Harris County Office of Homeland Security and Emergency Management)*

Another account from a spontaneous, unaffiliated volunteer illustrates the unwillingness of the Katrina Housing Taskforce to release evacuee housing data.

> *"A lot of it came down to who you knew in terms of having access to certain kinds of information. I called and asked for the list of housing developments they were moving evacuees into and was told they couldn't give it to me." (Spontaneous Unaffiliated Volunteer)*

The individual then proceeded to gain the necessary permission by leveraging personal relationships. Throughout our data analysis, reliance on personal relationships was a common action strategy in response to the intervening condition of unwillingness.

> *"So I called (the Houston Mayor's Deputy Chief of Staff for Housing), who I worked with before, on his cell and he cleared the information release right away." (Spontaneous Unaffiliated Volunteer)*

Clearly, this impediment touches upon aspects of regulation and even ethics. The actions taken by relief officers show the desperation of the moment. It is an ethical dilemma whether to obey a regulation that is thought to preserve individuals' rights during regular times or to obtain the required information to protect the lives and livelihoods of entire communities. In any case, this impediment calls attention to the need for legislating flows of information throughout major disasters. It also shows that the measures to be taken to guarantee information flows during disaster times transcend the technical aspects of information systems.

5. Discussion

The ability of inter-organizational information flows to improve supply chain resource flow performance is well-established in normal industries (Sahin and Robinson, 2002). In disaster times, however, this linkage has not been adequately examined. Through this extreme case study analysis of Hurricane Katrina relief efforts, we found that supply chain information flows did improve resource flows; however, the information flow was influenced by several impediments. Our examination revealed that each of these impediments arose, at least in part, from some combination of the

Table 3: Summary of Findings

Information flow impediment	Definition of information flow impediment	Support in literature that give rise to this impediment	Information flow activity adversely impacted	Strategy applied	Design principles
Inaccessibility	Inability to obtain data or information that is known or assumed to exist	Extreme Uncertainty [Beamon & Kotleba, 2006; Tomasini & Van Wassenhove, 2004, 2006] Short Life-Cycle [Oloruntoba & Gray, 2006; Denning, 2006]	Collection Sharing	Seek alternate information sources; Revert back to physical means of data collection	Geospatial applications
Inconsistent Data and Information Formats	Multiple sources of similar data or information cannot be compared or aggregated because of their different content configurations	Short Life-Cycle [Oloruntoba & Gray, 2006; Denning, 2006]	Processing	Aggregate unlike information; accept incongruent information and assume the worst case	Intelligent systems that points out and can deal with incongruent data points
Inadequate Stream of Information (Shortage/Overload)	Too little or too much data/information available to an organization	Urgent Responsiveness [Kelly, 1995; Van Wassenhove, 2006; Ödzamar et al., 2004] Extreme Uncertainty [Beamon & Kotleba, 2006; Tomasini & Van Wassenhove, 2004, 2006]	Processing	Rely on assumptions in case of information shortage; speed up processing in case of information overload	Intelligent system that is able to associate credibility values to information and to process information fast
Low Information Priority	Not placing appropriate precedence on information flow activities	Urgent Responsiveness [Kelly, 1995; Van Wassenhove, 2006; Ödzamar et al., 2004]	Collection Processing Sharing	Information inactivity or substandard activity	Pressing for technical advancements in audio and video conversion
Source Identification Difficulty	An organization not knowing where to get wanted data or information	Short Life-Cycle [Oloruntoba & Gray, 2006; Denning, 2006]	Collection Sharing	Information inactivity; deployment of extra resources	System that supports social relationships
Storage Media Misalignment	Characteristics of the chosen recording or storage media inherently	Urgent Responsiveness [Kelly, 1995; Van Wassenhove, 2006; Ödzamar et al., 2004] Short	Collection Processing Sharing	Increase processing efforts, or information inactivity	Pressing for technical advancements in

	inhibit efficient information flow activities	Life-Cycle [Oloruntoba & Gray, 2006; Denning, 2006]			audio and video conversion
Unreliability	An organization's low level of confidence in data or information it possesses	Extreme Uncertainty [Beamon & Kotleba, 2006; Tomasini & Van Wassenhove, 2004, 2006] Short Life-Cycle [Oloruntoba & Gray, 2006; Denning, 2006]	Processing	Leverage meaningful part of information only, accept information quality	Intelligent systems that are able to associate credibility values to information
Unwillingness	One organization will not transfer data or information to another organization	Short Life-Cycle [Oloruntoba & Gray, 2006; Denning, 2006]	Sharing	Leverage personal relationships	System that supports social relationships

disaster relief supply chain characteristics that we described in the literature review section as urgent responsiveness, extreme uncertainty, and short life-cycles. Thus, our findings confirm the themes identified in extant literature (Beamon and Kotleba, 2006; Denning, 2006; Van Wassenhove 2006; Oloruntoba and Gray, 2006; Ödzamar et al., 2004; Tomasini and Van Wassenhove, 2004), while empirically illustrating concrete instances of those themes.

Table 3 below provides a summary of our findings. While Column 2 provides a short definition of all impediments identified in this study, Column 3 ties these findings to extant disaster literature. We found that the underlying characteristics of the disaster situation (i.e., urgent responsiveness, extreme uncertainty, and short life-cycles) were observed to be contributing factors. Column 4 summarizes the information flow activities that we found to be adversely impacted by each impediment, while Column 5 lists the different reaction strategies that organizations adopted.

Overall, Columns 2, 3, and 5 represent a sequence consisting of "impediment, cause, and line of action applied." This sequence was key in our analysis, as it provided us with an anchor point during the selective coding process. More specifically, it allowed us to infer a set of IS design principles as shown in Column 6. Column 6 suggests certain characteristics of information systems that could potentially support the strategies aimed at alleviating the impediments. Thus, Table 3 synthesizes our main findings, both empirically and theoretically.

Each row of the table, with the combination of information flow impediment and its respective system solution, represents a theoretical proposition that could be subjected to empirical testing either by confirmatory studies or by action research. In other words, future research could test whether the proposed impediments, in combination with each proposed design principle, represent a comprehensive set that holds true across various organizations and disasters. Thus, each of the eight rows in the table—by virtue of its hypothetical nature—represents what Lee and Baskerville (2003) call a contribution to theory, which is one of the strengths of qualitative research.

The remainder of this section discusses in detail a set of design principles. The principles originate from reflecting on how IS might alleviate the impact of information impediments of future disasters and lead to an improved flow of resources throughout the disaster relief supply chain. These design principles comprise four aspects.[2]

As a first design principle, a system supporting disaster relief objectives should be able to identify and deal with both incongruent data points and data credibility issues. Storing factual data only, as most traditional systems do, is not sufficient in unstable environments like those presented in disaster situations. Traditional systems typically refuse to store incongruent data, as it might lead to inconsistencies and unstable database states. Associating a congruence percentage as well as a credibility value as an explicit attribute value to a data point would, therefore, be a simple and tangible solution to address inconsistent and unreliable data. Another potential solution is to display all the collected data, such as has been done in TweetNews, a new application that relates recent Twitter messages to breaking Yahoo news stories (Gilbertson, 2009). Such an approach may help disaster managers better understand the congruence and credibility of reports surrounding emerging issues.

As a second design principle inferred from our case study, we recommend a system that incorporates geospatial applications — not only to monitor the disaster area (especially if the disaster area is inaccessible), but also to provide useful data about relief zones and reconstruction areas. Existing applications include Weather.com and Google Earth. Continuing the example above, a system component seems feasible that links the geographical layout of a sheltering location with data about its potential capacities.

As a third design principle, a system capturing audio, video, or textual information should do so with

[2] We should clarify here that these principles are not specifically related to design science (for a detailed discussion in this area in IS see for example: Hevner et. al., 2004; Iivari, 2002; van Aken, 2007). The principles presented here aim at guiding IS designers.

the least amount of human interference possible while improving the technical conversion between data nature and data capture. For example, an application seems feasible that automatically converts spoken words during an interview into a textual transcript format that can be stored electronically; or a video capturing application that can easily be linked and stored with the geospatial component mentioned earlier. At present, the misalignment between the nature of the data and the way it is stored results in inefficiencies and low motivation to capture data at all. It should be noted that there exist several technologies for performing electronic data collection in various formats; however, failed and intermittent infrastructures (Larson et al., 2006), as well as the lack of wide-spread behavioral adoption of technology (Perry, 2007), has thus far made it difficult to leverage them in the wake of disasters.

As a fourth design principle, we suggest that future systems support a social network component. Social network systems, such as Xing or LinkedIn, provide users the ability to store their personal profile (including their title, role, and contact information), paired with a linked list of persons they know. A disaster preparedness network would not only visualize the formal network of people activated in disasters, but also a list of informal contacts that individuals possess from other contexts. In disaster times, the combination of formal and informal networks may contain valuable information and resources that can be leveraged to find appropriate people faster which, in turn, may result in speeding up the decision-making processes or in finding new and non-traditional solutions.

We do not claim that these design principles are comprehensive. After all, very basic recommendations, such as ensuring a system's reliability, speed, or backup, are already essential components of existing disaster management efforts. Nonetheless, we believe our case study has identified pieces beyond the existing recommendations that system designers might find worthwhile to consider for future systems that support disaster relief supply chain decision makers.

In addition to the design principles, we also recommend training employees to use improvisation when encountering unexpected situations. The complexity of disaster relief supply chains makes it almost impossible to plan for the unexpected situations that typically arise. In this sense, the impediments that we have identified can be the basis of training aimed at improvising solutions to information flow challenges following disasters (Weick, 1993 and 1998). Creatively finding ways to mitigate their impact throughout the disaster relief supply chain will improve the flow of information and beneficially impact the corresponding resource flow throughout the system-wide effort. As several action strategies from our case study illustrate, improvisations were common in attempts to solve many of the information flow problems encountered during Katrina relief efforts. The phenomenon of improvisation has been amply studied in the management literature (see for example Crossan, 1998; Meyer, 1998; Meyer et al., 1998; Weick, 1993; Weick, 1998) and also in the IS literature (see for example Ciborra, 1999; Junglas and Ives, 2007; Orlikowski, 1996; Orlikowski and Hofman, 1997; Silva, 2002). However, these works have not concentrated on improvisations for the managing of information flows and their relation to supply chain during a disaster.

6. Contributions and Implications

Contributions of our research are many-fold. First, we have identified classes of problems related to information flows that developers should address when designing information systems to support disaster relief supply chains. We believe this is a significant contribution given, as mentioned above, the sheer complexity and chaotic nature of managing information flows in post-disaster environments. Second, we have presented a concrete instance of activities within a disaster relief supply chain. That is, our findings lend additional empirical validity to previously identified characteristics inherent to disaster relief supply chain environments. Third, the impediments we found extend the supply chain theory that relates information flows and resource flows to a wider context (i.e., disaster relief). Our research and analysis affirm that normal industries' long-established relationship between information flow and resource flow also extends into disaster relief scenarios. Moreover, our identification and categorization of information flow impediments provides new insights into potential underlying reasons why adequate performance in disaster relief efforts has remained so difficult to achieve. Finally, we have proposed a set of general principles that may guide IS design for supporting

information flows during disasters.

The managerial implications of our findings offer additional value. Practitioners wishing to improve the overall system performance of disaster relief supply chains will want to consider the potential impact of the identified impediments when planning and mobilizing inter-organizational disaster relief efforts. Disaster relief planners will also want to encourage organizations to maintain capabilities for improvising responses to these identified impediments. Over-reliance on information systems designed for normal environments may lead to organizations being ill-prepared for operating in non-routine disaster relief environments. There may also be merit in investigating innovative technological methods—such as the ones proposed here—for responding to these impediments within the post-disaster context from which they arise. Such mechanisms that improve the flow of information and resources in these extreme supply chains might yield insights on how to improve inter-organizational efforts in normal industries; especially those industries that continue to experience increasing uncertainty, shorter life-cycles, and urgent responsiveness.

7. Limitations

Due to the magnitude of the disaster and the dramatic impact that Katrina has had on even the most fundamental elements of existence, choosing an appropriate sample set was challenging. We conducted interviews across a wide variety of profit and non-profit organizations, as well as individual volunteers that were not affiliated with any organization. We acknowledge that this sample might not be comprehensive—after all, Katrina displaced more than 780,000 people within a radius of 200 miles, and more than 250,000 people were at least temporarily out of work. Therefore, capturing information from the plethora of organizations involved was impractical. We also acknowledge that our sample might under-represent individuals and over-represent organizations. When interviewing individuals, we soon realized that each individual was serving it at least one role affiliated with at least one organization (e.g., as an employee, volunteer relief worker, donor). We rarely encountered individuals who were independent and most of them simultaneously held more than one role. Despite these limitations, however, we feel that this study provides value, as it showcases the information impediments experienced from a representative set of perspectives in a very salient form.

8. Conclusion

This extreme case study of disaster relief has revealed issues that may otherwise have gone unobserved. Often, retrospective analyses of disaster relief are either avoided or softened because people do not want to assign blame. Yet identifying impediments to avoid the same pitfalls in the future is vital. Our research has taken an initial step and provided a set of impediment categories that can either be subjected to empiric testing or serve as design considerations for information systems. Future research can test whether the proposed impediments in combination with the proposed design guidelines represent a comprehensive set and whether they hold across other types of involved organizations. Also, we had the opportunity to study an extreme case of a natural disaster, but the generalization of our findings to other domains, such as pandemics, terrorism, or even non-disaster efforts, remains untested (Lee and Baskerville, 2003).

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Appendix– Organizational Description of Interview Partners

The American Red Cross

Although the Red Cross is not a government agency, it is chartered by the U.S. government to provide emergency services following disasters. The Red Cross is expected to provide shelter, food, health and mental health services to address basic human needs. In addition, it feeds emergency workers, handles inquiries from concerned family members outside the disaster area, provides blood products to disaster victims, and helps those affected by disasters to access other available resources (American Red Cross, 2006). One of the core missions of the Red Cross is to provide assistance to individuals and families affected by disaster, enabling them to resume their normal daily activities independently. Hurricane Katrina was the biggest disaster in the history of the Red Cross, hosting 40,000 people in 200 shelters nationwide (American Red Cross, 2006).

Interfaith Ministries (IM) for Greater Houston

Interfaith Ministries (IM) for Greater Houston area is a non-profit social service agency that serves as an intermediary between governmental agencies (including the city, county, state and federal level) and local faith-based organizations. The spectrum of religious congregations active with Interfaith Ministries includes organizations affiliated with Christianity, Judaism, Hindu, Sikh, Muslim, and other faith traditions. Interfaith Ministry's tri-fold mission is to assist refugees with resettlement, provide daily meals for home-bound individuals, and encourage disaster preparedness in their affiliated faith communities. During Katrina, Interfaith Ministries was involved in feeding evacuees from Louisiana that were transported to Houston by buses.

The University of New Orleans (UNO)

UNO is a major urban university within the city limits of New Orleans. Prior to Katrina, it had approximately 17,000 students. Afterwards, enrollment declined considerably and it remained far from its pre-disaster status in 2008. Even 18 months later, the university remained only partially operable while administration and staff continue fighting for its survival.

Following Katrina, a group of volunteers consisting of staff and faculty established a control center on the Baton Rouge campus in an attempt to get the university IT system up and running again by resurrecting basic functions, such as email and Internet service. In addition, an ad-hoc phone bank was implemented and manned with volunteers. Locating, contacting, and disseminating information to university employees and students was of primary importance as the semester had just started.

Defense contractor in the Gulf Coast Area

The local defense contractor (who remains anonymous) provides aerospace and defense systems to the U.S. as well as global customers. Their spectrum of business lines ranges from designing to integrating and manufacturing defense electronics, advanced aircraft, shipbuilding, and space technology. Approximately 20,000 employees worked, and now work again, in three large facilities in the Gulf area: one in Pascagoula, Mississippi, a smaller facility in neighboring Gulfport, and one facility in New Orleans.

Prior to Katrina, the organization took its usual precautionary measures based on its business continuity plan. It evacuated employees and secured its facilities and IT functions. However, when Katrina hit with full force, all three facilities were severely impacted and mostly inoperable. Initiatives to restore the facilities were quickly overshadowed by the restoration of employee families instead.

Harris County Office of Homeland Security and Emergency Management (OHSEM)

The Harris County Office of Homeland Security and Emergency Management (OHSEM) in Texas is responsible for emergency management planning and ensuring continuity of social services throughout Harris County and the Greater Houston Area. It maintains and supervises the regional EOC that helps coordinate all local support agencies by preparing and distributing disaster information while working with federal, state, and local authorities.

Following Katrina, Harris County took on an estimated 250,000 evacuees. When the Superdome in New Orleans became uninhabitable, evacuees were transported by buses to the George R. Brown Convention Center in downtown Houston as well as the Reliant Complex, including the Astrodome. Government agencies from both the city and county took on the administration of these unprecedented mega-shelters and worked in conjunction with the American Red Cross, which managed sheltering operations. At its peak, 24,300 evacuees were staying at the Reliant Complex and 2,800 at the George R. Brown Convention Center downtown (Harris County Joint Information Center, 2006).

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