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An Investigation Into the Use of Geospatial Technologies as Part of Disaster Management Efforts Related to the Asian Tsunami of 2004

Robert William Redding Jr.
University of Southern Mississippi

The University of Southern Mississippi

AN INVESTIGATION INTO THE USE OF GEOSPATIAL TECHNOLOGIES AS PART OF DISASTER MANAGEMENT EFFORTS RELATED TO THE ASIAN TSUNAMI OF 2004

by

Robert William Redding, Jr.

A Dissertation
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

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ABSTRACT

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On the 26th of December, 2004, a tsunami impacted the countries surrounding the Indian Ocean, immediately killing over two hundred and eighty thousand people, displacing another million people, and initially causing at least US$10 billion in damage. The response by the international community was swift and massive. Disaster decision-makers who led their organization's responses to the tsunami used geospatial information to support their decision-making efforts with mixed success. When describing their use of geospatial technologies during the response, a select set of disaster decision-makers provided information about how they used geospatial information, they described what worked and what did not work to support their efforts. These disaster decision-makers' revelations include the need for information about the affected persons, the location and status of relief supplies and other resources, and the conditions of the terrain affected by the tsunami. Corroborated by documents produced by governments, academia, nongovernmental and international organizations, these information requirements are the basis for a logical model for a geographic information system that can be used to support a variety of disaster types.

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CHAPTER I

INTRODUCTION

This dissertation explores the aspects of using geographic information systems as part of the efforts to plan, coordinate, manage and monitor disasters. Specifically, it investigates by a case study what happened when disaster decision-makers used geospatial information to support their management of the disaster that was the Asian Tsunami of December 2004.

The Asian Tsunami of 2004 began with an earthquake off the coast of northern Sumatra at 00:58 Greenwich Mean Time, December 26, 2004. This earthquake generated tsunamis, or abnormally large sequences of ocean waves, that were measurable around the globe but created mass destruction in the coastal areas of the Indian Ocean, to include Indonesia, Thailand, Sri Lanka and India (Stein & Okal, 2005). As discovered in a United Nations Environmental Program Rapid Assessment (2005), these tsunamis immediately killed over two hundred and eighty thousand people, displaced another million people, and initially caused at least US$10 billion in damage. According to the same assessment, in some affected areas, the water from these tsunamis reached one and a half kilometers inland, and reached a height of 31 meters above mean sea level.

The response to this disaster was immediate and international in character. Disaster management organizations, to include governmental and non-governmental, responded almost immediately to those in need throughout the affected area. Simultaneously, and at multiple levels, disaster responders provided for a variety of needs. In the immediate aftermath of the tsunami, the nature of this particular disaster made it difficult to assess what had exactly happened. This made coordination and response inherently difficult. However, even without exact requirements, the international community responded to this major natural disaster as best it could with the information available (Katoch, 2006).

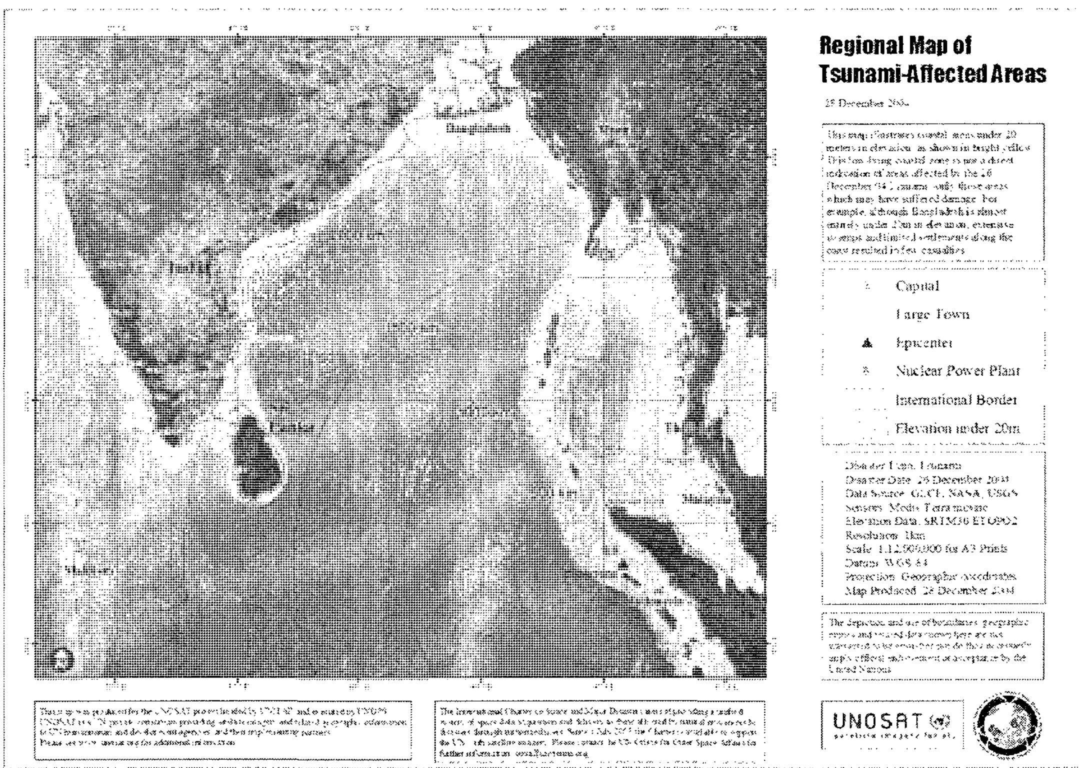

Figure 1. Regional Map of Tsunami-Affected Areas. This figure shows the area affected by the Asian Tsunami of 2004.

From UNOSAT web site, downloaded April 6, 2009 from http://unosat.web.cern.ch/unosat/asp/prod_free.asp (Copyright UNOSAT and The International Charter, 2004). Adapted with permission of UNOSAT and The International Charter

Geographic information systems, which are computer-based technologies used for analyzing spatial information, have improved on and thus superseded the manual methods of overlaying and analyzing spatial data on a paper map

(Foresman, 1998). The use of geographic information systems, or GIS, has expanded in the last 15 years, along with other information technologies, and this expansion includes applications in the discipline of disaster management. Specifically, GIS has expanded in use in all types of disaster management operations activities, to include initial and continuing assessment management, operational decision-making, logistical decision-making, event tracking, event modeling and prediction, interagency coordination and long-term reconstruction planning. However, disaster decision makers appear to be some of the least progressive GIS users within the GIS user community.

This dissertation focuses on how the use of GIS affected the process of decision making during the course of managing the Asian Tsunami disaster of 2004. Expressly, this research explores and evaluates data collected from and about the disaster decision-makers who responded to the disaster with the purpose of developing theory in the form of a model of how GIS is used to support disaster decision-making. The collected data is analyzed and summated using two qualitative research methods: interviews of disaster decision-makers who participated in the response to the disaster, and a review of documentation and archives in order to help generate theory, or specifically a model, of what and how decision-makers use geospatial data in order to support making decisions during disasters.

Research Strategy

While later chapters discuss in depth the methodology and supporting theories for this research, it is necessary to convey the research strategy for this dissertation at the beginning, as it sets the vision for remainder of this document. Yin (2003) prescribes three general strategies for analyzing case study data, of which the preferred is *Relying on Theoretical Propositions*. This strategy sets the framework for all of this dissertation's data collection and instrument design, as all efforts pursue the theoretical proposition that *there is a common, best practice for the use of GIS to support disaster management decision making.* The causal relations of how disaster decision-makers do their job and why they do it that way are essential to the development of a model of what information they use to make decisions.

Research Questions

This dissertation examines how decision makers used geospatial technologies to support the management of the damage caused by the Asian Tsunami of 2004. The principal question is: *What happened when geospatial information was used to support disaster decision-making during the humanitarian response to Asian Tsunami of 2004?* In order to answer this question fully, it is necessary to identify and examine the specific components of the question, to include:

1. Who were the disaster decision-makers who responded to the tsunami?
2. How was geospatial information used to support the response to the disaster?
3. What types of geospatial data were required to support decision-making?

Each of these questions is expanded upon in the description below.

Who were the Disaster Decision Makers during the Tsunami Response?

In analyzing this supporting question as it relates to the decision-makers for Asian Tsunami disaster management operations, a series of identifying questions are answered. As a group, those who occupied these positions as disaster management decision-makers were examined to identify their backgrounds:

1. What was the background of a person in this position?

2. What was the typical education level of decision makers who participated in the response to this disaster?

3. Were these people scientists, managers, or simply amateurs who wanted to help? Were they members of a professional society, where they discuss current decision-making methods, and current appropriate technologies?

4. What was the level of computer literacy among these disaster management decision-makers? Did they have access to technology during any part of their work, whether they were at their home offices or in the field?

In addition to the contextual findings above, an operational question was posed: How do disaster management organization decision-makers make decisions?

1. During the course of their disaster response workday, what types of activities did they perform?

2. Was there a strong effort to coordinate between organizations that are response participants?

3. What conflicts were there in the decision making process?

As part of examining the identity of the decision-makers and how they made decisions, this research considers the organizational effectiveness of disaster management organizations that participated in the response to the tsunami by asking:

1. Was the organization that responded to the tsunami a learning organization that changes based on external and internal factors, or was it static?

2. Did the addition of technologies such as GIS add value to relief organizations?

Within most professions, there are a set of ethics to which the individuals within subscribe. This research seeks to uncover what policies and ethics are involved in the tsunami disaster management, to include:

1. Did the policies in place at the time inhibit or encourage the use of GIS technologies?

2. Was GIS used as a tool to support the development of emergent policies for interactions in that disaster environment?

Similar to policy issues, there are always legal implications for any societal interactions. Research into this topic investigated what legal issues were present and observable to the disaster decision makers who participated in the response to the tsunami, to include:

1. What were the legal implications of GIS use, both domestically in the recovering nation and internationally?

2. Specifically, what were the known issues regarding data ownership and copyrights?

All these aspects were examined to build the picture of who the disaster decision makers were.

How was Geospatial Information Used to Respond to the Disaster?

Beyond defining the person who makes decisions during a disaster, this dissertation examines GIS as it is used as a disaster management tool. There are several aspects of GIS that are considered here but not just the actual components. There are also a variety of issues that could potentially inhibit or encourage the use of GIS for disaster management operations. A detailed examination of these potential inhibitors determines their significance to this issue.

The dissertation examines the general design of existing geospatial systems used for disaster management for appropriateness. As previously defined, a GIS is a geospatial analysis system made of many parts. During the tsunami disaster, what were the factors that inhibited or encouraged the use of GIS by disaster management organization decision-makers? What were the perceptions of disaster decision-makers in regard to GIS usage?

Another question asked during this research was how GIS interacted with a given disaster management operation during the tsunami. At what stages of response decision-making were inputs from GIS appropriate and useful?

One of the issues that influenced (positively or negatively) the use of a GIS for disaster management operations is that of data modeling. The common term for this (as with other databases) is schema development. Was an appropriate schema developed and available that appropriately represented the data conditions during the tsunami disaster management operation? There are existing schemas that have been designed to specifically support disaster management operations, but there has not been one single standard that has emerged that can be called the industry standard. This investigation examines whether this was a factor in GIS use during tsunami disaster management operations.

As with any individual or any organization that creates new and unique products, some organizations that participate in disaster management operations have an interest in maintaining ownership of any proprietary developments. The concept of using GIS in disaster management operations generally requires the sharing of information. If a GIS application is created for a response activity is a customized solution (that is, not "commercially off the shelf"), then the sharing of the custom solution might be required in order for other users to gain the coordination benefits of its use. Data ownership issues are examined in order to determine their significance as factors in the use of GIS in disaster response.

Related to the previous issue of ownership are the issues of access to and control of the GIS and its data set. When a tool is developed (whether it is software, a process, or a way of doing business) and deployed in business, the non-profit world, or, even in academia, it is a common practice that the tool is held in a proprietary state. This research addresses the question, what were the factors that went into facilitating access (if existent) to the GIS and geographic data set during the tsunami disaster management operation? What kinds of agreements were required? Was there a payment involved? Was there open access to the data and the tool? Was there a continuum along which there is an agreed upon compromise? In related doctrines, and even in existing disaster management operations activities, there have been attempts to give access to those outside the organization (Cutter, 2003). The existence and effectiveness of that type of sharing is evaluated.

How does a tsunami disaster management operation use geospatial data as a component of decision-making. The development of a dataset is typically the most significant effort in the development of a GIS, and thus can be affected by budget issues. Does the quality of available data affect its use during the response? Additionally, does the data quality become compromised by either unauthorized access or by inept users? How does the ability to update the data during the event affect the propensity for disaster management decision-makers to use GIS as a decision support tool? Some efforts to support response efforts with near-real time data have been successful, while Salazar and De-Vries (2001) infer that because of the *ad hoc* nature of current data management efforts, there is much wasted effort.

Another important evaluation criterion is the pervasiveness of standardization as applied to any GIS data used during the disaster, and how that affected GIS usage during the tsunami disaster management operation. In the field of geospatial technologies, there are many standards available. Some are applied to the software and the applications. These include CORBA compliance, Rumbaugh (for object orientation), ability to accept an SQL query, and compliance with the standards set by the Open GIS Consortium (Puder, 2004; Williams, 1995). There are also standards for geospatial data, to include the US government-sponsored Spatial Data Transfer Standard and National Spatial Data Infrastructure standards (United States Geological Survey, 2004). Other basic standards include the cartographic standards, such as projection, datum and scale.

Another very important component of data is the metadata, which is the set of information about the geospatial dataset. This includes information about when the data were acquired, at what resolution, and by whom. Without quality metadata, confidence in the fidelity of available geospatial data may not be high enough for a disaster decision-maker to rely on GIS as a key decision support tool. Metadata are typically accumulated at the same time and as part of the same effort through which those particular data are acquired. For tsunami data sets, where did base geospatial data come from, and where did the data reside prior to its use? These data sets can come from a variety of sources, to include government, commercial, and academic data producers (ESRI, 2006). Was the confidence of the disaster management decision-makers during the tsunami in their GIS reflective of their confidence in the data that their GIS used?

It is not just the pre-existing data that is important to disaster management decision-makers. The data that can be collected during disaster management operations are both varied and important. What processes were used to update data from the field during the response to the tsunami? Were they the same for all situations or users, or did they have to be modified for each particular case? Did all users of the GIS have the ability to add to the dataset, or was there a tier of users with respect to their access to the data? What were the security issues that applied to the data? In a multi-agency situation, what kinds of agreements were in place to resolve these issues? The new data from the event that can have the most impact on the ability for the GIS to support timely decision-making is as important as any other component of the system; thus its importance is thoroughly explored.

While new, emergent data sets were potentially valuable to the disaster decision maker during the response to the tsunami disaster, tying any existing data with the new may have increased the value of the tool. In cases where GIS data existed prior to the tsunami response, was there consideration in the design of the particular system that allowed for integrating legacy data with the newly acquired data? Was any existing data base layer data? Did any data used during the response exist as non-geospatial data (data not tied directly to a specific location), such as energy usage records?

In addition to links to legacy data, other issues regarding access can be present in a GIS configured to support disaster management operations. New technologies allow data of many types to be accessed, even if they are disparate and not collocated in the same database. This is particularly true of mobile computing technologies. Levels of data interoperability and access are possibly the most critical aspects of GIS effectiveness for supporting tsunami disaster management. During the relief effort, did disaster management decision-makers implement or otherwise access geospatial systems via the World Wide Web using satellite links, wide area networks, and/or regular telephones? Was field data input by mobile computing devices? Did this capability affect decision-makers' abilities or desire to use these systems? What other relatively new technological capabilities for distributed systems (such as terminal servers) were used to enhance access to the GIS and its data sets? Connectivity to data and the nuances thereof are a significant aspect of this issue.

One of the strengths of geospatial systems is the ability to take the variety of available data and consolidate it for use in accurately predicting or anticipating outcomes when certain conditions are met. The modeling capabilities of a GIS allow for predicting such things as the impact of terrain on population movements, or how fire will act in certain environmental conditions. What capabilities were in place or otherwise became available for decision makers during the response to the tsunami? One method of modeling is the application of time to the disaster and its aftereffects. Tracking the changes of the various data components over time can be a powerful component of the geospatial data set. A GIS's capability to model the temporal aspect of data allows for events or effects to be documented in the data over time, and then compared to other data for the purposes of decision support. An example of this type of application is the predictive modeling of behaviors by people in flood prone areas based on previous documented behaviors during floods. In a case study conducted in Ontario, Boyle (1998) found that there are many advantages to using GIS for flood hazard spatial analysis. How did tsunami disaster management decision-makers use these capabilities during the response? Did they apply any modeling results to their decision making efforts? This research examines what decision-makers used in regard to GIS modeling.

What Types of Geospatial Data Support Disaster Response?

After presenting the technical aspects of data management and access, it is important to engage the issue of what exactly is available as data, and what significance these types of data sets had in decision-making during disaster management operations following the Asian tsunami of 2004. For any purpose that a GIS is used for, there are commonly used standard sets of data. These include roads, waterways, landforms, building footprints, and other features that would be of use in determining who requires a graphic reference to a real-world place. This dissertation does not discuss in significance these data sets, as they are usually ubiquitous and not contentious. It does examine those data sets that are useful for disaster management decision-makers to apply geospatial technologies to their professional activities. These types of data sets are the key providers of information for use in modeling projected events, or in tracking current operations.

One of the types of data sets that can provide a large variety of planning inputs is that of hazard distributions. Hazards, or potential sources of danger, are important to both identify and document as part of disaster response. The acquisition of hazards data allows for subsequent sophisticated hazard analyses, to include such products as risk mapping, mitigation support and vulnerability assessments. This research investigates the use of this type of data during the course of disaster response management after the tsunami, to include the effects of use or non-use of this type of data set.

There are many types of hazards, and various ways to document those hazards. Temporally, any particular hazard can be appropriately documented within three different categories: past events, current events, and future events. Past events are the locations of previous dangerous events that may or may not manifest themselves in the future, such as tornados. Current events are hazards that are imminently dangerous, such as a heavily snow-laden avalanche field. Finally, future events are those locations where modeling predicts that a future event would cause damage *in extremis*. These types of hazards include floods, volcanoes, tidal waves, and earthquakes. In 1998, Gomez-Fernandez suggested that GIS was an effective tool for integrating and modeling data that are kept for volcanic risk assessments. Other types of hazards that present historical value include fires and tornados. In a study based on data from a risk analysis project in Honduras, Zaitchik (2003) determined that the use of a GIS was the premier method for risk data visualization. Regardless, once these types of data sets begin to be collected, they tend to have a synergistic effect with each other in regard to analysis. This research investigates the application of hazards data in the GIS to the disaster decision makers on the ground in response to the tsunami.

Epidemiological data lends itself quite well to geospatial exploitation, and this dissertation examines its use during the response to the tsunami. The typical analysis of the characteristics of disease outbreaks leads to clearly observable trends that can be tracked geographically over time. Even rudimentary tracking of disease outbreaks has great benefits and advantages for the disaster responder. This is especially true since diseases are omnipresent and of primary concern during disaster management operations. Even with this knowledge, the use of geospatial technologies for the purposes of tracking epidemiological data during a disaster has been irregular. Kaiser et al. (2003) reported that the use of geospatial technologies has increased since the 1990s, but that there has been little research and that the use of this technology has been essentially an *ad hoc* effort. Those who have used GIS for epidemiological applications have found many successes in the use of the tool. In a 2002 article, a group of authors led by Kistemann et al. found that using a GIS to not only map tuberculosis, but to model potential propagation was extremely useful for help scientists to stop the spread of this disease.

Another type of hazard that lends itself to tracking and documentation by geospatial means is that of human conflict. Regarding disasters, conflict tracking can range from mapping lands owned by tribes on opposite sides of a minor economic dispute, to tracking actual combat on the ground. In the case of the Asian Tsunamis of 2004, the disaster affected several zones of conflict in Thailand, Indonesia and Sri Lanka. Knowing where conflict is and where it has been can be invaluable to disaster decision-makers, particularly those who are neutral food and shelter providers like the International Committee of the Red Crescent and Red Cross. This type of information allows decision-makers to avoid conflict as much as they can, while being able to identify those groups who need to be engaged in order to seek permission to operation in their area of influence. Maintaining accurate and up-to-date data may be difficult during the course of responding to a disaster in a conflict zone, but the payoff can be great. This is particularly true when the effects of the disaster that are potentially worsened by conflict can be anticipated and averted. As far back as 1993, Juhl found that the US government had begun to develop and deploy a system that could accomplish these goals; while in June of 1996, Silver found that this same system was having tremendous benefits during actual emergencies.

In examining a different military theme, it should be noted that disaster management operations can have some of the same characteristics as military operations. This investigation examines the use of these existing systems by disaster management organizations during the response to the tsunami. Corollaries include logistics bases, movement of forces, and intelligence (or knowledge of current activities by others on the ground). Military forces in most developed nations use some type of geospatial command and control software to support military decision-making. These existing technologies are generally appropriate for use in disaster management operations, and are typically available as commercial off the shelf products. However, the use of geospatial situational awareness tools during other disasters has been noted while using the context of military terminology such as Common Operating Picture. In fact, as recently as 2006, the US Government has recognized (on page 36 of a document titled *The Federal Response to Hurricane Katrina, Lessons Learned*) the need for the establishment of "a National Operations Center to coordinate the national response and provide situational awareness and a common operating picture for the entire Federal government."

GIS is not a panacea for decision-makers who plan and execute disaster management operations. However, a review of previous efforts to use geospatial technologies during disaster responses presents evidence that indicates that the use of GIS to support disaster management efforts can greatly maximize the relief efforts of those who would help others in a time of need. Even more so, when the appropriate data sets are available, the use of GIS appears to be a high-payoff investment for decision-makers and can have effort-multiplying effects.

Purpose and Tentative Hypothesis

The purpose of this dissertation is to examine the experience of disaster decision makers who supported relief efforts during the Asian Tsunami of 2004 and then, using those examined experiences, present a research-based model developed as part of the conclusions that demonstrates how GIS can best be used to support disaster management during similar efforts.

A tentative hypothesis can be seen in the light of this dissertation's research proposition: *there is a common, best practice for the use of GIS to support disaster management decision making.* This dissertation's hypothesis is that the data collected via interviews of disaster decision-makers and examination of documentation and archives will be sufficient to generate theory in the form of a model. This model will be definitive in showing what was used by disaster decision-makers to support logical decision-making during the response to the Asian Tsunami of 2004. Based on the quality and depth of information provided by interviews, and the subsequent examination of documents and achieves, the model produced by this dissertation will be a testable theory, induced from primary data, and will be beneficial in helping to develop a broader model for disaster response anywhere in the world.

Significance

There are many current users of geospatial technologies out in practical field situations who support disaster management. However, a review of the literature provides a dearth of research-based methods, data sets or schemas that reflect foundational support for these existing efforts. This dissertation builds on the research that currently exists, and puts forward further findings that provide a framework for the development of a research-based model for a "best practice" GIS template, all based on the experiences of those who used GIS to respond to the Asian Tsunami. Additionally, this research presents the data and academic writings about the use of GIS in disaster management in the framework of the more robust set of data regarding decision making in disaster management in general.

The most significant effort with any GIS implementation and operation is the acquisition and management of appropriate, current and manageable data sets. This is also true within the context of disaster management. Moreover, disaster management decision-makers best know what information is needed to make decisions during the response to a disaster. There is little research, however, that links these two concepts and that details the "best practice" data model that can be used to support the very sophisticated GIS applications that can be used to enhance decision-makers' efforts (Gall, 2004). These applications include tracking socio-economic data over time, proximity studies of poverty areas to heavy industrial areas, and tracking and predicting urban sprawl. (Steinitz et al., 2005; Nellis, 2005; Maktav et al., 2005; Janelle & Gillespie, 2004).

The temporal aspect of the use of geospatial data and analysis is important to crisis decision-making and is examined in depth. In a discussion of lessons learned from the field, Kaiser et al. (2003) related that the age of data sets (by themselves or as compared to other data sets) is an issue that is rarely addressed, but has the potential to greatly enhance decision making during relief operations.

Another key aspect of this research is the examination of how the use of geospatial technologies facilitates the examination of large amounts of data. One characteristic of decision-making during disaster recovery operations is that pertinent but disparate information regularly presents itself to the decision maker, but this information is difficult to receive or interpret because of its source, format or content. This research examines the use of GIS as a tool that allows the decision maker to more readily process information that leads to a more successful outcome during disaster management.

There are a few recent examples of the use of GIS to mitigate information saturation during disaster recovery. As related by Schwartz in 2005, the National Institute of Environmental Health Sciences' recovery efforts for Hurricane Katrina have been able to include the use of GIS to document the environmental hazards that were present for residents of affected areas. The use of GIS in this case (as most) was reactive and not apparently part of an overall, deliberate geospatial effort that was coordinated with other agencies with similar missions, such as the US Environmental Protection Agency. In a similar effort to support recovery from the devastating Pacific tsunami of December 2004, groups of international volunteers used current satellite imagery to support the planning of placement of Displaced Person camps, medical facilities, communications networks, and transportation routes (Preuss, 2005). This work supported the disaster management efforts immensely by providing much needed information about what conditions were on the ground, where resources were and were not needed. As with the previous case, however, the effort was *ad hoc*.

Synopsis of Balance of Dissertation

This dissertation has eight chapters and four appendices. The structure of the dissertation is consistent with current academic standards. This synopsis concludes Chapter I (Introduction). The literature review is found in Chapter II. In this chapter, the literature is examined initially to show the current trends in using geospatial systems to support disaster decision-making. This includes common uses of GIS in disaster roles, to include its predictive capabilities, provision of awareness, and facilitation of quality in decision-making. The literature review additionally provides a potential corollary for geospatial technology use found in sustainable development. Finally, the literature review examines the disaster decision-makers themselves.

Chapter III presents the theoretical basis for the research conducted as part of this dissertation. Existing GIS models are presented for comparison and examination, to include sub-components of much larger models. The basis for the decision-making aspect of this research is presented in pertinent models of disaster decision-making.

The Methods and Data are offered in Chapter IV. This chapter lays out the objectives and foci of the research, and presents the reasons for using a case study as the framework for this dissertation's research. The design of the research is described, along with the conduct and sequencing of research efforts. After describing the controls inherent to the research design, the chapter concludes with a description of how the analysis of the case study evidence will be done.

The Interviews are presented in Chapter V, to include their format and outcomes. The perceptions of the interviewees are analyzed and described, to include emergent themes that are used subsequently to perform document and archival research.

The themes that emerged in Chapter V are examined and corroborated with documentary and archival evidence in Chapter VI. The research documents are described, and then used to correlate the emergent themes. The chapter concludes with an analysis of the corroborating evidence discovered during document and archival research.

Based on the results of the interviews and the subsequent corroborating documents and archives, Chapter VII presents a model of a GIS that supports disaster decision-making. This model presents the geospatial functions needed by disaster decision-makers, as well as the data required by those functions. Chapter VIII presents the conclusions of the dissertation, to include an assessment of hypothesis validity and recommendations for future research.

CHAPTER II

LITERATURE REVIEW

An examination of the literature indicates that the use of disaster decision-making geospatial applications, in a variety of forms, is becoming more prevalent during disaster management operations. This prevalence is found in disaster responses by large and small organizations. Even though GIS as a technology and tool for use by disaster decision-makers has developed and matured in function and usability over time, not all applications and models are fully functional, viable and easily usable by disaster decision-makers. This lack of maturity in disaster decision-making support from GIS means that a set of standards for the use of geospatial technologies to support disaster management decision-making has not presented itself to this particular user community. In the opening of this review, the pertinent literature regarding the use of geospatial technologies in disaster management is examined to determine efficacy and pervasiveness of those technologies. Subsequently, literature regarding the use of GIS by similar disciplines is reviewed, particularly those disciplines that either make decisions in a similar manner or those that conduct similar activities. In concluding the literature review, the literature on the subject of pertinent decision making methods is examined in general, as Chapter III is a more deliberate examination of those methods from a theoretical point of view.

Disaster Management and GIS

Around the world, all countries with functioning governments have a particular ministry or agency that is primarily responsible for responding to disasters within that country. Within the United States, the Federal Emergency Management Agency is the lead agency for federal-level disaster management efforts. The agency's mission is:

> To support our citizens and first responders to ensure that as a nation we work together to build, sustain, and improve our capability to prepare for, protect against, respond to, recover from, and mitigate all hazards. (FEMA, 2009a)

For any large disasters that exceed the capacity of local and state responders, the Federal Emergency Management Agency is the organization in the United States that responds for the federal government.

As part of its responsibilities, the Federal Emergency Management Agency has committed to maximizing the use of geospatial information to support its work. Within the agency's organization, there is a GIS department that acquires data, maintains it, performs appropriate analyses, and produces many different outputs in a variety of formats in order to support disaster decision-making before, during and after disasters. In fact, the Federal Emergency Management Agency is one of the pioneers of GIS use in the United States federal government, and it typically finds itself at the forefront of innovative uses of the technology.

One of these pioneering efforts included being one of the first US agencies to completely digitize a set of primary products of work. The set of products probably most used by the public, the Flood Hazard Boundary Maps and Flood Insurance Rate Maps, were first digitized as geospatial information beginning in 1997. The Federal Emergency Management Agency was also one of the first United States federal agencies to implement web-based GIS applications, such the HAZUS application described later in this dissertation. As such, these agency mapping products, including those that are primarily used for property insurance purposes, can now be found as a web-delivered GIS product. For example, as of 2009, the agency's GIS department still maintains a web-accessible geospatial data set that supports decision-making for Hurricane Katrina recovery. This web site includes information such as high water marks, surge inundation limits, and contours (FEMA, 2009b).

Efforts to expand and improve the use GIS for disaster decision-making, however, have not been exclusively concentrated at the federal/national level. In a 2000 article, Gunes and Kovel describe the effective use of GIS in several local and regional efforts for emergency management. For example, Gunes and Kovel reported that the Emergency Management Agency for Douglas County, Kansas, implemented a GIS-based decision support system that supports decision-making for preparation, mitigation and response to disasters that are likely to be encountered by disaster decision-makers for the county. This GIS based decision support system uses three distinct databases to support its applications: a disaster/emergency database, a facilities database, and a resources database. Interestingly, the Gunes article additionally reveals that the Douglas County system has a predictive capability in that it is designed to identify facilities that are likely to be affected by any particular disaster. Nonetheless, the article primarily conveys that the system allows disaster decision-makers the ability to better visualize disaster problems so that the best solution available can be applied to save lives and property.

Review of Trends in Disaster Management GIS

When certain conditions are in place, it is likely that a GIS can be found supporting core disaster decision management efforts for any particular disaster response effort. This phenomenon is observable in disaster management operations throughout the world, where disaster decision-makers can be found using GIS to support their efforts to respond to disasters. However, very limited research has been conducted on the interaction between disaster management decision-makers and GIS. In one of those few efforts uncovered in the literature regarding a survey of GIS disaster decision support system case studies, Zerger and Smith (2002) presented that during the decade of the 1990's, GIS was generally used in a primitive fashion that provided limited results and thus limited support for disaster decision-makers. Simple or otherwise inappropriate uses for disaster management, such as non-operational foci on research and experimentation or a use of the simple, primary GIS function of cartography were found, as opposed to more sophisticated uses of spatial analysis functions for modeling, predicting outcomes or managing resources. Additionally, this article infers that although GIS is typically available in some form to disaster decision-makers, the use is frequently *ad hoc*, without standardization, and simplistic in nature.

To expand upon this theme, a review of the literature provides insight into the existing barriers to GIS usage as part of disaster decision-making.

Geospatial technologies are used extensively as part of some disaster management operations (particularly larger ones), to the extent that the primary operational planning and tracking tool is a geospatial system. Conversely, many disaster management operations begin their efforts without significant technological support of any kind, to include the use of geospatial technologies. As a reflection of the disparate nature of disaster responders, there are a variety of methods of responding to disasters. Many groups or individuals who have the resources that they perceive as being required by those affected by the disaster can be found providing those resources as part of a relief effort, and their reasons for doing so are just as different. Regardless, groups or individuals may arrive at the scene of a disaster without the state of the art equipment required to integrate into a modern disaster management effort. Additionally, and for a variety of reasons, GIS is being more effectively used in some aspects of disaster management than in others.

Many potential users appear hesitant to effectively use GIS because of the front-end costs of data acquisition and user training. Zerger and Smith (2002) related that an unclear concept of ownership and custodianship of a disaster support GIS can be an impediment to GIS usage during a disaster response. Primarily for copyright and other legal considerations, some organizations just will not handle, distribute or otherwise use data where the legal rights to that data are unclear. The lack of data can be a significant impediment to GIS use, even when the GIS software is otherwise in place and available. Even so, there are plenty of examples cases where GIS have been the cornerstone of information management from the beginning of a project. On occasion, however, the use of GIS appears to be an afterthought.

A commonly observation in the literature is that many organizations that use GIS do not appear to have maximized the potential use of their implemented system. Kaiser et al. (2003) noted that for the purposes of responding to humanitarian emergencies, GIS has not yet been documented to be a routinely used tool for supporting decision-making. They noted, however, that GIS has become an essential planning for the larger humanitarian relief organizations, to the extent that organizations such as the World Health Organization and the United Nations High Commissioner for Refugees have dedicated GIS offices that are organic to their organizations. Kaiser et al. recognized that these larger organizations have the resources to implement expensive technologies such as GIS, but that the preponderance of humanitarian relief responders does not have such resources. Thus, these other, lesser resourced organizations are impeded from having decision support GIS's as part of their set of resources. Zerger and Smith (2002), in their examination of an Australian case study example, found that:

> The utility of GIS for real-time decision making is questionable owing to a number of practical and implementation impediments including the requirement for paper maps, lack of training, computational overheads when analyzing large urban databases, and the need for temporal resolution rather than spatial detail. Results from the broader research initiative have also highlighted the common incompatibility between the

> scale and resolution of human disaster decision making, and that of spatial data and models. (p. 124)

This example, even though it is case study evidence, gives an example of the set of impedances consistently found in this research.

The lack of ability to gain the initiative, or "get ahead of the game" during a disaster event may inhibit the use of GIS in many disaster management and relief organizations, since the use of the technology requires preparation and effort to implement and use. Some organizations are very frugal by nature, have a limited budget and very few staff. While not very expensive compared to some technologies (such as communications infrastructure), geospatial systems can be financially challenging for an organization to acquire, particularly when custom data sets are required. The lack of funding, for whatever reason, can inhibit decision-makers' innovations in their fields, including potentially implementing an effective GIS. Additionally, organizational momentum may lead to an attitude that states, "The old way has always worked well enough in the past." Zerger and Smith (2002) noted that disaster response GIS usage can be restricted by a variety of "non-technical" impediments, to include custodianship and implementation issues. Regardless of these impediments, Laefer, Koss, and Pradhan (2006) identified the need for increased geospatial technology usage in an article specifically addressing disaster GIS data needs. They related that proper use of geospatial data that is comprehensive, accurate, timely and accessible can greatly enhance a disaster management organization's performance while it is executing its core functions.

Another emerging technology related to information management is that of social networks and how they support and integrate into disaster responses. Social networks are potential sources of geospatial data for disaster management operations. Shankar (2008) noted that blogs and wiki web sites provide a valuable conduit for local, grass roots information to be aggregated and made available to, among others, disaster decision-makers. However, this integration effort requires further research and development in order to properly include this information at the correct place and time during a disaster response. Shankar suggests that areas for future research in social networking include methodologies for vetting or otherwise certifying volunteer or otherwise non-professional information providers in order to include the information that they provide into disaster response data sets. Given the ease of geo-coding information (such of geo-coded photos), this type of information could be easily integrated into a geospatial tool that supports disaster decision-making. During a conference on computing sciences in January 2008, White et al., presented research information on the characteristics, composition and trends of usage of wikis during responses to emergencies. White et al. found that there were many existing initiatives for using wikis during disaster response, and that these efforts were not being used at their full potential. They also found that there was a great disparity of standards of use and accessibility that were inhibiting the use of wikis to support disaster response.

This research is driven by the premise that there are many potential positive effects that a GIS can have on decision-making during disaster management operations. These positive effects are categorized here with the range of applications described as predictive modeling, enabling situational awareness, and quality management.

GIS as a Predictive Modeling Tool

The first supposition that the literature reveals is that a geospatial system can be used to help model potential outcomes in a disaster management scenario, even through multiple branches and sequels of decision options. Jaiswal et al. reported in 2002 that when appropriate geospatial applications are used to manage fire disaster outcomes, predictive models can be very successful in mitigating negative outcomes. In a 2003 article, Montoya states that the modeling of disaster risk can be greatly enhanced by the use of geospatial technologies. However, if a decision-maker has not been exposed to potential value that can be added by GIS, then the disaster decision-maker might be skeptical and conclude that the costs and significant efforts of using a disaster oriented GIS are not worth the and not use GIS, thus not realizing the benefits of the technology.

In a general discussion of the potential benefits that a disaster response organization can realize the use of geospatial technologies, Kovel (2000) wrote that disaster management officials typically come from underfunded and under resourced organizations that would perform better if a disaster response model were available to support their efforts. Kovel puts forward a model that is potentially useful to disaster decision-makers, with the key data components of Kovel's model as presented including key facilities, resources available for disaster response, and the extent of likely damage to those key facilities. Most importantly, Kovel states that these key data components have to be populated with information prior to a given disaster's response in order to be effective.

A GIS-based model such as Kovel's can be used to predict the outcome of a particular disaster. Given an appropriate dataset and some type of appropriate model, a GIS can display the results in a variety of methods that allow for visualization that is better than non-graphic modeling. Visualization of modeled effects can greatly increase the understanding of a potential situation well prior to a disaster event. For example, VanLooy and Cova (2007) provide an example of how GIS-based model can be used to visualize the impact of volcanic eruptions on airplane traffic. This model effectively shows the economic vulnerability that is present when a volcanic eruption disrupts commercial air traffic. Before the development and subsequent use of this model, the effects of a volcanic eruption on necessary air traffic pattern adjustments were difficult to understand and thus difficult to use in developing plans.

Another predictive disaster management decision-making support capability is that a GIS is capable of analyzing and considering more sophisticated options than is normally possible by a team not supported by technology. In a *Biotech Week* article (Global positioning systems gaining use in humanitarian emergencies, 2003), the use of a particular geospatial technology called global positioning systems is deemed able to enhance other data types by giving a spatial component to it. The addition of geo-location to a data set is relatively simple compared to other factors present in primary data collection.

Additionally, Thayer (2002) offers that geo-statistical applications can be used to model trends and latent activities based on those spatial components. An example of this would be the data that contained information geo-location and condition of persons displaced after the tsunami. Lee and Choi (2004) provided another example of an analysis that would have otherwise been impossible to conduct with technological assistance in their landslide susceptibility mapping GIS application. This probability model uses many types of geospatial information about the land to predict within a certain probability where and under what conditions a landslide would occur. This model allows for disaster decision-makers to not only predict an outcome of a landslide, but allows them to model landslides in order to support land-use restrictions.

As an example of modeling available resources, Kar and Hodgson (2008) defined a model integrated into a GIS that evaluated the location, condition and accessibility of public shelter locations in Florida. This model, which supports hurricane disaster planning, examines candidate shelter locations, suitability, as well as their respective proximities in order to provide disaster decision-makers with options based on where, when and how a hurricane makes impact on their location.

Using a similar methodology, Cova et al. (2005) developed a GIS-based model that gives disaster decision-makers a tool that supports making evacuation decisions during a wildfire event. This model, after evaluating weather, topography, fuels and evacuation times, gives decision-makers a set of "triggers," or decision points at which evacuations should be initiated. This model, however, has many uncertainties that are not accounted for. These include a lack of real-time data inputs, the reliance on perfect and uniform conditions, as well as estimates for evacuation times.

GIS as a Situational Awareness Enabler

The next idea found in the literature is that a GIS is an enabling technology that facilitates the effective comparison of disparate data (even temporally disparate). An article in *Civil Engineering* ("GIS gains ground as disaster mitigation tool," 1996) reported that the use of geospatial technologies as a disaster mitigation tool was progressing in effectiveness. However, Maniruzzaman et al. (2001) detail that during a disaster response to a cyclone in Bangladesh, weather, terrain, population and relief assistance data were readily available to disaster decision-makers. However, most disaster responders were not enabled with GIS and were not able to synthesize the available information into a cogent product for decision support. The reasons for not appropriately using a GIS in situations like this are unclear, but access to real-time geospatial data is a multi-faceted challenge that few organizations have the resources to overcome. Xue, Cracknell and Guo (2002) found that an emergent combination of telecommunications and geospatial technologies that allow for "real-time spatial databases updated regularly by means of telecommunications systems in order to support problem solving and decision-making at any time and any place" (p. 1851). This combination allows for the best possibility for a GIS model or application to have the most current information available. Xue et al. describe this technology as telegeoprocessing. They additionally subcategorize telegeoprocessing as WebGIS (an integration of Internet and GIS), Mobile Geoprocessing (Wireless Mapping—an integration of mobile computing and GIS) and TeleGIS (an integration of GIS and other telecommunication techniques). Each of these capabilities has current, practical uses in providing geospatial data that can support disaster decision-making.

GIS as a Quality Management Tool

The last factor revealed during this review of the literature involves quality. Most professional organizations have a process improvement process that analyses past results in order to make future efforts better. As a potential component of process improvement efforts, a GIS is able to enhance the ability of disaster recovery managers to archive existing decision-making materials to support after action reviews. In Turkey, a GIS is integral to the operations of the National Crises Management Center, to include retention of data for after action analysis (Tumay et al., 2002). Epidemiological information has been recorded in geospatial data and used to track cholera in South Africa (Kharif, 2003). This information is to be used to find out where outbreaks occur and to prepare future responses to them. Audisio et al. (2009) found that geoscientists were able to improve their ability to accurately capture and assess landslide and avalanche data when that data was entered into a specially developed GIS. In their observation, Audisio et al. found that not only was the data quality better when entered into a GIS, but the ability to examine disparate type of data was greatly enhanced by using the tool. When used as a component of a total business management system, GIS is found providing an integration capability unlike any other.

Sustainable Development as a Related Discipline

One of the disciplines that is similar enough to disaster response to be valuable as a comparative example is sustainable development, defined in 2008 by the United Nations Environmental Program as "development that ensures that the use of resources and the environment today does not restrict their use by future generations." As noted by Susan Cutter in a 2003 article, GIS can be and have been used for supporting sustainable development. Sustainable development decision-makers appear to have been able to overcome the impedances found by decision-makers who deal with disaster recovery and relief operations. While most of the work that is accomplished by these two types of professionals is similar, the real difference is temporal. Both disaster management and sustainable development deal with life support and sustainment (such as food distribution and shelter). As is the nature of long-term development work, sustainable developers have longer periods to gather information, analyze and synthesize, then produce decisions in response to emergent problems. For example, Pettit (2005) found that GIS-based planning support systems, used for planning development in a sustainable manner, were "an effective way of integrating social, economic, and environmental datasets, enabling a number of holistic spatial planning scenarios to be generated and evaluated by local planners" (p. 523). These criteria are the same and use the same types of information that a disaster decision-maker would use in the course of managing the response to a disaster.

However, disaster management decision makers are usually challenged with a lack of time during the course of their typical operations. One of the GIS data sets that lends itself to use during disasters that is also commonly used in sustainable development is remotely sensed data, typically from orbiting satellites or high altitude aircraft. Chen (2002) reported on the use of multi-temporal satellite imagery being used to classify changes in land used in the Republic of Korea. This technique, which examines the same location over time, is exactly the same as what is used to examine disaster damage that is observable from overhead. For example, during the response to the tsunami, those who had access to both pre-tsunami and post-tsunami satellite imagery were able to rapidly and accurately assess damage caused by the tsunami over large areas.

Another capability touted for use in a disaster response GIS is that of modeling the effects of any particular disaster. Modeling of this nature can be performed during the planning stages before a disaster, or after the fact. Modeling after a disaster has occurred can be extremely effective in determining the extent of the disaster, particularly early on when information about the effects is scarce. In a 2000 article, Li & Yeh (2000) described modeling techniques that are used in sustainable development, and consequently provides a great example of coincident GIS uses between sustainable development and disaster management.

Throughout the world, sustainable development projects use GIS as part of automation efforts to enhance activities such as encouragement of social justice, environmental resource management and poverty mitigation. All of these applications of GIS in sustainable development require significant efforts to implement, but as discussed earlier, the most significant effort is the acquisition of appropriate, current and manageable data sets.

Decision-Making as Observed During Disaster Management

There are as many different methods of making decisions during disasters as there are people that do such work. As observed by Smith and Dowell in 2000, however, a few eminent models are found in use during disaster response decision-making. These models include the *progression of multiple options*, *recognition-primed* and *edge of chaos* models of individual decision-making. These models are discussed as part of current theory in Chapter III –Theoretical Basis. However, in order to build a basis for these models, this review initially evaluates the applicability of generic individual and group responses to disasters.

In the article discussed above, Smith and Dowell (2000) suggest that coordination and unity of effort continue to be significant problems during disaster management. This dissertation's examination and understanding of decision making models offers a basis for understanding what data sets are typically required and used by disaster decision-makers in order to make decisions during a disaster response. Additionally, this research delves into what methods are best for presenting this data to decision makers during the course of the response. Using these results, a subsequent examination of the observed and potential use of GIS during the course of disaster management operations is evaluated to show how and why GIS use can present a different outcome during future disaster management operations.

Reactions as Individuals to Disaster

Of importance to any examination of disaster-oriented decision-making is the psychological reaction of the individual decision maker to the disaster. During this section, the consideration is given to the decision-maker as a reaction of the person to the event as well as the quality of the decisions made as an actor in the incident response process. In evaluations of how individuals react to disasters, Helsloot and Ruitenberg found in 2004 that for the most part, individuals react rationally to disasters. Additionally, they found that panic of any kind is actually quite difficult to come by in a disaster. While a model was not presented by Helsloot and Ruitenberg, the preliminary results of their study suggest that an individual's perception of threat and risk usually allows them to respond rationally to an emergent disaster. In the Preliminary Results of the World Trade Center Evacuation Study (2004), the qualitative interpretation of that horrific albeit specific incident, the average person did not panic and was able to rationally respond and participate in collective evacuation tasks. Based on these results, this dissertation presumes that decision-makers during disaster management are rational actors. Any non-rational individual responses are outside of this study.

Disasters and their management are certainly multi-faceted. As such, disaster management organizations tend to be complex and have multi-faceted management styles that reflect their operational environment. One of the issues that has been identified as impedance to the appropriate management of disasters is that of poorly shared mental models (Smith & Dowell, 2000). First related as a concept by Kenneth Craik (1943), a mental model is a mechanism for accumulating disparate environmental information into a synthesized virtual representation of events, personalities, resources, and other components of knowledge. For the purposes of this dissertation, a mental model is the cognition of all of the components that are necessary for proper decision making during disaster management. The academic discourse regarding decision-making presents other options to mental modeling, but the bulk of disaster decision making literature derive from this concept. Considering all this, Smith and Dowell present a compelling case that the inability of coordinative efforts to effectively share a common mental model impedes the ability of decision-makers (whether collocated or not) to collaboratively make disaster-related decisions because they do not see the same mental picture.

Reactions as Teams to Disaster

Once the individual reaction to a disaster is understood, the next examination is of the set of possible conflicts that may be present when there is a requirement in an organization for distributed decision-making. As related by Matthew and McDonald in 2006, a persistent shortcoming that is observed during US government disaster exercises is in the category of "command and decision-making." They reported that responsibility is typically poorly defined at all levels, that this is particularly true during multi-agency responses, and that the "competing goals of saving lives, preventing further injury, reassuring the public, limiting liability and gathering evidence ... can lead to confrontation and failure unless there is an effective decision-making center" (Matthew & McDonald, 2006, p. 112). Of course, this is true only if the decision-making center is able to address adequately those conflicts. But as Potter et al. wrote in 2005, most decision-making centers would have a difficult time of addressing significant conflicts, particularly when resolving issues in the categories of governmental powers, civil liberties, information sharing among agencies and information dissemination to the public.

In 2000, Crichton et al. related a collection of common features found in many disaster management organizations. They found that these types of organizations tend to be composed of multi-person systems, with different people and teams having important roles to play in the successful management of an incident. Crichton et al. also found that the subcomponents of disaster management organizations are typically geographically separate units that have key roles to play in the emergency management process. This physical separation leads to high demand for improved communication and coordination solutions.

Another characteristic of disaster management teams is that they tend to be *ad hoc* in nature, in that they work together only when responding to an emergent disaster. This observed method of operation compliments the finding that there are many specialized roles on the team and there is typically a requirement to assemble the varied types of expertise in order to respond to a disaster.

In regards to the environment conditions in which disaster response teams operate, Crichton et al. (2000) found that multiple objectives had to be achieved in simultaneously in order for a disaster incident to be successfully controlled. Consequently, it is not surprising that there are typically high psychological demands on the team, with people working under time constraints and stressful conditions. In order to be effective in these conditions, the literature reveals a specific set of characteristics that decision-makers should have in order to be successful members of a disaster response organization. As related by Flin and Slaven in 1995, the specific skills that are most useful for disaster management include the following general attributes:

1. Leadership ability
2. Communication skills, especially briefing and listing
3. Delegating
4. Team working
5. Decision making under the pressure and especially under stress
6. Evaluating the situation (situational awareness)
7. Planning and implementing a course of action
8. Remaining calm and managing stress in self and others
9. Preplanning to prepare for possible emergencies.

As a foundation for study, these characteristics and attributes of disaster management organizations that the individuals that serve in them are used as evaluating criteria for the population being examined.

In a specific reference to GIS, MacEachren et al. in 2005 recognized these issues and applied them to the design of GIS's to support decision-making in a variety of contexts. Their findings included the observation that GIS is an ideal tool for collaborative decision-making in a technology facilitated, task-oriented, multi-modal environment. Moreover, it is important that the GIS be properly designed in order to get this result, otherwise a component (data, application, etc.) will not be present and able to support the disaster decision-maker's needs. In a previous article, MacEachren (2000) was more specific about the geospatial aspect of GIS and how it best fits the typical human to human modes of interaction; that is, the ability to view spatial information allows for a better sharing of the mental map that each individual brings to the collaboration. Visual examination of geospatial information in a collaborative, albeit stressful scenario can be the component of decision-making that makes an effective disaster response team when one would have otherwise not been functional.

Summary of Disaster Management Literature

The literature presents a picture of GIS use for disasters that is relatively clear. Disaster management organizations have used and continue to use GIS to support decision-making during the response to disasters. Their efforts have been varied, but in generally, GIS usage by these organizations has been found to be positive in nature, although those efforts can be regularly be found to be lacking when compared to the potential that is available. There are several comparable disciplines that use GIS in similar fashions as to what is needed to support disaster management, and these disciplines can be examined to determine what other features could be used for a disaster GIS.

A critical component of understanding the use of GIS for disaster decision-making is the understanding of how decisions are made during a disaster response in general. While there are many models of disaster decision-making, three of those models have emerged as preeminently identified as characterizing disaster decision making. The theory behind these models is examined in the next chapter.

CHAPTER III

THEORETICAL BASIS

Geospatial technologies have been used successfully for many purposes similar to disaster management (Tumay et al., 2002). There have certainly been many uses of the technology to support disaster management, particularly in the latter half of 2005 in support of the responses to Hurricanes Katrina and Rita. As Gunes and Kovel related in 2000, most GIS efforts in emergency management have been applied to the mitigation and preparedness phases of disasters. However, some local disaster managers reported using applications that support the response phase of disaster management. These applications include near-term disaster forecasting, vulnerability analysis, damage assessment, hazardous materials, personnel resources, resource inventory and infrastructure locations, as well as mass care and shelter status (Gunes & Kovel, 2000).

There have been many attempts to use geospatial technologies to support disaster management (Kaiser et al., 2003). As Noji related in 2005, one of the first tasks in disaster management is to determine an accurate estimate of the affected population. Reflecting on his experience as a practicing medical doctor with the Centers for Disease Control, Noji noted on page 164 of the Bulletin of the World Health Organization (2005) that "a hand held...GIS" could be used to assist in estimating populations, but left it at that. Indeed, information-consolidating activities such as the estimation of an affected population are exactly what decision makers appear to need from GIS.

Decision-making during disaster management is typically very complicated. The two most apparent reasons for this are the varied information generally required to make disaster-related decisions, as well as the requirement to share that information and decisions with other organizations that are often very different (Smith & Dowell, 2000). In the case study used to illustrate these complications, Smith & Dowell described a railway accident near Ais Gill, England that presented examples of these reasons that were clearly complicating factors in the disaster decision-making that occurred during the response to the accident.

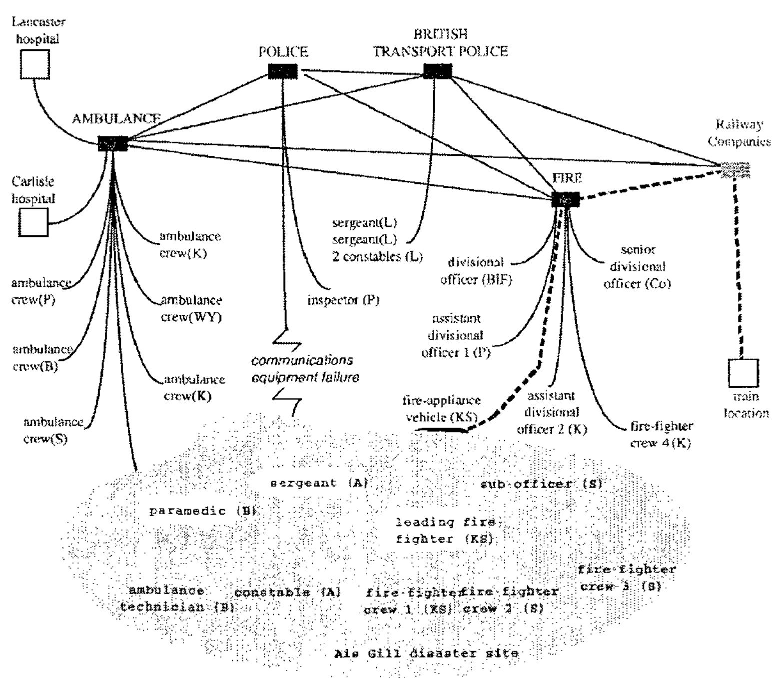

Figure 2. Information sharing during Ais Gill disaster response. This figure shows the complexity of information flow during this relatively discrete, simple disaster response.

From "A case study of coordinative decision-making in disaster management." Smith & Dowell (2000), p. 1159.

The previous figure infers the variety of information that being passed to disaster decision-makers by showing who is providing that information. In regards to distinction, each category of responder (hospitals, emergency medical personnel, police, firefighters, and the rail company) can be further divided by their own jurisdiction or office. A final consideration is that this structure is *ad hoc* and had not existed until the beginning of this particular disaster response.

There is no doubt that the information and data that are used to support decision-making during a disaster are important. However, the decision-making method and the processes that support the method demand a certain type, quantity and quality of data. This research ties the method of decision-making to identified categories of GIS data.

GIS Models that Support Disaster Management

A few documented GIS models exist that are specifically designed to support disaster response efforts. Three models have been selected based on commonalities with the research objectives of this dissertation. These include the Prototype GIS-based Infrastructure Management Information System for Disaster Management; the Dialogue-Assisted Visual Environment for Geoinformation; and the Hazards US Model. As described in Chapter One, one of the aspects of geospatial technologies that is examined in this research is how a GIS can be effectively used by a disaster decision-maker to assess large volumes of critical information during the course of a disaster response. These selected models display the characteristics of being able to fulfill that apparent requirement. Both of these models vary in maturity, depth and focus, but provide useful components as references for this research.

Prototype IMIS for Disaster Management

In 2006, the research team of Laefer, Pradhan and Koss queried members of the North Carolina emergency management community in order to determine what data they use for their work, and how they use it. Using a workshop methodology, Laefer et al. facilitated almost sixty members of North Carolina's community of disaster response practitioners in producing a prototype framework design for a disaster-management GIS. This design was data-oriented and broad spectrum in nature. Purposefully, this research team used a general approach as to what type of disaster was addressed so that the study was as inclusive as possible when considering potential results (Laefler et al., 2006). Based on the results of that examination, Laefler et al. developed a data-oriented model that not only addresses what data are typically used, but also a temporal sequencing aspect of data use that supports typical decision making before, during and after a disaster. They called this model "a Prototype GIS-based Infrastructure Management Information System for Disaster Management" or IMIS. This model focuses on what they identified as the four key aspects of disaster management: depiction, integration, connection and evolution. Laefer, Pradhan & Koss (2006) describe these aspects as follows:

1. Depiction - the physical representation in a digital format of the physical environment, including streets, utilities, buildings, and other major infrastructure components.

2. Integration - the combination of various required data sets into a single, integrated repository (e.g., layouts of all utility systems).

3. Connection - the establishment of relationships between key infrastructure features and various attribute data (e.g., size, shape, age, and depth of embedment of a section of a utility line) and their linkage to identifiable visual representations (e.g., a gas line versus a water line).

4. Evolution - the periodic updating of a data set reflective of changes instigated by various external factors (e.g., replacing or extending utility lines). These four key aspects set the framework for how the model engages the decision-making process during disaster management.

The IMIS model also contains a temporal sequencing that helps the disaster decision-maker focus on critical issues as the disaster event proceeds. The six phases of disaster management the authors identified are identification, prediction, mitigation, preparation, response and recovery (see Table 2). These phases were adapted primarily from the definitions determined by the United States Agency for International Development. Using a hurricane scenario, Laefer et al. (2006, p. 4) characterized these phases as follows:

1. Identification – "Information from past hurricanes and coastal proximity helps to identify areas potentially affected by future hurricanes."

2. Prediction – "A disaster management system should also be able to estimate the loss of human and physical assets based on existing infrastructure and population of those areas."

3. Mitigation - "In addition, the system should assist communities in optimizing safe evacuation exit routes..."

4. Preparation – "and make such information available to impacted populations. Such a system should also be able to accommodate evolving conditions and communicate those changes to the community without delay (e.g. identify changes in safe routes due to changes in a hurricane's path)."

5. Response – "As the hurricane wanes, the displaced survivors may need medical attention, food, and shelter, for which available resources must be identified and allocated."

6. Recovery – "The damaged infrastructure quickly needs to be repaired or rebuilt. A disaster management system should help engineers in speedily removing debris by a combination of identifying and distributing equipment and staff and in presenting alternatives routing and facilities."

This temporal sequence, combined with the priorities, constitute a framework through which Laefler et al. used to structure their examination of what GIS data sets are required to support disaster management decision-making issues.

The final structural component of the model is what Laefler et al. determined to be the set of three essential criteria for an effective disaster management system: a cogent data framework; efficient infrastructure management information system architecture; and adequate data analysis capabilities. Importantly, Laefler et al. emphasized that the cogent data framework aspect of the model is the key to the use of GIS to support a disaster management system. The cogent data framework, which consists of depiction, integration, connection, and evolution, "essential to adequately address key challenges in terms of (i) the ability to design an efficient data model, (ii) the capability to share data among multiple organizations, (iii) the flexibility to encompass future upgrades, and (iv) the capacity to analyze temporal data evolution. Without addressing these, a cost effective, expandable, and flexible disaster management system cannot be achieved" (Laefer et al., 2006, p. 11).

While this model is designed generally to support explosions in urban areas, as a whole it is useful as a basis for this dissertation's research. It provides a logical method of examining the issue (the four key aspects) and a sequence of disaster management, all in the context of using GIS as a tool to support disaster management decision making.

Dialogue-Assisted Visual Environment for Geoinformation

In 2005, a research group led by MacEachren developed a GIS model based on research into how decision-makers interact with a GIS during a disaster event. Specifically, they focused on the actual interface between the system and the decision-makers. In an effort to better use a GIS as a decision enabler, MacEachren et al., focused on how a GIS could best interact with the decision-making team in a multi-modal fashion, as opposed to a single person giving instructions to the GIS and distributing the results linearly. The result of their efforts is a model they called Dialogue-Assisted Visual Environment for Geoinformation, or DAVE_G. This model only minimally addresses data, but instead presents a novel approach to the use of GIS in a collaborative, immersive technique that better enables the use of the GIS in support of core disaster response functions. This interface environment includes speech recognition, recognition of hand/arm gestures, and can provide multiple responses from sequential inputs. (MacEachren et al., 2005). As a response to the research observations, the DAVE_G model was developed to better engage and support more emergency responders. While the application of this model continues to expand, the model has basic functionally and can be applied in a variety of disaster response GIS designs. (MacEachren et al., 2005).

There are several coincident aspects of research that that DAVE_G has in relation with this dissertation. The first aspect is defined by MacEachren's team as *developing semantic frameworks to support geospatial information dialogue*. This refers to the disaster decision-makers' ability to recognize, integrate and interpret information required to make decisions. MacEachren's model addresses this issue in its design, which is particularly pertinent when viewed in relation to the decision-making models that are referred to subsequently in this dissertation. As a geospatial model, DAVE_G addresses the difficulties in sharing a common mental model during the course of a disaster response. The other aspect of this model is that it attempts to address group collaboration issues. As a GIS model, DAVE_G presents a method of better facilitating group interactions that allows for system managed dialogues that focus decision-makers on appropriate decision-making activities. This model's use of accessibility functionality makes it pertinent to this dissertation's effort.

HAZUS GIS

One of the potential effects of a disaster is the saturation of communication systems. Even beyond the normal relationships, some organizations are required during a disaster to engage in communications with many other organizations with whom they would not normally communicate. Saturation of all types of communications can cause an organization to cease proper functioning. During the response to Hurricane Katrina, there were many examples of confusion in the national-level response based on the lack of appropriate information moving up and down the chain of responsibility (Grier, 2006, February). Louise Comfort (2007) noted that the standard model of disaster management disintegrated during Hurricane Katrina, and this was reflected in the severely reduced ability of all levels of the United States disaster management system to detect risk, recognize and interpret risk, communicate that risk, and then respond to the risk and danger. The result of this severely reduced function was that national level decision-making authorities made decisions without appropriate information and thus a poorly developed mental model of the unfolding disaster.

One of the geospatial tools developed to enhance information management during a disaster in the United States is *Hazards U.S.,* or *HAZUS*. Developed and distributed by the United States Federal Emergency Management Agency (FEMA), *HAZUS* is "a nationally applicable standardized methodology and software program that estimates potential losses from earthquakes, hurricane winds, and floods" (FEMA, 2008). This application also allows the user to evaluate risk in particular geographic areas, based on examining different types of hazards (FEMA, 1997). The *HAZUS* application produces damage estimates for examined areas based on the hazard and the physical characteristics of the subject location. The system is able to visually display the results based on the inherent graphic capabilities found in a GIS (FEMA, 1997).

HAZUS has the capability to use a variety of data sets, and can use any geospatial data supported by ArcGIS, which is its host program created by ESRI. Most of the usable GIS data sets that are available to the public, however, are broad in area and short in detail (Cutter, 2003). As stated by FEMA, this tool has limited capabilities for supporting disaster management operations. This tool is more oriented toward mitigation as opposed to comprehensive disaster management. The application's orientation toward pre-disaster analysis results in the quality and resolution of data being appropriate for mitigation, but not for disaster management. The HAZUS application is documented as being difficult for "updating and providing data on local building inventories, geology, and critical infrastructure" (Cutter, 2003, p. 442). This tool is not flexible enough to be used as part of comprehensive disaster management, and is fundamentally not designed to support detailed efforts in disaster recovery.

Decision-Making Models that Support Disaster Management

There are as many ways to make decisions as there are people. However, researchers have observed and categorized discrete, identifiable patterns as to how people make decisions under a variety of conditions, to include during the response to a disaster. These documented decision-making methods give insight into the nature of individual decision-making and the information that is typically required to make those decisions. While there is a massive amount of literature that has endeavored to describe decision-making methodologies observed in various contexts, this research focuses on decision-making methods that are appropriately applied to the discipline of disaster management operations.

The literature that presents models and theories about disaster decision-making can be found in two broad categories: individuals and groups. While generally similar, there are some distinctions that are significant to this research. The literature concerning individuals typically represents how individuals respond personally to a disaster, and then presents how they may typically make a decision. The literature regarding group decision-making discusses intra-group dynamics and intergroup dynamics, with the intra-group literature examining the role that the leader takes in the decision-making process.

The people who participate in disaster management decision-making are very diverse and disparate in background, education and worldview. When considering the different echelons of disaster response in all the countries of the world (local, regional, national; military and civilian; governmental and non-governmental), it is east to estimate that there are hundreds of thousands of people around the world who are in a position to make decisions during the management of a disaster. However, there are characteristics common to all disaster decision-makers. Most decision-makers in disaster management operations recognize their place as part of the event. While there may be some who deny that their efforts are critical to the whole (for example, a local fire chief during a hurricane response), for the most part, decision-makers' awareness of their part in the response plays into the decisions they make and the impact on the overall response.

One characteristic of disaster decision-makers is that they know they need to prioritize their efforts during disaster management operations. In 1998, Hurricane Mitch, which at the time was the most powerful Atlantic hurricane on record, moved across Central America and onto Florida. US disaster response personnel were involved across the hemisphere because of the magnitude of the storm. Glantz and Jamieson noted in their writings in 2000 about the response to Hurricane Mitch by US government personnel in Honduras that, "explicitly or implicitly, the notion of triage" (p. 870) is applied by decision-makers to the decisions they make during response. Furthermore, they observed that decision-makers make decisions based on what information is immediately available, and that expedience was the rule at the sacrifice of more information gathering or even the entertainment of a long-term solution. The succinct sequence is:

1. A problem emerges.
2. It receives a response.
3. It is considered solved, even if it is a short-term solution.

In the case of Hurricane Mitch, it is worth noting that the persons in place to make disaster management decisions from the United States Agency for

International Development were explicitly trained and experienced in making decisions in the context of sustainable development; that is, long term thinking.

What follows is a selection of decision-making models that are being used during disaster management operations. These models are identified using the rationale put forth by Comfort (2005, p. 344) is that each of these decision making approaches in that they "differ from standard administrative practice: all acknowledge that dynamic environments require learning processes that enable flexible adaptation and collective action rather than attempts to exert control through an administrative hierarchy of rules and constraints." Each of these models is primarily defined based on how information flows throughout the decision-making system.

As part of model evaluation, the discriminating factors for their descriptions are their differences from what is called the rational model of decision-making. As related by Flin in 1997, the rational model consists of problem assessment, alternative identification, assessment of likely consequences, and then finally deciding on the course of action. As an optimized model, the rational model uses assumptions that typically do not become fact during a disaster: the problem is clear, all options are known, preferences are obvious and constant, there are no time or resource constraints, and the optimal outcome is achievable (Flin, 1997).

This research examines the ways in which each of these models shows not only how the model works, but also present the information requirements for each. As reported by Smith and Dowell in 2000, the goal of all of these models is to show how any grouping of individuals and/or teams of disaster decision makers can achieve "a reflexive shared mental model; that is a shared mental representation of the distributed decision-making process itself, and its participants" (p. 1153). Inherently, the information requirements that support a team's sharing of a mental model of the event can also tie directly to how the use of GIS to support decision-making can positively impact the decisions being made during a disaster.

Recognition-Primed Model

One theoretical model that describes the phenomena surrounding disaster decision-making is the recognition-primed decision model. Gary Klein crafted and published this model in 1989 to describe stress-affected decision-making during fire-oriented emergencies. Klein and his associates advanced this line of research over the years, mostly through investigating military decision-making processes (Klein, 1997; Ross et al., 2004; Kaempf & Klein, 1996).

The recognition-primed model is best described as "how people can use experience to make rapid decisions under conditions of time pressure and uncertainty that preclude the use of analytical strategies" (Klein, 1997, p. 343). While the model was perfected based primarily on literature describing observations of firefighters and military personnel, it is certainly applicable to other disaster decision-makers, to include those who responded to the Asian Tsunami. The primary populations used to develop the model were firefighters from the East Coast of the United States, as well as leaders from the United States Marine Corps. However, to apply the model exclusively to a GIS that supports disaster decision making would require an assumption that the decision-makers who used it were experienced individuals previously involved in making the decisions for an organization during a disaster.

Klein documented in 1997 that this method of decision-making involves the operational art of the individual. Instead of having a very detailed plan or checklist that is referred to constantly during the disaster event, an individual who is operating under the recognition-primed model is observing the functions of his or her organization and responding based on what their mental model from previous experiences tells them. This model is observed where expert practitioners are in leadership of organizations participating in time-critical decision-making, and where the organization's members are experienced in responding to disasters. Klein (1997, p. 344) determined that the aspects of decision-making skills that support this model include:

1. Recognizing patterns (situation awareness).
2. Making fine perceptual discriminations.
3. Recognizing typicality and detecting anomalies.
4. Mentally simulating future states (to evaluate courses of action) and past states (to generate explanations for events).
5. Improvising.
6. Adapting to events.

All of Klein's aspects of decision-making directly align with functions readily available with an appropriately designed GIS that is populated satisfactorily with temporally current and reasonably accurate data. The most obvious GIS capability is the ability to recognize a pattern during the course of a disaster. An example of pattern recognition can be found in an example of a response to a flood. When a flood occurs in a particular area, a GIS is able to show characteristics of the terrain, population densities and other significant features to the disaster decision-maker. So, when a given disaster decision maker sees that the flood waters are threatening an area of constrained terrain (such as a canyon), the experienced decision maker can reasonable predict that the high velocity of flood waters in that area will cause significant damage to infrastructure. Thus understanding the potential damage, the decision maker can make resource decisions to counter that potential damage, such as requesting aerial support and heavy equipment to deal with damaged roads and buildings.

A comprehensive and visually straightforward means such as a GIS greatly enhances the ability of a decision-maker to observe and analyze pertinent information. Additionally, the fundamental capability of a GIS to automatically detect patterns in data greatly enhances a decision-maker's ability observe any particularly crucial pattern. Similar to pattern detection, the detection of anomalies is another ability directly related to a core GIS capability. Continuing the flood example, when a post-disaster satellite image is compared to a pre-disaster image, a GIS would be able to recognize where structures have changed physical characteristics (or have disappeared completely) because of the impact of the flood. Equipped with this information, the disaster decision-maker would be able to recognize the likely need for shelter for displace persons.

Finally, the capability of a GIS to provide simulations of disaster events during the course of an on-going disaster directly ties to the Klein-observed decision-maker's mental simulation of future and past states. Using the flood example, a GIS would be able to simulate the effects of rainfall in a particular area and estimate the flood waters downstream. With this information, the disaster decision maker could predict what damage would be likely in an area, even without have post-disaster satellite imagery or reports from the disaster area. In all, the recognition-primed model is highly conducive to being supported by GIS.

Edge of Chaos Model

Another representation of a method of disaster decision-making is the edge of chaos model. According to Comfort's expansion in 1999 of Kauffman's 1993 discussion of the order-chaos continuum, disaster management decisions are best made at a point where there is enough structure in the system to adequately provide information, but accommodating enough to allow for innovation in a non-static environment. This model is included here based on the significance of Comfort's 1999 evaluation of the types of decision-makers and decision-making teams to which it pertains. For this model, the essential informational inputs (and thus GIS) that support decision-making are those that indicate transitions with significant prior notice for the team to respond to those inputs. In total, this model applies to the profile of disaster decision-makers and the teams of which they compose that are experienced in what they are doing, both as individuals and as a team. The input of appropriate information (such as with a GIS) during the disaster response has the effect of increasing capacity and thus pushing the tipping point of the balance toward more efficient and effective response. Conversely, the removal of information from the system does quite the opposite.

With the unfortunate experience of Hurricane Katrina, Comfort (2007) found evidence to confirm this model. Comfort expanded on previous positions by positing the thresholds that can be modeled; essentially the "edges" in the edge of chaos model:

1. Detection of risk.
2. Recognition and interpretation of risk for the immediate context.
3. Communication of risk to multiple organizations in a wider region.
4. Self-organization and mobilization of a collective, community response system to reduce risk and respond to danger. (p. 195)

In the same 2007 article, Comfort provided examples of each of these chaos "edges," although her examples were not all negative. In regards to detecting risk, Comfort noted that the appropriate agency, the National Weather Service, accurately detected the risk presented by the storm as it increased in intensity and move toward the gulf coast of the United States. Unfortunately, the appropriate authorities and strategic decision-makers failed to properly recognize and interpret the risk, and made no decisions, that would have initiated preparation for an adequate response. Additionally, the lack of cognition of risk led to the failure of state and national authorities to adequately communicate the risk to peer and subordinate organizations. Thus once, the disaster of Katrina struck, the responders found themselves relatively unprepared to respond. Interestingly, Comfort (1993) and Comfort et al. (2001) predicted the use of geospatial systems as the key to ensuring information adequacy during disaster response.

Progression of Multiple Options Model

During the course of any disaster event, multiple options for solving any particular emergent problem may present themselves to the disaster management decision-maker. Initially, more than one of the options may appear to be viable as a solution to a problem. The progression of multiple options model (Smith & Dowell, 2000) observes that in certain conditions during disaster responses, multiple options for solutions are typically pursued in parallel to each of the other efforts. Over the course of the response, inadequate solutions present themselves as being unviable, while others will continue to compete for implementation. This methodology of continuing to consider multiple options differs from the recognition-primed model in that, based on the experience of the senior decision-maker or decision-making team, focuses very quickly on implementing one option (Smith & Dowell, 2000).

Interestingly, Smith & Dowell noted that while successful, this method of disaster decision-making has an inherent characteristic during a disaster response in that it is difficult to convey the shared mental model of the response situation and plan to all participants. This is particularly true of what they termed as the "Incident Organization," which is the *ad hoc*, multi-agency organization that is typically formed to respond to larger disasters. In their case study, Smith

& Dowell (2000) found that the lack of a shared mental model encouraged subordinate decision-makers to develop their own independent courses of action, sometimes regardless of what other peers were doing. In the Ais Gill case study that is the core of Smith and Dowell's article, the decision makers provided an excellent example of this phenomena – because they did not share the common mental model, they requested medical and transportation support that was both duplicative and excessive.

The impact of this is that there are potential difficulties in overall coordination at the senior decision-maker level. There also tends to be a lack of depth in analysis in any given solution, particularly at the onset of the disaster response. Clear information requirements and their fulfillment enhance the effectiveness of decision-making during a "progression of multiple options" response by communicating the shared mental model to all respondents.

The models presented in this section represent the best theories that support this dissertation's primary research question: *What happened when geospatial information was used to support disaster decision-making during the humanitarian response to Asian Tsunami of 2004?* They provide references for developing the methodologies for interviewing the disaster decision-makers who participated in the response to the Asian tsunami of 2004. The information requirements that support these models will be used to develop questions for interview participants by eliciting indicators as to what model they are conforming to. The results of the interview will provide crucial insight as to what information is required to support a "best practice" disaster decision support GIS.

CHAPTER IV

METHODS AND DATA

The nature and maturity of the examined theory, model and methods, as well as the sources of data drives this research toward a qualitative examination of the topic. As such, this study uses a snapshot case study as the overall method of research investigation. This study draws on the experiences of Asian Tsunami disaster responders, as well as appropriately related documents and archives developed by others, in order to find data that can be appropriately evaluated.

Within the general method of a case study, this investigation follows the convention of Yin (2003) and uses two data-gathering techniques in order to support the inquiry of disaster responder actions during the tsunami response. The data gathering techniques used for this case study include interviews in the form of an open-ended web-based survey, and examination of archival data and documentation. The data and documents to be examined will be identified in two ways. Primarily, the data and documents will be nominated by interviewees as part of the interview process. These documents include internal working documents, after action reviews, meeting records, and similar documents that would be produced by organizations participating in disaster response. Additionally, other documents will be identified through appropriate disaster-oriented organizations and acquired from them. These documents include reports, primary interviews, research papers and similar documents.

Objective

The objective of this research is to determine what types of data (spatial and otherwise) were used by disaster management decision makers in order to make decisions during the Asian Tsunami of December 2004, and how these data relate to any of the identified decision-making models. Additionally, these findings are used to assist in the development of a model of a participatory geospatial system that supports decision-making during disasters. Using a multi-method approach, this dissertation presents a set of convergent themes that are adequate enough to be presented as a model of how GIS can be best used to support disaster decision-making.

Study Foci

The core activities of this research delve into the making of decisions during disaster management operations. For this investigation, the questions answered by all data collection techniques are found within two general categories: demographics and organizational information; and decision-support information, both of which are examined in greater depth in the ensuing two sections.

Disaster Decision-maker Demographics and Organizational Information

Within this category, the questions develop a demographic description of the sample. The types of demographic information collected are Occupation and Employment, Education Attainment, Experience in Decision Making and Age. The collection of this demographic information provides discriminating data that provides additional fidelity for examining experience-oriented interview results. In addition, the acquisition of organizational information allows for the interview results to be further examined within the context of organizational type. For example, an interview of a GIS specialist within a non-governmental organization is expected to provide results from a perspective different than a senior manager in a governmental disaster response organization.

Decision-support Information

For this category, the questions relate to the topical program areas as described in five subcategories: planning, response targeting, coordination, documentation and resource mapping.

Planning. This subcategory focuses on data requirements that support disaster management planning prior to an incident. It is common to use GIS to analyze terrain, evaluate population locations and status, and determine the extent of hazards and opportunities. As described by Wong, Geist and Venturato (2005), a properly designed and implemented GIS is an excellent tool for risk and hazard analysis of tsunami conditions. In addition, a GIS is a powerful integrator of varied, non-geospatial data that is useful for planning. Through its inherent capability of displaying disparate graphic and tabular data, GIS is able to accurate represent many different types of data that correspond to a single location or area on the earth.

Response targeting. This subcategory relates to planning, but focuses on the use of data that is immediately available at the start of a disaster event to support the implementation of a plan. High payoff locations are targeted during disaster recovery for many reasons. For a food provider, for example, the location of population concentrations is a high payoff location for maximizing food distribution efforts during the course of a response.

Coordination. The coordination subcategory asks questions that support information requirements for synchronizing the efforts of the many different organizations that typically participate in disaster management. There are usually many relief organizations working on any particular disaster. The ability of organizations to coordinate with each other allows for a maximization of effort, an enhanced capability to coordinate operations seamlessly, and a general reduction in the redundancies that plague these types of operations. One of the recommended changes from the United States Government (2006) for post-Katrina disaster management was the implementation of a common operating picture between agencies. In this context, a common operating picture is standardized view of the situation on the ground in all aspects, to include locations of disaster impact, resources location and status, critical infrastructure, and other significant information. According to Comfort (2007), an effective common operating picture would have solved or mitigated the three major problems found with intergovernmental disaster response operations during Hurricane Katrina: heterogeneity among actors, asymmetric information processes, and asynchronous dissemination of critical information to participating groups. A properly configured and distributed GIS can provide a tool that facilitates coordination by showing where activities are occurring for multiple agencies.

Documentation. This subcategory focuses on archival requirements. For a variety of reasons, disaster management operations must be documented. It is important to track where work has been done so that it can be properly evaluated later or repeated if necessary. It is also important to document disaster management operations because virtually all of the organizations that conduct disaster management are donor beneficiaries. The donors that contribute must be informed as to how their money was spent and how effective the operations it supported turned out to be. In a *Social Science Quarterly* article, Lewis (2003) expands upon this theme by explaining that without visibility on field operations, major donors to relief operations are not as likely to provide funds to support future operations.

Resource mapping. This subcategory focuses on information related to locating pre-placed or existing resources, or the places that they can arrive. This information ultimately helps to improve efficiency within a recovery effort. Within any organization that manages resources, asset visibility can enhance decisions about allocation of these resources by giving supplementary information about resource locations, proximity to priority efforts, and information about the proximity of resources to transportation assets.

Why a Case Study is Appropriate

The goal of this dissertation is to develop by induction a theory in the form of a model that provides a description of how decisions are made during disaster response. Beginning with the research question (*What happened when geospatial information was used to support disaster decision-making during the* *humanitarian response to Asian Tsunami of 2004?)*, the data collected show a depiction of how disasters are managed and how this management relates to information (and thus GIS). Upon examination to find the common phenomenon, the results are presented as what can be expressed collectively as a best practice for using GIS for disaster management.

Description of Case Study Protocol

The subject of this dissertation presents a challenge in that it is an event that occurred in the past, and thus is outside the limits of experimental controls. Additionally, the tsunami was a single event and not part of a series of events, so in effect it was a snapshot in time that has passed and cannot be recreated. In order to retrieve data about the event, an appropriate exploratory protocol must be used that does not rely on surveys or experiments.

When initially proposed, this dissertation was planned to be quantitative and explanatory. However, the lack of large numbers of interview participants for this study indicates the necessity of using a qualitative method for exploring what happened during the Asian tsunami of 2004. Additionally, this study is intended to generate theory in the form of a model of GIS usage, so a form of qualitative research is required to fulfill the research objectives.

There are a variety of case study methods that can be used to support qualitative research. Feagin et al. (1991), in their general advocacy of case study research, noted that the case study methodology is the ideal style of investigation for the purposes of holistic research, and multiple aspects of disaster management lend themselves to being incorporated into studies as a whole. They also noted that the narrative that accompanies qualitative research results is the best way to present the varied supporting documents such as "diaries, correspondence, newspaper reports, and even personal interviews with participants" (p. 19).

Applying the Case Study Method

This investigation uses a version of the case study methodology derived primarily from the work of Robert Yin (2003). Yin is recognized as one of the premier modern case study methodologists for social research. It should be noted that Yin's work, while significant, amalgamates most current case study research practices. Virtually all modern literature regarding case study research cites Yin when describing the methodology. When considering Yin's methodology, however, research styles from other methodologists were considered for applicability to this dissertation. These methodologies are subsequently described and annotated as to why Yin's methodology prevails in this dissertation.

Yin's methodology is a specified and tested protocol that lends itself to type of research this dissertation documents. Other case study methodologies tend to be specific toward a discipline, and are thus not appropriated configured to support this dissertation's research. For example, the methodology designed by Stake, while a valid case study method, is oriented toward education-related studies. As such, they have a bias toward phenomena uncovered in that milieu: repetitive events that can be compared to one another. The nature of the tsunami suggests a snapshot in time, with validation and reliability controls that support this. Yin's protocols support the application of case study towards a more diverse set of research conditions. Bill Gillham (2000) presents a case study methodology that is distinct from Yin's in that it does not focus on the establishment of a set protocol at the onset of research. It allows for the development of the methodology during the course of data collection in order to emphasize focus on data. However, this study has established limits at the onset as it is conducted after the fact. The lack of need of flexibility is reinforced by the validity and reliability that is present with Yin's protocol, and Yin's protocol prevails as the indicated methodology for this study.

Yin (2003) defines the case study as an investigation into a phenomenon within its existing context. He additionally asserts that a case study is even more useful when margins between phenomenon and context are ambiguous. Under examination, Yin's descriptions match the conditions for this case, as the response to the tsunami disaster was a blend of actions of many different disciplines. When specifically considering the nature of the disaster being studied, the examination of a single case allows for focusing on what specifically occurred during the response to the Asian tsunami, which is unquestionably a unique occurrence in modern history. As such, it is would be incomparable in a specific sense to other disasters in the modern era. As this study's objective is the definition of a model of how GIS is best used to support disaster decision-making, an examination of a single, snapshot case is best supported.

Design Summary

According to Yin's methodology (2003), there are four phases to case study research. The design of the study presented here is phase one. The remaining phases are conduct of the case study, analysis of the case study evidence, and writing the case report and articulating the research implications.

As defined by Yin (2003), the five components of a case study are the study's questions, its propositions, its unit of analysis, the logic linking the data to the proposition, and the criteria for interpreting the findings. This section describes each of these design components and establishes the framework for the conduct of the study. Each of these components is described in more detail later in this chapter.

Research Question

What happened when geospatial information was used to support disaster decision-making during the humanitarian response to the Asian Tsunami of December 2004?

General Theoretical Proposition

There is a common, best practice use of GIS that best supports disaster management decision making during a tsunami response.

Specific Research Propositions:

- *There is a commonly used set of geospatial data that best supports disaster decision making during a tsunami response.*

- *There is a common set of functions that a GIS performs that best supports disaster decision making during a tsunami response.*

Unit of Analysis

The nature of the tsunami presents a one-time event to be studied. Additionally, the disaster decision-makers who participated in this research self-identified themselves by registering with organizations that track GIS usage during the course of disaster response. The record of those registrations represents a self-identified sample that is ready to use for research. This dissertation examines a convenience sample of self-identified disaster decision makers and supporting staff that used GIS to make disaster relief-related decisions in response to the Asian Tsunami of 2004.

Logic Linking Data to the Proposition

In accordance with Yin's methodology, this study uses the concept of pattern matching to support tying collected data to the research proposition. Patterns (or themes, as they are termed in this study) are matched to the study foci, which are derived from the previously described related theories and other examinations of pertinent literature.

Criteria for Interpreting Findings

In order confirm or deny the research proposition, the emergent themes are evaluated to determine if they are consistent with the research proposition. Additionally, the interpretation includes data gathered from corroborating sources, such as related documents and archival records. As previously described, these other sources, identified through appropriate disaster-oriented organizations, include reports, primary interviews, research papers and similar documents.

Conduct of the Case Study

This study conducts a structured examination of data, employing two different data collection processes. The literature reveals that the most practical and accessible data can be obtained by interviews in the form of the open-ended web-based survey, as well as a review and examination of documentation and archival data.

Interviews

The principal approach to this research is the conduct of interviews in the form of an open ended web-based survey. According to Yin (2003), as a non-optimal approach, the nature of those being surveyed (see *Sample* below) indicates the use of this method. Executed via the internet, the survey instrument is designed to extract the interviewee's experiential information regarding their participation in the response to the Asian Tsunami. While some questions are answered from a picked list, the bulk of survey responses are open-ended in order to maximize the quality of the data gathered. These open-ended responses are designed to provide a level of detail that allows for subjective examination of the timelines involved, emotional state of disaster workers and system performance.

Population. The population for this research includes all of those primary disaster decision-makers and their supporting staff who, as part of their duties in a disaster management organization, used geospatial technologies in any capacity in order to respond to the Asian Tsunami of 2004. As is the nature of the population, the exact number of those who fit this definition is difficult to ascertain. However, the nature of this inductive study leads to the discriminative selection of a sample (or unit of analysis).

Sample. As prescribed by Yin (2003), the sampling that supports a case provides for sources of data that are robust and informative about the research problem. As such, a convenience sample for the unit of analysis is used based on the self-identification of those who used GIS to support disaster recovery and relief efforts in response to the Asian Tsunami of 2004. Two sources are used to gain this sample: the Pacific Disaster Center and the Disaster Tracking Recovery Assistance Center.

Pacific Disaster Center. One set of approximately 100 GIS data users are identified by their registered and validated use of one of the premier GIS data providers for this disaster: the Pacific Disaster Center.

The Pacific Disaster Center is known as a world leader in disaster studies. It began as an institution as part of the US federal government response to Hurricane Iniki in September 1992. During the course of that storm, the Hawaiian island of Kauai endured winds of over 140 miles per hour. This storm resulted in over 14,000 houses damaged or destroyed, which combined with other damages, resulted in over 3 billion dollars in losses. Hurricane Iniki is on record as the most destructive disaster to affect Hawaii in modern history (Pacific Disaster Center, 2007). One of the lessons learned from this storm was that disaster decision-makers need to have better information in order to make better and more effective response decisions. In order to address this lesson, the US federal government established the Pacific Disaster Center in 1995 (Pacific Disaster Center, 2007).

The Pacific Disaster Center is an entity of the East-West Center, which is a public, non-profit research and education institution. The East West Center was established by the U.S. Congress in 1960 in order to promote better relations and understanding between the United States and the nations of Asia and the Pacific. (Pacific Disaster Center, 2007). Since its inception, the Pacific Disaster Center has expanded its program areas to cover all aspects of disaster management. The current mission of the Pacific Disaster Center is "to provide applied information research and analysis support for the development of more effective policies, institutions, programs, and information products for the disaster management and humanitarian assistance communities of the Asia Pacific region and beyond." Their stated goal is to "promote disaster management as an integral part of national to local economic and social development to foster disaster-resistant communities" (Pacific Disaster Center, 2007).

To support this mission and goal, the Pacific Disaster Center has developed a variety of capabilities and assets that are in place to support disaster decision-makers as the need arises. One of the assets that are available is a fully developed GIS data set that is accessible through the World Wide Web. This capability, termed "Geospatial Information and Sharing," allows users to download GIS data in order to support their disaster decision-making efforts. As part of the registration process, the Pacific Disaster Center requires the potential user to register in order to determine the user's authenticity and subsequent data access privileges. As such, the Pacific Disaster Center has specific records for every user of geospatial data set that it is providing, to include the Asian Tsunami of 2004 (Pacific Disaster Center, 2007). It is these registered Asian Tsunami GIS data downloaders who are included in the sample.

Disaster Tracking Recovery Assistance Center. The Disaster Tracking Recovery Center is an aid organization that as of 2007 was operating in southern Thailand as a facilitator of other aid organizations. In this capacity, this organization collects information on what organizations have participated in the tsunami relief efforts – past and present (Disaster Tracking Recovery Assistance Center, 2007). This organization publishes a directory that is used as part of this dissertation to determine a list of organizations that have participated in the relief, and it is this list that is the basis of this portion of the interview sample. Potential respondents from this list are further screen in order to determine their decision-making responsibilities, as well as their use of GIS.

Instrument. The research instrument for this survey is a web-based, self-administered questionnaire. The questions in the questionnaire are designed to support the stated objective, as well as to biographically describe the sample. As a condition of achieving the previously described objective, the credentials of the respondents are of prime importance. As such, the questionnaire ascertains biographic information about the respondents in order to describe, screen and validate their participation in the study. Participants are asked to indicate how they conducted business during the tsunami recovery and response efforts. The questions presented in the instrument are directly derived from the Study Foci. There is the ability for the participant to add categories of data not specifically covered in the instrument. The survey results are analyzed to gather appropriate findings according to appropriate methods within the context of this qualitative study.

The survey questionnaire was prepared and delivered via web-based online survey software created to manage the survey. This type of survey lends itself to being used with this population, which is presumed to be computer literate based on the technology being examined. Additionally, the population is spread across the entire world and as such, a web-based instrument is the most efficient method of surveying this population.

The instrument was prepared in a manner as to ensure that it is clearly written and easily understandable. All technical terminology and acronyms are defined prior to use in a question. Additionally, the instrument is as concise as possible while still remaining effective, so that the respondent can concentrate on the survey item without distraction. Moreover, the instrument focuses on one theme at a time and uses each question to focus on a single aspect at a time. Appendix C of this dissertation contains the interview questions used for the interviews that were conducted as part of this research.

Pilot testing. Prior to delivering the instrument to the full sample, pilot testing was conducted on three of the willing sample participants in order to affirm the survey instrument. Based on the results of the pilot test, the instrument was refined for clarity in preparation of delivery of the instrument to the entire sample.

Data collection and entry. The survey instrument was deployed via the World Wide Web to the selected sample using a commercial online survey vendor. Once the survey period was concluded, the data from the survey was downloaded locally for processing and analysis.

As part of the survey, respondents were asked to provide internal documents, archives or other references that could further the second part of data collection for this survey. Those documents and archives were collected and examined in the subsequent part of data collection.

Review of Documentation and Archives

Once the interviews were completed, the results of the interviews were used to identify categories (or sometimes specifics) of pertinent documents and archives for review and evaluation. According to this methodology, these documents and archives can include correspondence, academic and non-academic publications, personal notes, and other documents that are relevant to this research (Yin, 2003). Specific documents and archives that, based on common practices, are found in the review of literature, would be expected to include organizational meeting minutes, GIS system designs, data requests, periodic reports during the disaster, news articles, training manual, standard operating procedures and GIS software documentation.

In this case, there are two categories of documents. The first category of documents is the set that are directly and specifically linked to the response to the tsunami. These include standard operating procedures, after action review and records of activities conducted by disaster responder organizations. This category of organizations includes governmental organizations (such as the Government of Thailand's Department of Local Administration, Civil Defense Secretariat), international organizations (such as the United Nations Disaster Relief Office), and large non-governmental organizations that have well established business practices (such as the International Committee for the Red Cross and Red Crescent). These documents add directly to the information found by the web-based surveys, as well as for fact checking and correlating. The second category of documents are those that pertain to similar disaster responses or are otherwise indirectly related to the tsunami disaster response, and are used for the same purposes as the first category.

Sequence of Effort

The sequence of effort for data collection was in two phases: Phase 1 – Interviews; and Phase 2 – Gathering of Corroborating Evidence.

Phase 1 – Interviews

The initial set of potential interviewees was identified as previously described in the methodology. At the onset of phase 1, the interviewee set were notified by e-mail that the survey was about to commence. The interview instrument, which was developed using the study foci previously described, was submitted for approval in the appropriate format and with the appropriate supporting documentation to the Institutional Review Board's Human Subjects Protection Review Committee at The University of Southern Mississippi. Once approved, the instrument was deployed on the Internet via a web-based survey site (http://www.surveymonkey.com) in a test mode. The instrument was tested on a subset of interviewees. Based on an evaluation of this initial set of respondents, the instrument was slightly modified to improve clarity for the respondents. Once the final version of the instrument is drafted and deployed, all respondents were notified and given an appropriate amount of time to respond to this web-based interview.

Phase 2 – Gathering of Corroborating Evidence

Once the interview phase was completed, the interview results were analyzed in order to determine the presence and availability of other sources of evidence that can be used to validate the emergent themes that were revealed during the interviews. These other evidence sources include documents, archives and other geospatial systems that present evidence to support the research proposition.

Inherent Quality Control

Triangulation is a common method of quality control in qualitative research. It involves the use of multiple, disparate data sets to clarify, verify and validate observations and interpretations (Yin, 2003). In this research, the discussion involves how geospatial systems were applied to the problem of disaster management decision-making during the Asian Tsunami of 2004. Given that the aim of this research is to gather information about what makes up an effective GIS that supports disaster management, this research focuses on how the unit of analysis conducted itself during the disaster. As such, the data collected is for a specific point in time and contains data on a variety of biographic, decision-making and GIS-specific topics.

Validity

In order to maximize the quality of this research study's design, this methodology uses three of Yin's four case study tests as the basis for this dissertation's protocol. The fourth one that is excluded from use is internal validity, as it does not apply to exploratory research. The three other study tests provide substantiation that the study accurately depicts the observations found as part of the study. Additionally, this section describes the tactics used during the course of this research to address these tests.

Construct Validity

The construct of the problem as defined is increased by using two different tactics during this research. Using the principle of triangulation, the source of data for this investigation will come from multiple sources, to include interviews, documents, archives and other geospatial systems. Additionally, a case study database has been used in order to ensure the "chain of custody" as described by Yin (2003).

External Validity

The external validity of this study increased through the basing of the research proposition on existing theories and models. As explained previously, the theories on decision-making and the models on GIS use lead to a conjunction that this research will seek to bring to light.

Reliability

This research study is designed to address reliability, as reflected in the use of a standard protocol and a case study database.

Standard protocol. The use of Yin's standard, proven methodology provides the best way to ensure that the findings can be replicated if a subsequent researched chooses to investigate this specific case again (Yin, 2003). One of the weaknesses of a snapshot case study is the potential that the snapshot is misappropriated as a general representation of reality as opposed to what it really is: a view of a single point in time. Since a convenience sample is used for this study, it is presumed that the results of this study are not representative of the entire population of disaster management decision-makers. Instead, the results indicate the development of a model (a form of theory).

Case study database. As part of the use of Yin's methodology, this research employs the use of a research database. This database documents all data gathering activities, from acquisition to disposition, and thus supports the reliability of the case (Yin, 2003).

Analysis of the Case Study Evidence

Once the survey instrument was given and all documents and archives selected, the results were collected and interpreted. This research uses Yin's preferred analysis strategy of relying on theoretical propositions (Yin, 2003). The basis proposition of this research is that *there is a common, best practice use of GIS that best supports disaster management decision making during a tsunami response.* The "how's" and "why's" as to how spatial data (or data that could be appropriately used in a GIS) are used during disaster management is the lead that is pursued during analysis of this dissertation's data. Additionally, this study uses the concept of *pattern matching* to link the data found in the interviews to the research proposition. For the purposes of this study, the patterns discovered will be described as "themes." In light of these factors, the best style of written product for the analysis of the web-based interview is itself the question and answer format (Yin, 2003).

CHAPTER V

INTERVIEWS

Introduction

Beginning on 19 October 2007 and ending on 14 December 2007, web-based interviews were conducted with 17 disaster decision-makers in order to identify common, best practices for the use of GIS in support of disaster management. Representatives from a variety of academic, governmental, and non-governmental organizations that responded to the Asian Tsunami of December 2004 participated in the interviews (Table 1).

Table 1

Organizations of Interview Participants

Type of Organization	Name of Organization	Where Located
Government Donor		
	USAID Office of Foreign Disaster Assistance	USA
Academia/Research		
	Institute for Environment & Development (LESTARI), National University of Malaysia	Malaysia
	SERTIT	France
	L´Institut de Recherche pour le Développement	Thailand
	Stockholm Environment Institute, Asia Center	Thailand
	Juniata College	USA
	Sastra University	India
	California Institute of Technology	USA
International/Non-Governmental Organizations		
	Jesuit Refugee Service	Indonesia
	British Red Cross	Indonesia
	Caritas - Austria	Austria
	Care International	Indonesia
	UNOSAT	Switzerland
	Muslim Aid Australia	Indonesia
	United Nations Office for the Coordination of Humanitarian Affairs	USA

Interview Format

The interviews took place over the course of two months, and were conducted via a world wide web-based survey, with follow-up by electronic mail correspondence. While over 200 persons were invited to participate in this research directly, 17 chose to participate and completed a web-based interview. The participation rate directly affected the type of study this dissertation would be, as the small numbers of participants led toward qualitative research as opposed to quantitative research. The sequencing of invitations prior to full development of the interview instrument allowed for proper development of a qualitative survey and study.

The format of the interview precluded the free-flow of discussion that is usually present when an interview is conducted in person or by telephone. However, the web-based interview software's capability to allow for open-ended questions was used for this research. This capability was enhanced by the use of follow-up questions via e-mail for clarification and member-checking.

Participants

As part of defining the unit of analysis, the participants were pre-qualified as either primary disaster decision-makers makers or those who were supporting disaster decision-makers. In addition, these decision-makers were part of organizations that had some access to geospatial information, either through a GIS in their own organization, or from a partner organization's GIS. Two-hundred participants were initially identified by their registration with the Pacific Disaster Center or with the Disaster Tracking Recovery Assistance Center.

These pre-qualified individuals were invited via e-mail to participate in the web-based, self-paced interview. Seventeen individuals completed the interview, the results of which are recorded and analyzed below.

On the opening page of the interview, the participants were reminded that they were invited to participate in the following survey based on their participation in the response to the Asian tsunami disaster in 2004. They were also notified that if interested, they would have access to the aggregated results of the interview once the research period was complete. The participants were also reminded that their participation in this study was voluntary and that they could withdraw from the interview at any point. They were notified that their responses would be strictly confidential and data from this research would be reported anonymously. Finally, the respondents were notified that the project had been reviewed by the Human Subjects Protection Review Committee at The University of Southern Mississippi, which ensures that research projects involving human subjects follow federal regulations. They were also given the contact information for the Institutional Review Board at The University of Southern Mississippi should they desire to contact that organization. The interview questions are divided into two categories: demographics and perceptions.

Interview Questions

See Appendix C for a detailed description of all interview questions, as well as the research question to which they pertain.

Participant Identification

Based on the nature of the interview format, the summary of results for the web-based interviews is presented in a question and answer format. Yin (2003) notes that this format is preferred when case study evidence is intended to be cross-analyzed with other research methods, as the reader can follow the answer to each question across the entire study.

The identifying questions about the interviewees focused on the practical need for research understanding as to how they were part of the decision-making process during the tsunami. As noted below, the interviewees included participants in tsunami relief with a variety of levels of experience, responsibility and job duties. An identifying number designates each participant for positive identification throughout this dissertation. Given these questions during the web-based interview, the participants self-reported the following identifying information.

Participant #1

This interviewee chose not to disclose her age. However, Participant #1 did report that she has a Master's degree and that she fits into the Support Personnel category of respondent (logistics, planning, and operational staff; GIS specialists, hospital staff, and similar positions). She reported being in that position for more than three years up to four years, that she had been somewhat involved in disaster response and recovery operations previous to the Asian Tsunami of 2004, and that she has never participated in any seminars, conferences or other professional gatherings that primarily dealt with disaster.

Her organization has participated in disaster response operations in Nepal, India, Pakistan and Sri Lanka, and she participated in local GIS user groups that meet occasionally (although she reports that they are not well organized).

In regard to the situation at organization to which she belonged at the time of the tsunami response, she reported that:

1. There were two dedicated GIS staff.

2. There were two periodic or casual users of GIS.

3. The organization had been using GIS for more than three years up to four years

4. The organization was governmental in nature, with a mission of saving lives and assisting in developing the nations, and had a set of moral codes, principles or ethics (but did not provide details).

5. Primarily used ESRI & ERDAS GIS software packages (industry standard packages).

6. Primarily used GIS for mission program planning during the response to the tsunami; were able to map and delineate disaster areas as well as disaster response and operations.

Participant #2

This interviewee disclosed that he is between 26 and 35 years of age, that he has a Master's degree and that he fits into the Other category of respondent, specifically as a post-tsunami rapid assessment team member. He reported that at the time of the disaster, he had been in that position for more than four years up to five years. He reported being somewhat involved in disaster response and recovery operations previous to the Asian Tsunami of 2004, and that he had participated in many seminars, conferences or other professional gatherings that primarily dealt with disaster. His organization has participated in disaster response operations in Malaysia and the Asia Pacific region, and he reported that he regularly meets with government agencies and private sector as part of GIS user groups or other organizations that facilitate professional contact among GIS users.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There was two dedicated GIS staff.

2. There were five periodic or casual users of GIS.

3. The organization had been using GIS for more than four years up to five years.

4. The organization was academic / educational in nature, with a mission of advising governments, advocating policy and conducting environmental assessments. Participant #2 was not sure if his organization had a set of moral codes, principles or ethics.

5. Primarily used ArcView, Erdas Imagine GIS software packages (industry standard packages).

6. Primarily used GIS for displaying and recording mapping information; were able to perform mapping, processing and modeling functions.

Participant #3

This interviewee reported that she is between 26 and 35 years old, that she has a doctoral degree and that she fits into the Other category of respondent, specifically as a “researcher.” She reported that at the time of the disaster, she had been in that position for more than six months up to one year, and that she had been somewhat involved in disaster response and recovery operations before the Asian Tsunami of 2004. She stated that she has participated in many seminars, conferences or other professional gatherings that primarily dealt with disaster, to include ADPC, USAIDS, UNDP, and others about disaster recovery process and resilience planning. Her organization operates worldwide, but her regional office has participated in disaster response operations in Thailand, Sri Lanka, and the Mekong region. She reported that she does not participate in GIS user groups or other organizations that facilitate professional contact among GIS users.

In regard to the situation at organization to which she belonged at the time of the tsunami response, she reported that:

1. There was no dedicated GIS staff (all GIS functions were outsourced).

2, There were no periodic or casual users of GIS.

3. Participant #3 was unsure as to how long her organization had been using GIS products to support its operations.

4. The organization was nongovernmental in nature, with a mission of “supporting decision making for sustainable development by bridging science to

policy." Participant #3 did not report whether her organization had a set of moral codes, principles or ethics.

5. As her organization outsources its GIS support, Participant #3 noted that her organization does not use any GIS software packages.

6. Her organization primarily used GIS information for mapping purposes.

Participant #4

This interviewee chose not to disclose his age or report his level of education, but did state that he fit into the Support Personnel category of respondent (logistics, planning, and operational staff; GIS specialists, hospital staff, and similar positions.). He reported that at the time of the disaster, he had been in that position for more than one year up to two years, that he had been very involved in disaster response and recovery operations previous to the Asian Tsunami of 2004, and that he had never participated in any seminars, conferences or other professional gatherings that primarily dealt with disaster. His organization has participated in disaster response operations in Indonesia. He reported that he does not know whether he has participated in GIS user groups or other organizations that facilitate professional contact among GIS users.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There was one dedicated GIS staff person.

2. There was one periodic or casual user of GIS.

3. Participant #4 did not know how long the organization had been using GIS.

4. The organization was nongovernmental in nature, with a mission of accompanying, serving, and pleading the rights of displaced persons. Participant #4 stated that his organization had a set of moral codes, principles or ethics in the form of a "code of conduct."

5. Participant #4 did not know what GIS software his organization used or what the capabilities of his organization's GIS.

6. Participant #4 could not describe the capabilities of his organization's GIS.

Participant #5

This interviewee chose not to disclose his age, but he did report that he has a Master's degree and that he fits into the Decision Maker category of respondent (incident commander, unified command, Government officials, community leaders, etc.). He reported that at the time of the disaster, he had been in that position for more than five years up to ten years. He stated that he had been very involved in disaster response and recovery operations previous to the Asian Tsunami of 2004, and that he had participated in "too many to list" seminars, conferences or other professional gatherings that primarily dealt with disaster. His organization has participated in disaster response operations in more than eighty countries. He reported that he does not participate in GIS user groups or other organizations that facilitate professional contact among GIS users.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There was one dedicated GIS staff person.

2. There were no periodic or casual users of GIS.

3. Participant #5 did not know how long the organization had been using GIS.

4. The organization was nongovernmental in nature, with a mission to distribute disaster relief supplies to affected individuals and communities. Participant #5 stated that his organization did not have a set of moral codes, principles or ethics".

5. Participant #5 didn't know what GIS software his organization used, but that during the tsunami his organization's GIS was used primarily for mapping purposes.

6. Participant #5 describes the capabilities of his organization's GIS as "very limited."

Participant #6

This interviewee chose not to disclose his age or level of education. However, Participant #6 did report that he fits into the Other category of respondent, specifically as a "project officer." He reported that at the time of the disaster, he had been in that position for more than six months up to one year. He stated that he had been somewhat involved in disaster response and recovery operations before the Asian Tsunami of 2004, and that he had not participated in any seminars, conferences or other professional gatherings that primarily dealt with disaster. His organization is based in Austria, but has participated in disaster response operations worldwide. He reported that he does not participate in GIS user groups or other organizations that facilitate professional contact among GIS users.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. His organization did not have its own GIS, but used GIS products from other organizations. Thus, there was no dedicated GIS staff, only consumers of GIS information.

2. The organization was nongovernmental in nature, with a mission of "Healing the Body — Enriching the Mind — Nurturing the Soul." Participant #6 stated that his organization's values include "dignity, respect, care and concern for all, responsive to community needs, responsible stewardship".

3. In light of the fact that his organization outsources it GIS requirements, Participant #6 reported that his organization did not have GIS software or capabilities.

Participant #7

This interviewee reported that he was between 36 and 45 years old, and that he has a doctoral degree. He disclosed that he fits into the Other category of respondent, specifically in "producing 24/7, rapid situation and damage maps using satellite imagery in the context of the International Charter 'Space and Major Disasters' to support the Civil Protections and relief team." He stated that at the time of the disaster, he had been in this position for less than six months.

In regard to his previous experience with disaster response and recovery operations, Participant #7 stated that he and his organization were "involved worldwide in rapid mapping production in different cases by natural or man-made disasters (earthquake, floods, eruption, and forest fire)." Additionally, he reported that the "results of this rapid mapping activities were presented in different conferences in Space application organized by Space agencies (ESA, CNES, UNOSAA)." His organization is based in France, but has participated in disaster response operations worldwide. He reported that he participates in GIS user groups or other organizations that facilitate professional contact among GIS users, specifically those that focus on standardization procedures.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There were 6 to 10 dedicated GIS staff persons.

2. There were four periodic or casual users of GIS.

3. The organization had been using GIS for more than ten years.

4. The organization was academic / educational in nature, with a mission to transfer knowledge and research and development results from earth observation applications. Participant #7 stated that his organization did not have a set of moral codes, principles or ethics.

5. The organization used ARCGIS and Erdas Imagine GIS software

6. During the tsunami his organization's GIS was used primarily for modeling of potential impact on infrastructure.

7. Participant #7 describes the capabilities of his organization's GIS as "Professional industry standard GIS."

Participant #8

This interviewee disclosed that his age is between 36 and 45 years, and that he has a doctoral degree. He stated that he fits into the Other category of respondent, specifically that he "participate(d) to the coordination of scientific help from France; (he) participate(d) to FAO meetings about soil salinity impact of Tsunami in Thailand," and that he "writes a proposal for founding for EEC application." He reported that at the time of the disaster, be had been in that position for more than ten years, and he had never previously been somewhat involved in disaster response and recovery operations. Additionally, he reported that he had participated in all "all the seminars (held) in Bangkok, (about) the coordination of scientific help about Tsunami in Thailand." His organization has a presence in thirty-three developing countries. He reports that he does not participate in GIS user groups or other organizations that facilitate professional contact among GIS users.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There were 6 to 10 dedicated GIS staff persons.

2. There were 21 or more periodic or casual users of GIS.

3. The organization had been using GIS for more than 10 years.

4. The organization was governmental in nature, specifically "a …public science and technology research institute under the joint authority of the … ministries in charge of research and overseas development."

5. The organization's mission set includes "research, consultancy and training. It conducts scientific programs contributing to the sustainable development of the countries of the South, with an emphasis on the relationship between man and the environment."

6. Participant #8 stated that his organization did had a set of moral codes, principles or ethics in the form of a guide, available in French, English and Spanish, has been issued to all staff and its partners in the field.

7. He stated that he did not know what GIS software the organization was using at the time of the response to the tsunami.

8. During the tsunami his organization's GIS was used primarily for modeling "Relief Soil."

9. Participant #8 describes the capabilities of his organization's GIS as "having a lot of capabilities in GIS. One of our researchers provides a freeware GIS to users in the field. There are extensive database capabilities (but not centered in Thailand) of Aerial and Satellite data."

Participant #9

This interviewee chose not to disclose his age or level of education. However, Participant #9 did report that he fits into the Volunteer category of respondent (church groups, non-government organizations, social services, search and rescue, etc.) He reported that at the time of the disaster, he had been in that position for more than 10 years, and that he had been very involved in disaster response and recovery operations prior to the Asian Tsunami of 2004. Additionally, he reported that he had participated in many seminars, conferences or other professional gatherings that primarily dealt with disaster, to include "intern(al) to the organizations or external such as trainings on Community Based DRM (disaster risk management)." His organization has a presence in many countries, but supported this disaster response effort in Indonesia, Sri Lanka, Thailand, India and Somalia. He reported that he does not participate in GIS user groups or other organizations that facilitate professional contact among GIS users.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There were two dedicated GIS staff persons.

2. There were two periodic or casual users of GIS.

3. The organization had been using GIS for more five years up to 10 years.

4. The organization was nongovernmental in nature, with a mission "to serve individuals and families in the poorest communities in the world. Drawing strength from our global diversity, resources and experience, we promote innovative solutions and are advocates for global responsibility. We facilitate lasting change by: Strengthening capacity for self-help, Providing economic opportunity, Delivering relief in emergencies, Influencing policy decisions at all levels, Addressing discrimination in all its forms."

5. Participant #9 stated that his organization did not have a set of moral codes, principles or ethics.

6. He stated that he did not know what GIS software the organization was using at the time of the response to the tsunami, or what his organization's GIS was used primarily during the tsunami response."

7. Participant #9 could not describe the capabilities of his organization's GIS."

Participant #10

This interviewee disclosed that his age is between 46 and 55 years and that he has a doctoral degree. He stated that he fits into the Other category of respondent, specifically that at the time of the disaster, he was a "provider of processed earth observations from space of damaged regions." He reported being in that position for more than four years up to five years at the time and that he had been very involved in disaster response and recovery operations previous to the Asian Tsunami of 2004. Participant #10 has participated in many seminars, conferences and other professional gatherings that primarily dealt with disaster, particularly those hosted by the United Nations. His organization has a worldwide presence. He reports that he participates in GIS user groups or other organizations that facilitate professional contact among GIS users, specifically the United Nations Geographic Information Working Group, the subgroup for the United Nations Spatial Data Infrastructure and the subgroup Geographic Information Support Team.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There were 21 or more dedicated GIS staff persons.

2. There were 21 or more periodic or casual users of GIS.

3. The organization had been using GIS for more than four years up to five years.

4. The organization was nongovernmental in nature, and had a mission of being "a people-centered organization integrating satellite solutions for human security, peace and development applications."

5. Participant #10 stated that his organization did have a set of moral codes, principles or ethics in the form of a charter.

6. The organization was using Mapinfo as its GIS software.

7. During the tsunami his organization's GIS was used primarily for damage assessment purposes.

8. Participant #10 describes the capabilities of his organization's GIS as including functions such as "imagery procurement, pre-processing (ortho) classification, feature recognition, thematic analysis, map design, map production, map dissemination, ground control, user feedback gathering, training, institutional building."

Participant #11

This interviewee chose not to disclose his age, but did report that he has a doctoral degree. Participant #11 did report that he fits into the Volunteer category of respondent (church groups, non-government organizations, social services, search and rescue, etc.), and that at the time of the disaster he had been serving in that capacity for more than 10 years. Prior to the Asian Tsunami of 2004, he had been somewhat involved in disaster response and recovery operations and, additionally, he had occasionally participated in seminars, conferences and other professional gatherings that primarily dealt with disaster, to include regional conference in India. His organization has a presence in the United States, but has participated in disaster relief operations in India. He reports that he participates in GIS user groups or other organizations that facilitate professional contact among GIS users, specifically the Asian Disaster Center.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There was one GIS staff person.

2. There were no periodic or casual users of GIS.

3. The organization had been using GIS for more than five years up to ten years.

4. The organization was academic / educational in nature, but he did not report the organization having a specified mission statement.

5. Participant #11 stated that his organization did not have a set of moral codes, principles or ethics.

6. During the tsunami his organization's GIS was used primarily for research purposes.

7. Participant #11 describes the capabilities and software sets of his organization's GIS as ArcView, ArcGIS, ENVI, GRASS, R-Spatial, GeoDA, MapMaker Pro, Idrisi, PostGres, PHP, Python, Multispec, HecRAS, Microdem, GPS (Meter and Submeter), Basic Surveying (dumpy level), GPS integrated depthfinder.

Participant #12

This interviewee disclosed that his age is between 36 and 45 years and that he has a doctoral degree. Participant #12 reported that he fit into the Support Personnel category of respondent (logistics, planning, and operational staff; GIS specialists, hospital staff, and similar positions.) and that, at the time of the disaster, he had been in that position for more than six months up to one year. Prior to the disaster, he had been somewhat involved in disaster response and recovery operations, and that he had participated in few seminars, conferences or other professional gatherings that primarily dealt with disaster, to include one where he presented two projects entitled "Area of Mapping of Inundation - from Tharangambadi to Kollidam mouth" and "Damage Assessment - from Pondicheery to Kollidam mouth." His organization has participated in disaster relief operations in India. He reports that he participates in GIS user groups or other organizations that facilitate professional contact among GIS users, specifically with his academic department.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There were three GIS staff persons.

2. There were six to 10 periodic or casual users of GIS.

3. The organization had been using GIS for more than four years up to five years.

4. The organization was academic / educational in nature, with a specified mission statement of "serving people."

5. Participant #12 stated that his organization did not have a set of moral codes, principles or ethics.

6. During the tsunami his organization's GIS was used primarily for supporting government activities.

7. Participant #12 describes the software sets of his organization's GIS as ARC INFO, ARC MAP, GEOMATICA, and ArcView.

8. The capabilities of his organization's GIS at the time of the tsunami included having three different GIS software and three different remote sensing software packages as well as having fully qualified and capable personnel.

Participant #13

This interviewee disclosed that his age is between 36 and 45 years and that he has a bachelor's degree. He stated that he fits into the Other category of respondent, and reports, "As volunteer, I gather information on Internally Displaced Person camps and other Internally Displaced Person relevant information and share it to public / other organization. When I was working for Care, I did damage inventory mapping, integrating land parcel data with ownership and family database, and also detail topographic survey for area intended for resettlements." He reported being in that position for more than one year up to two years at the time of the disaster response. Additionally, he had not been involved in disaster response and recovery operations before the Asian Tsunami of 2004, and that he had not participated in any seminars, conferences or other professional gatherings that primarily dealt with disaster. . His organization has a presence in the United States, but has participated in disaster relief operations in Indonesia and other countries. In regard to GIS user groups or other professional associations, Participant #13 is a member of Aceh-Nias GIS Consortium, where he actively supports GIS human resources development.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There were six to 10 GIS staff persons.

2. There were 16 to 20 periodic or casual users of GIS.

3. The organization had been using GIS for less than six months.

4. The organization was nongovernmental in nature, with a "humanitarian" mission.

5. Participant #13 stated that his organization had a set of moral codes, principles or ethics that precluded use of GIS to support conflicts.

6. During the tsunami his organization's GIS was used primarily to "show situation on the ground, to shows what interventions have been given (plan to support decision making, but although the data have been organized, but the system to do this never been explored by decision making within the organization)."

7. Participant #13 describes the software sets of his organization's GIS as Arc View, Arc GIS, Global Mapper, and Erdas Imagine.

8. The capabilities of his organization's GIS at the time of the tsunami were not fully disclosed, but Participant #13 stated that after June 2007, his organization's GIS unit had been closed.

Participant #14

This interviewee disclosed that his age is between 26 and 35 years and that he has a doctoral degree. He stated that he fits into the Other category of respondent, specifically that of a geologist. He reported that, at the time of the disaster, he had been in that position for more than five years up to ten years, and that he had been involved in disaster response and recovery operations before the Asian Tsunami of 2004, to include two other post-earthquake geologic surveys: Hector Mine, California (1999) and Bhuj, India (2001). However, he had not participated in any seminars, conferences or other professional gatherings that primarily dealt with disaster by December 2004. His organization has participated in disaster relief operations worldwide. He reports that he does not participate in GIS user groups or other organizations that facilitate professional contact among GIS users.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There was one dedicated GIS staff person.

2. There were 11 to 15 periodic or casual users of GIS.

3. The organization had been using GIS for more than ten years.

4. The organization was academic / educational in nature, with a "research" mission.

5. Participant #14 stated that his organization did not have a set of moral codes, principles or ethics.

6. During the tsunami his organization's GIS was used primarily to support field work.

7. Participant #14 describes the software sets of his organization's GIS as ArcGIS, ArcView, GMT, and ENVI for raster.

8. The capabilities of his organization's GIS at the time of the tsunami "included a dedicated GIS lab to help map in the field. Different investigators used GIS to varying degrees."

Participant #15

This interviewee disclosed that his age is between 66 and 75 years and that he has a Master's degree. Participant #15 reported that he fit into the Volunteer (church groups, non-government organizations, social services, search and rescue, etc.) and that, at the time of the disaster, he had been in that position for more than 10 years. He had been somewhat involved in disaster response and recovery operations before the Asian Tsunami of 2004, and that he had participated in professional gatherings he characterized as "training programs" that primarily dealt with disaster. His organization has participated in disaster relief operations in 65 countries in Asia and Africa. He reports that he does not participate in GIS user groups or other organizations that facilitate professional contact among GIS users.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There was one dedicated GIS staff person.

2. There was one periodic or casual user of GIS.

3. Participant #15 did not know how long his organization had been using GIS.

4. The organization was nongovernmental in nature, with a mission of serving humanity in the eradication of poverty and assistance in disasters.

5. Participant #15 stated that his organization did not have a set of moral codes, principals or ethics that applied to GIS.

6. During the tsunami his organization's GIS was used primarily to support disaster coordination.

7. Participant #15 did not know what GIS software packages his organization used.

8. The capabilities of his organization's GIS at the time of the tsunami as "basic."

Participant #16

This interviewee disclosed that his age is between 26 and 35 years and that he has a doctoral degree. Participant #16 reported that he fit into the Support Personnel category of respondent (logistics, planning, and operational staff; GIS specialists, hospital staff, and similar positions.) and that, at the time of the disaster, he had been in that position for less than six months. He stated that he had not been involved in disaster response and recovery operations before the Asian Tsunami of 2004, and that he had not participated in any seminars, conferences or other professional gatherings that primarily dealt with disaster. His organization has participated in disaster relief operations in Sri Lanka and Indonesia. He reports that he participates in GIS user groups or other organizations that facilitate professional contact among GIS users, specifically the United Nations Geographic Information Working Group and the related subgroup Geographic Information Support Team.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There were 6 to 10 dedicated GIS staff persons.

2. There was one periodic or casual user of GIS.

3. The organization had been using GIS for more than five up to ten years.

4. The organization was nongovernmental in nature, with a mission of supporting the co-ordination of humanitarian assistance through the provision of information products and services, as well as supporting the decision-making process at headquarters and field level by contributing to the creation of a common framework for information management within the humanitarian community.

5. Participant #16 stated that his organization has a set of moral codes, principals or ethics in the form of humanitarian resolutions.

6. During the tsunami his organization's GIS was used primarily for Displaced Person mapping as well as general cartography.

7. The organization used ESRI ArcGIS 9.0 as its GIS software set.

8. The worldwide capabilities of his organization's GIS at the time of the tsunami included a variable number of GIS officers (up to 15) involved with humanitarian crises around the globe.

Participant #17

This interviewee disclosed that her age is between 26 and 35 years, but declined to give her level of education. However, Participant #17 did report that she fit into the Media Personnel category of respondent (local and national news reporter, information officer, etc.). She reported that, at the time of the disaster, she had been in that position for more than two years up to three years. Additionally, she stated that she had been very involved in disaster response and recovery operations before the Asian Tsunami of 2004, but that she had not participated in any seminars, conferences or other professional gatherings that primarily dealt with disaster. His organization has participated in disaster relief operations in Indonesia. She reports that she participates in GIS user groups or other organizations that facilitate professional contact among GIS users, specifically the Office of the United Nations Recovery Coordinator for Aceh and Nias.

In regard to the situation at organization to which he belonged at the time of the tsunami response, he reported that:

1. There were no dedicated GIS staff persons or periodic or casual users of GIS.

2. The organization had been using GIS for more than five up to 10 years.

3. The organization was nongovernmental in nature, with a mission of supporting the co-ordination of humanitarian assistance through the provision of information products and services, as well as supporting the decision-making process at headquarters and field level by contributing to the creation of a common framework for information management within the humanitarian community.

4. Participant #17 stated that his organization has a set of moral codes, principals or ethics based on the religious order that founded the organization.

5. During the tsunami his organization's GIS was used primarily for supporting field work.

6. The organization has no organic GIS software or capabilities.

Participant Perceptions

The perceptions questions focus on how the interview participants perceived their roles within their organization's decision-making process, and how they observed geospatial information affecting decision-making during the response to the tsunami. These perceptions include direct observation and indirect interpolation by the interview participant. The interview participants' responses to the Perceptions section of the interview examined in accordance with Yin's are summarized here using the previously described question and answer format, while pursuing the general theoretical proposition that *there is a common, best practice use of GIS that best supports disaster management decision making during a tsunami response.*

In pursuing the theoretical proposition, the themes identified during the web-based interviews categorized according to the study foci previously described were planning, response targeting, coordination, documentation and resource mapping. This is done by applying Yin's question and answer method to the review of the responses. Additionally, there are several emergent and unanticipated themes subsequently included.

Planning

This study focus pertains to activities, within the context of using geospatial systems, which support disaster management planning prior to an incident. Several interview questions provided insight into the research focus on the function of planning.

<u>What role do senior leaders in your organization play in making sure the organization is best prepared for disaster response?</u>

The following roles played by senior leaders in their respective organizations include:

1. Ensure the overall preparedness of the organization to perform its mission.

2. Ensure the readiness of the organization's skills for action through the use of training (individual and team), exercises and drills in preparation of all aspects of disaster response.

3. Develop documentation, manuals and standard operating procedures to provide the organization with a doctrinal basis.

4. Develop and maintain partnerships with other organizations at the strategic/policy level, as well as at the operational level during the course of a disaster response.

5. Lead during their organization by personal example in times of stress and discomfort.

6. Provide senior level expertise and experience during the course of disaster response.

7. Make decisions for and supervise the operations of the organization. Provide quality control for all aspects of the organization's disaster response efforts.

8. Maintain adequate personnel, equipment, financial and other resources that are necessary for the organization to respond properly to a disaster.

<u>Please check the box(s) next to the type(s) of GIS data that your organization currently has on hand (one or more)</u>

The GIS data on hand for the organizations of those who participated in this interview include:

1. Orthoimagery (aerial photography, satellite images, and similar imagery).

2. Elevation (topography).

3. Transportation (street center lines or ROWs, rail/transit lines, airports, and similar infrastructure).

4. Hydrography (rivers, streams, lakes, wetlands, watersheds, and similar hydrologic features).

5. Governmental boundaries/political units (cities, counties, election districts, and other similar boundaries).

6. Population.

7. Environmental (soils, habitats, and other similar environmental features).

8. Cadastral information (parcels, property lines, and other real property defining features).

9. Environmental (soils, habitats, and other similar environmental features.).

10. Land use/ zoning.

11. Utilities (water, gas, telecom).

12. Geology, groundwater.

13. Public safety/public health.

14. Tsunami inundation boundaries.

15. Geodetic control.

16. Damage inventory.

Some organizations, however, reported that they had no GIS data on hand, as they relied on GIS operations outside of their own organizations for GIS support.

Does metadata exist for any of this GIS data?

As previously defined, metadata is information that is used to describe the GIS data as to its origin and format. Metadata is important to providing confidence in the GIS data in use to support analysis. Many of the interviewees reported that there was either no metadata associated with their GIS data, or that they did not know if metadata existed. Others stated that their metadata situation was mixed. Those that did report the presence of metadata did exist include:

1. Source of the data.
2. Dates the data were acquired.
3. United Nations (UNGIWG) approved standard.
4. Projection (in terms of cartography).
5. Imagery source (as in what aircraft or satellite was the platform).

Is this GIS data in an industry standard format?

One of the factors in the ability to coordinate through the sharing of GIS data is the actual format of the data. Data that is in a standard format is easier to share than data in a proprietary format that could be difficult to convert. Most respondents reported that their GIS data sets were in a standard format, although some did not know the answer, or stated that the answer was no.

Response Targeting

This study focus relates to the previous focus of planning, but concentrates on the use of data that is immediately available at the start of a disaster event to support the implementation of a plan.

Please describe any data that you have the capability and plans for accumulating during the course of a disaster response. An example of this would be plans for keeping locations of internally displaced persons as their locations become known during a disaster response.

This question seeks to determine the desire and ability of disaster response organizations to obtain current GIS data that provides situational awareness suitable enough to support response targeting. Some interviewees reported that they had no plans or capabilities to collect GIS data after the disaster had occurred and when the response was ongoing. Those who did positively respond about this type of data acquisition reported that they typically plan to collect the following categories of immediate post-disaster GIS data:

1. The number and location of internally displaced persons. This was by far the most common answer.

2. Environmental impact assessments.

3. Social-economic impact assessments.

4. Risks and vulnerabilities assessments.

5. Disaster extent intensity and impact information.

6. Post-disaster satellite imagery.

7. Road networks, particularly post-disaster conditions and high use routes (such as those around Internally Displaced Persons camps).

Some interviewees reported recognizing many of the tabular data sets that they accumulated during disaster response operations could be better used as GIS data, but for some reason or another, they could not or would not do so. These include such things as field notes normally intended for local use, but, if placed in a GIS, could prove useful in aggregate to support larger scale decision-making. For example, disaster workers regularly accumulate retail pricing information for potential disaster relief supplies in the zone around the disaster. If placed in a

GIS, an aggregation could show pricing and availability trends, as well as locations of potential illegal price gouging.

Please describe any and all data that you accumulated during the course the response to the Asian Tsunami of 2004.

This question seeks to determine the actual performance of disaster response organizations in obtaining post-disaster GIS data that was actually used to provide situational awareness for response targeting during the response to the disaster. Responses included:

1. Post-disaster satellite imagery and aerial photography.
2. Numbers, locations and condition of Internally Displaced Persons.
3. Locations of logistics resources.
4. General population locations.
5. Needs assessments.
6. Actual damage assessments.
7. Damage predictions.
8. Uplift locations and other earthquake effects.

How are decisions normally made in your organization during a disaster response?

In order to gain insight into how disaster decision-makers normally make decisions, the interviewees were asked to describe how they understood that decisions are intended to be made during a disaster response. Some of the interviewees who were from supporting organizations reported that their organizations did not have a decision-making methodology, as they do not make disaster response decisions. Others reported that even though their organization made disaster response decisions in responding to the Asian tsunami of 2004, they had no known methodology. Those that did detect a decision-making methodology within their organization reported observing:

1. Centralized decisions made away from the disaster location.

2. Group meetings.

3. Focused team decisions (assessment and logistic/action).

4. Leader on the ground makes the decisions (e.g., country project managers make decisions for what is going on in country).

5. Team decisions with senior leader approval.

How were decisions normally made in your organization during the response to the Asian Tsunami of 2004?

The question seeks actual observations of how decisions were made during the response to this particular disaster. As with the previous question, some interviewees noted that they were not in a position to observe decision makers in action. Of those who were able to discern their organization's decision-making, their responses included:

1. Decisions made by (out of country higher headquarters) using information from on the ground team.

2. Via group discussion or coordination committee.

3. Functional decision-making – team is divided into two parts; rapid assessment team and logistic team. Assessment team defines the requirements and the logistics team works to fulfill the requirements.

4. There is no methodology; personality driven (who can convince who is right).

5. Leader on the ground determined was necessary; to include information provided by collaboration with other relief agencies on the ground.

6. Leader on the ground makes the decisions (e.g., country project managers, principal investigator and directors make decisions for what is occurring in country).

Coordination

The coordination subcategory asks questions that reveal information requirements for synchronizing the efforts of the many different organizations that typically participate in disaster management.

What reporting requirements during your response to the Asian Tsunami of 2004 that involves GIS data? For example, do you produce maps that depict your organization's response to disasters?

Most of the respondents to this question answered that there were no reporting requirements. Those who responded positively provided answers including:

1. Disaster impact and affected areas.

2. Satellite imagery.

3. Response and intervention activities (what was, is and will be provided).

4. Conditions in the intervention areas.

It should be noted that all of the positive respondents noted that their reporting requirements included graphical content (maps, imagery, and other GIS content).

<u>During your organization's response, were you able to properly fulfill these requirements?</u>

This question asked the interviewees to assess their effectiveness in satisfying reporting requirements. The responses to this interview question were split in half, with not much detail provided as to why. The sole response that provided explanation noted that while she and her organization was able to fulfill its reporting requirements, the information quickly became out of date and of limited use.

<u>Does your organization serve, share, or provide GIS data or maps via the internet?</u>

This question asks the interviewee if the internet is being used a distribution tool for GIS data. Over half of the interviewees responded negatively or that they did not know the answer to this question as related to their organization. The positive responses included:

1. Data is available via a request on the organization's web page.

2. Data is shared via a secure web application such as InfoWorkSpace (IWS) and Hypertext Transfer Protocol over Secure Socket Layer (HTTPS).

3. Maps and other graphic information are posted on unsecure web sites.

Does your organization have a data distribution policy?

This question solicits responses that give indications as to the maturity of the interviewee's organization in regard to GIS data policy. Around half of the interviewees responded negatively or that they did not know the answer. The positive responses included:

1. GIS data is distributed to those who need it.

2. GIS data is made available to those who agree to specific conditions about the use of the data.

3. The distribution of GIS data is restricted to non-for-profit organizations or anyone in the humanitarian community.

4. GIS data is for (internal) use only.

5. GIS data is distributed based on (internal guidelines), which details how to share all information to both internal and external entities.

Would you use or deploy a GIS that users could sign up to, add and update themselves?

This question allows the interviewee to describe their organization's willingness to collaborate in regard to GIS database development and management during disaster response operations. Approximately half of the interviewees responded negatively to the question. To summarize the positive responses, those who would participate would need to:

1. Be able to trust the information being shared (to include terms of use).

2. Allow collaboration in a practical manner, such as through more open and familiar programs, such as Internet Explorer or Google Earth, so time to learn the difficult software such as GIS could be cut to none.

3. Be responsively managed.

One of the reasons presented for participation in a collaboration effort such as this would be the imparting of a sense of ownership among users that would improve availability and quality.

Has the use of your organization's GIS ever been subject to a legal proceeding?

This question allowed interviewees to give insight into previously experienced legal issues in regards to GIS. All respondents (except one inconclusive response) either responded negatively or did not know the answer to the question.

Documentation

This study focus pertains to archival requirements, with specific attention on future needs in the perspective of past performance.

Are there any other GIS data layers that you do not currently have that you would like to have?

While this question pertains to the design of a GIS's data structures, the interviewees' response is cast in the light of their disaster response experience. As part of this study, it is a cross-check against the question, "*During your disaster experience and while in your particular role as part of the response to* *the Asian Tsunami of 2004, was there any essential information missing that you needed?*" Responses included:

1. High resolution satellite imagery.
2. Current Information on Internally Displaced Persons.
3. Access to a more precise worldwide dataset.
4. Of course, list is infinite like Christmas list.

<u>Are you currently conducting any major data gathering or data creation activities, or will you be doing so within a year?</u>

The implication of this question is that the interviewee's organization has been prompted to seek additional data to correct some type of information shortfall within the organization, either by the tsunami that is being studied here or by another disaster. Many interviewees responded negatively. However, several organizations are gathering basic GIS data for worldwide use, or for specific countries (such as Nepal). There are also efforts to gather:

1. Baseline hazard assessments.
2. The operating locations for disaster response NGOs.
3. A poverty assessment.

Resource Mapping

This study focus pertains to information related to locating pre-placed or existing resources, or the location where resources can enter into the disaster response area.

<u>During your disaster experience and while in your particular role as part of the response to the Asian Tsunami of 2004, was there any essential information missing that you needed?</u>

This question is prompts the interviewee to provide a list of information that would have been useful in supporting the response to the tsunami. Additionally, it is a cross check for the previous two questions: *"Are there any other GIS data layers that you do not currently have that you would like to have?"* and *"During your disaster experience and while in your particular role as part of the response to the Asian Tsunami of 2004, was there any essential information missing that you needed?"* Only a few interviewees presented a negative response. The positive responses included:

1. One interviewee reported that her organization had no data to start with at all, so they were required to acquire their data through external coordination.

2. Local and community data (on-site scale).

3. Inter-organizational coordinating and operating information.

4. Current information on Internally Displaced Persons; frequently Internally Displaced Persons data was too late to use in decisions.

5. Current information (in general).

6. Long time environmental impact of tsunamis.

7. High resolution optical imagery…*"Ironically, a few tiles now available on Google Earth are nicer than anything available at the time."*

8. Detailed and verifiable lists of beneficiaries as well as sources of construction material.

Did your organization encounter any bureaucratic problems in regards to GIS during the response to the Asian Tsunami of 2004?

This question, as posed to interviewees, gives insight into how the interviewee's organization interacted with other responding organizations and/or other echelons of the same organization. The preponderance of interviewees responded negatively or that they didn't know the answer to the question. The three positive responses included:

1. Always.
2. Critical GIS data arrived after the response.
3. Governmental permissions could not be secured to perform on-the-ground surveys in a timely manner.

During your disaster experience and while in your particular role as part of the response to the Asian Tsunami of 2004, what types of vital information did you receive that directly supported your organizations mission?

This question allowed the interviewees to present a completed list of mission critical information that supported their disaster response operations. Additionally, this question provides a cross check against previous interview questions that asked about "necessary information" that was either missing or required during the response to the tsunami. Responses included:

1. Disaster delineation information.
2. Affected population information.
3. Locations and disposition of Internally Displaced Persons; field surveys of Internally Displaced Persons conditions.

4. NGO operational mapping.

5. Needs assessments, to include locations.

6. Resource locations.

7. Satellite images (pre- and post tsunami event).

8. Roads and other facilities.

9. Field conditions.

10. Physical information that supported impact assessment.

11. Situation reports.

Uncategorized - Needs for Improvement

One interview question was posed that presents an opportunity for the interviewee to draw on his or her experience and asks: *List three improvements in order of importance that you would like to see made to your GIS to provide better support for disaster management.* A summary of responses includes:

1. Better data preparedness for the region; data availability and sources.

2. Better communication/internet networks and communication.

3. Better portable hardware/software preparedness; better equipment in general.

4. Instant access (to GIS information).

5. More current information; access to timely information, quick updates of available information.

6. Current, high-resolution satellite images; early access to satellite imagery; better access to satellite imagery achieves; seamless high-resolution optical imagery for mission planning.

7. Need better understanding of GIS capabilities.

8. Improvement in coordination.

9. Better maps.

10. Updated resource locations.

11. More timely information about location and status of Internally Displaced Persons.

12. Hazard information.

13. Precise GIS dataset; well-organized datasets with metadata at hand.

14. Field data.

15. Access to information while it is still useful.

16. To know more about GIS capabilities.

17. Improved of classification methods and tools.

18. (Improved) processing time (for imagery).

19. Financial support (for GIS).

20. Ability to post (GIS data) to Internet.

21. Ability to update attribute data through Internet (so wider staffs could participate).

22. Migrate away from (GIS packages that require significant training), which are far too obtuse, cumbersome, and unreliable in the field.

23. More timely information on locations of people affected by the disaster; more information about where people in need are as soon as possible.

24. Have a better base set of data before the disaster.

25. Have a relationship set up with others for better data sharing.

Uncategorized - Concluding Comments

The final question of the interview asks: *Please add anything else that you would like to on the topic of using GIS to respond to disasters.* Responses included:

1. GIS products inform a great deal which improves the efficiency of response planning.

2. Many people were asking for satellite images but we for a long time did not have anything new enough to show the damage from the water. More access to current new images will help us support field work better.

3. As we published, "Relief and recovery efforts after the 2004 Indian Ocean Tsunami in South East Asia are burdened by extreme competitiveness and lack of collective action. The recovery in countries severely affected by the tsunami such as Sri Lanka and Indonesia provides an important opportunity for building societies that are more equitable, sustainable and resilient to environmental risks. However, a lack of collective action amongst agents delivering humanitarian and livelihood support, governments, and those directly affected by the tsunami, represents a considerable obstacle in this process."

4. I do not know GIS well enough, with more knowledge I would be able to use it better.

5. It could be done a lot better.

6. This organization does not create and use its own GIS data. We use mostly UN data but sometimes others.

7. Electro-optical imagery taken after the tsunami was the most requested geospatial support. Most users used images for all purposes including navigation; ended being used as base maps that were later written on by end users.

8. I think: a) the time of establishing a GIS is not the time of responding disasters. b) I am not sure that efficient response disasters are a good promotion of the establishment of a GIS. GIS is usually established for another purpose. c) I am sure that sometimes GIS can be useful in the short time response to a disaster, but it is a question of opportunity. d) Tsunami changed the coast! GIS data are then old fashioned, update of GIS is them the question (before the response).

9. I have found that this tool (GIS) is very important to the work we do in the field. I can see that if I had access to more information about internally displaced persons (if collected by a reliable source) then I would be able to do my work so much better.

10. Data integration between GIS and database; Sharing and updating data through open collaboration.

11. We are mostly interested in finding where everyone who needs aid is.

12. We are very challenged with gathering information during the course of the providing aid.

13. Trying to understand what is going on around you and the people you are trying to help is the most during disaster response is usually the most

challenging thing you do. GIS can help make this easier so I hope that you can find a way to make that happen.

Analysis of Interview Results

The interview results provide the thematic framework for answering the research question: *What happened when geospatial information was used to support disaster decision-making during the humanitarian response to Asian Tsunami of 2004?* The interviews were conducted with self-identified disaster response participants, who either used GIS data to make decisions or provided support to those principal decision makers.

The analysis of these interviews is presented in two parts. Part one of interview analysis presents themes (or patterns) that emerged from all the interviews. The identification of these themes was cued based on Yin's case study analysis strategy of *Relying on Theoretical Propositions,* which for this study is that *there is a common, best practice use of GIS that best supports disaster management decision making during a tsunami response.* Additionally, the interview data were analyzed for themes (patterns) that logically tie to the research proposition. The second part is a summary of themes identified in part one within the previously described, together with discussion of perspectives and counterpoints of those themes. The outcome of part two is an assessment confirming or denying the validity of each particular theme.

Emergent Themes

The themes revealed during the course of the interviews are presented in the context of what and how geospatial information was required in order to make decisions during the response to the tsunami disaster. Each of these themes is presented within the framework of the study foci, and is indicated for inclusion here by the interviewees. Although presented in a similar manner as the actual interview responses, these themes draw from summarized responses found through each of the study foci.

Preparation is essential for organizational effectiveness during disaster response. As previously described, the planning study focus relates to geospatial activities that support an organization's preparations to respond to a disaster. Interviewees reported that there are certain preparations that should occur prior to an organization's disaster response in order to provide the best support to disaster management planning. Interview results presented that organizations must be trained and effective teams prior to responding to a disaster. If deploying a GIS with the disaster response organization, all aspects of the geospatial systems to be used (software, hardware, data and training) to support disaster response must be understood and ready to go prior to responding. As an example related to geospatial data, many interviewees reported that they knew what data they had on hand, but did not know the reliability of the data (via metadata). In light of a lack of metadata, they questioned the validity of the data as to its capability to support in an adequate manner decision-making, thus hindering the use of GIS to support decision-making.

Current information about affected populations and displaced persons is critical to effective disaster response. Throughout many of the responses from the interviewees, the focus on displaced persons repeatedly arose as a key indicator for disaster decision-making. Interviewees note that during the tsunami, displaced persons location and status information provided a consolidated, high payoff target for applying resources to relieve the consequences of the catastrophe. As noted previously, displaced persons numbered up to one million across the affected countries during the tsunami. During the period after a disaster, those who are unable to take care of themselves at home, or who no longer have a home, tend to move toward concentrations of displaced persons (whether sanctioned camps or not). Therefore, over the course of time, displaced persons become the focus of where resources need to be applied. The information required about displaced persons not only oriented on current locations, but also planned locations for displaced persons camps.

Current information about conditions in the disaster area is required. Interviewees reported that information about the physical conditions on the ground in the disaster-affected area served as significant indicators for resource allocation. This is particularly true early in the disaster when the patterns of displaced persons migration have not yet been detected. Experienced decision-makers can predict where to apply resources by knowing where there was likely or actual significant damage to structures and infrastructure. While reliable information can be gained by field reports produced by workers on the ground, the communications situation may delay the transmission of that information in a timely manner. Numerous interviewee responses indicated a requirement for post-disaster satellite imagery to fill this condition information gap. Although the term "satellite imagery" was indicated during the interviews, it is reasonable to include aerial photography or videography in this category of geospatial data for the purposes of this research. This is because these data sources provide a similar resolution of imagery (or better) to satellite imagery, and depending on the situation may be available days in advance of satellite imagery. It is important to note that condition information also was a significant resource for planning for the emplacement of displaced persons camps. Condition information provides likely location for the migration of people as well as infrastructure information that is available to support a proposed camp.

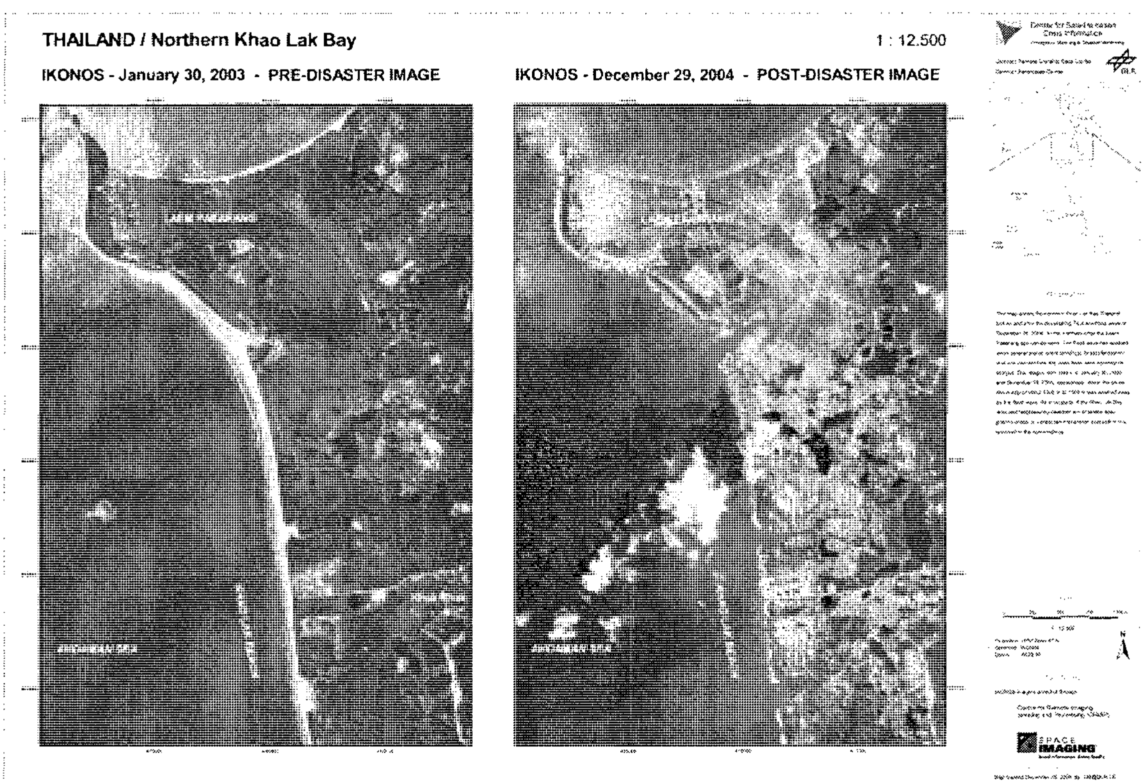

Figure 2. Before and After Satellite Imagery of Tsunami Affected Thailand

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From UNOSAT web site, downloaded April 6, 2009 from http://unosat.web.cern.ch/unosat/asp/prod_free.asp (Copyright Space Imaging and The International Charter), 2004). Adapted with permission of Space Imaging and The International Charter.

Figure 2 provides an example of how imagery can be used to compare conditions before a disaster to those after a disaster. In addition, it should be noted than an estimation of the situation on the ground, particularly one using a scientifically developed model, is useful when limited or no information is available to decision-makers.

All decision-making methods have similar data requirements. The results of the interviews presented evidence that each of the three disaster-oriented decision-making models (recognition-primed, edge of chaos, and progression of multiple options) were used to make disaster response decisions during the response to the tsunami. Interestingly, there are also indications that some organizations use combinations of methods to support decision-making, depending on the situation and relationships involved. For example, the interviews gave indications that individual decision-makers on the ground were making decisions based on what they expected during a tsunami, all based on their previous disaster response experience. This indicates a recognition-primed model, which best supports quick decision-making in a familiar environment. However, the same organization collaborated with other organizations on the ground that were part of the response. These intra-organizational decisions required coordination and negotiation, which are indications of using the progression of multiple options model. Regardless of how the interviewees described their decision-making, however, they still presented a similar need for three key sets of information: location and condition of displaced persons, conditions on the ground, and resource locations.

In the absence of current data, a predictive model is useful. As the last of the Response Targeting themes, this one builds on the previous three. In the absence of information about affected populations and displaced persons and the conditions on the ground, and knowing this information is essential to making good decisions, it would extremely useful to disaster decision making to be able to predict this information with reasonable certainty. Additionally, several interviewees noted that information regularly arrived well after it was useful in making particular decisions. Modeling predictions of such things as displaced person movements and tsunami damage would allow decision makers to make preliminary estimates and decisions that would allow for a much quicker response once the actual information comes in (assuming comes in while it is still useful).

The most effective relationships with external supporting organizations are already be in place when the disaster occurs. This is particularly true if relying on another organization to provide geospatial decision-support information, the relationship and coordination should be already in place to give the best possibility of organizational effectiveness. This coordination should include data sharing agreements and arrangements for physically transferring the geospatial information from the supported organization to the end user. If relationships with key players are not in place at the onset of the disaster, deliberate and significant efforts will have to take place in order to make an effective liaison. During normal periods, making liaison and creating an agreement takes significant efforts and time. During a crisis, organizations have challenges with internal matters, let alone the development of a new external relationship.

The internet is an important GIS data distribution tool during disaster response. The distribution of information of all kinds has been transformed by the internet, and as this truth has encompassed this field of work as well. Interviewees reported that for many organizations, the internet is the principal method of distributing data, both during routine periods as well as when a disaster response is ongoing. When disaster organizations share their information, two trends appear. Raw data is controlled in order to preserve reliability, while processed information such as reports and maps are freely shared with anyone who is interested. Additionally, organizations that share data typically have policies that support the relatively free sharing of information with other organizations involved in disaster relief activities. Given the opportunity and the proper conditions, interviewees reported they would be willing to host a version of their data that could be updated by other external (albeit vetted) users during the course of response to a disaster.

Current information about resources available in the disaster area supports better decision-making. As disaster response organizations develop the situation on the ground during the response to the disaster, they inherently develop requirements for resources that need to be fulfilled eventually. While an organization might have awareness of where its own resources are located (not to be assumed, however), the awareness of others' resources regularly becomes essential to the relief organization. This is because of the simple fact that in the chaos of the response, different resources from different organizations arrive at different times. For example, there can be an emergent need for a particular relief item that becomes depleted at a camp run by a particular organization, while adequate supply of the same item is located a short distance away in a warehouse run by another organization that would be willing to share it if asked. Accurate and timely resource location information that is available to all disaster decision makers allows for better and timelier resource allocation decisions to be made.

Theme Discussion and Summary

The interviews revealed clear themes in regard to the perceptions of disaster decision-makers and support personnel who participated in the response to the Asian Tsunami of 2004. According to these experienced experts, these themes constitute the required conditions, geospatial functions and information that best support disaster response.

Prior to a disaster response, the organization must be prepared to evaluate the disaster situation and make decisions to support relief efforts. These preparations include internal considerations, such as the proper training, equipping and management of the organization. It also includes external preparations, such as coordinating for data support and transportation, all within the context of geospatial resources.

During the course of the disaster, the organization can only be effective if it can properly target where to apply relief resources. In order to do this, the representatives of that organization must be aware of the location and condition of those persons in need. If they do not know where they are, they must be able to predict where they are likely to be in a timely manner.

Once the need is known, the decision-makers must understand the practical aspects of getting relief to those in need. For example, if there is damage (or predicted damage) to the transportation networks, the decision-maker must be aware of this and factor it into decision-making. Likewise, if security in a particular area is not conducive to a particular method of relief, the disaster decision-maker is most effective when aware of this.

During a disaster response, decision-makers, regardless of their background and decision-making methodology, generally require the same types of information in order to make adequate decisions. Some of this information is collected from field reports, such as the condition and location of displaced persons. Similarly, decision-makers can respond more effectively to identify needs using information about available resources. Other information, such as damage assessments, can be had quickly and effectively by examining overhead imagery such as satellite images aerial photography. However, if they do not have current information, then they should have the ability to predict what has occurred or will occur.

There are many types of organizations that respond to disasters. Each of these organizations collects information that could be appropriate for use in a decision-support GIS. Larger and more capable organizations regularly share this geospatial information to their partner organizations via the Internet or by other means. However, the demand for current geospatial data regularly exceeds what is available. Interviewees recognized that most disaster response organizations could potential contribute to a master data set, but, communications, vetting issues and geospatial skills difficulties get in the way of sharing this information.

CHAPTER VI

EVALUATION OF EMERGENT THEMES AND CORROBORATING EVIDENCE

The interviews show specific observed patterns that are clearly identifiable and thus able to be examined. As part of investigating the question, *What happened when geospatial information was used to support disaster decision-making during the humanitarian response to Asian Tsunami of 2004?*, these themes are examined in the context of what is presented by other sources of evidence.

Tsunami Documents and Archives

This section reviews pertinent documents and archives produced as part of the disaster response to the Asian Tsunami of 2004 in order to validate those themes identified by the interviewees in the previous section. Termed as *data triangulation* by Yin (2003), these documents and archives show correlations between the themes of interviewee observations and other sources of evidence, all while pursuing the theoretical proposition that *there is a common, best practice use of GIS that best supports disaster management decision making.* This section presents the selected documents and archives, and then compares the themes revealed during the interviews with topics found in these documents, all within the context of the study foci.

Tsunami Response Archives

During the course of the tsunami response, the Pacific Disaster Center provided a variety of support to multiple organizations and governments. This support included the provision of geospatial data, in the form of satellite imagery to the following entities:

Table 2

Pacific Disaster Center Geospatial Data Users (PDC, 2007)

International and Regional *Organizations*	**National Agencies (U.S. and *International*)**	**Non-Governmental Organizations (International and local)**	**Educational *Institutions***
Geo Information and Space Technology Development Agency (Thailand)	Belgian Ministry of Defense	Global Aid Network Canada	California Institute of Technology
International Atomic Energy Agency	Indonesian Government	Indonesian Institute for Sciences	Cornell University
International Sustainable Development Studies Institute	Indonesian Ministry of Marine Affairs	MS Swaminathan Research Foundation	Manchester Metropolitan University, UK
United Nations Food and Agricultural Organization	Indonesian Telecommunication Users Group	The World Conservation Union	Ressenlaer Polytechnic Institute
United Nations Office for the Coordination of Humanitarian Affairs	United States Army Corps of Engineers	Walhi North Sumatra	Tamil Nadu Agricultural University
United Nations Population Fund	United States Army Strategic Command	www.recoverlanka.net	University of Alaska
UNOSAT	United States Department of Agriculture		University of Durham
	United States Geological Survey		University of Edinburgh
	United States Department of State		University Paris 1 Panthéon Sorbonne
	Wildlife Institute of India		University of Peradeniya, Sri Lanka

During the course of the response, the Pacific Disaster Center produced numerous internal communications, to include e-mails. Selected internal e-mails were made available by the leadership of the center for the purposes of this research in a document titled, “Tsunami Notes.” In addition to the e-mails, the Pacific Disaster Center provided internal after action review and lessons earned documents. This archival information provides unique insight in the operations of the center’s team that responded to the tsunami.

Post-Tsunami Reports

After the tsunami, major organizations of all types produced documents that reported on the results of their assessment of efforts to respond to the tsunami. These reports are generally available to the public, but are not necessarily academic in nature. The documented efforts in this section mostly report the actions taken by each particular organization to respond to the tsunami, and the results of those actions. Some documents, however, perform assessments of preparations in other areas in the world, within the context of the Asian Tsunami.

Fourteen documents that represent the findings of the world's primary disaster response organizations (whether governmental or not) are presented here as corroborating documentation to the themes revealed during the interview portion of this research. The documents included here may or may not specifically refer to geospatial data or GIS functions, but all do refer to decision-making and the information and functions that are required to perform decision-making. Each of these documents is listed and briefly described:

U.S. Tsunami Preparedness: Federal and State Partners Collaborate to Help Communities Reduce Potential Impacts, but Significant Challenges Remain. This document was published by the US Government Accountability Office in 2006 and focuses on the impact of the Asian Tsunami of 2004. It presents assessment information about the preparedness of the United States to respond to a similar tsunami.

The Post-Tsunami Recovery in the Indian Ocean: Lessons Learned, Successes, Challenges and Future Action. The United Nations Development Program published this document in 2005 in order to record the lessons learned by the organization during its response to the tsunami.

The 2004 Indian Ocean Tsunami Disaster Evaluation of UNICEF's Response (Emergency and Initial Recovery Phase) - Synthesis Report. Published by the United Nations Children's Fund in 2007, this report documents an evaluation of the organization's relief efforts in Indonesia, Sri Lanka and the Maldives.

Global Symposium +5 on Information for Humanitarian Action - Final Report. Published by the United Nations in April 2008, this report summarizes the proceedings of this symposium, which focused on documenting the best practices and lessons learned from humanitarian responses around the world. This report is the basis for an action plan to be implemented by the United Nations Office for the Coordination of Humanitarian Affairs.

10 Lessons Learned From The South Asia Tsunami of 26 December 2004. Published by the Inter-Agency Secretariat of the International Strategy for Disaster Reduction at the United Nations in January of 2005, this report presents 10 lessons that were learned immediately after the tsunami.

Annual Report Fiscal Year 2005 Office of US Foreign Disaster Assistance – US Agency for International Development. This is the annual report for the primary official US foreign disaster relief agency.

Regional Workshop(s) on Lessons Learned and Best Practices in the Response to the Indian Ocean Tsunami – Indonesia, Sri Lanka, Thailand, Maldives & Summary. These are a set of documents, published in 2005 by the United Nations as a result of workshops hosted in each of these countries. Co-hosted by the United Nations Resident Coordinator (equivalent of ambassador) and a Minister, the workshops hosted a broad spectrum of government, non-governmental and international organization members who responded to the tsunami.

Humanitarian Response Review - United Nations - Office for the Coordination of Humanitarian Affairs (OCHA). This document, published in 2005, presents a comprehensive set of observations and lessons learned based on experiences of key responders to the tsunami.

Guidelines Published After the Tsunami

In addition to reports, some organizations went further with the lessons learned from the tsunami and incorporated them into subsequent guidelines for future operations. These guidelines include the following documents:

Field Operations Guide – US Agency for International Development. This document, published in 2005, is the current manual for field operations for US international disaster relief.

Disaster Preparedness for Effective Response: Guidance and Indicator Package for Implementing Priority Five of the Hyogo Framework - United Nations - Office for the Coordination of Humanitarian Affairs (OCHA). Published in 2008, this document presents a framework for implementing procedures based on lessons learned as agreed upon by over 168 countries.

Theme Evaluations

The themes that emerged during the interviews are evaluated here as compared to the pertinent documents and archives that relate to the response to the Asian Tsunami of 2004.

Corroboration of Theme: Preparation is Essential for Organizational Effectiveness during Disaster Response

The theme, *Preparation is Essential for Organizational Effectiveness during Disaster Response*, presents itself with the need for two aspects of preparedness – internal and external. The following documents and archives provide corroborating evidence for the legitimacy of this theme:

Pacific Disaster Center Tsunami Notes. In regard to preparation, the internal Pacific Disaster Center (PDC) e-mails corroborated this theme on several points. In regard to internal preparation (that is, preparation of the organization to engage the tsunami problem), the PDC archives relate that some opportunities were lost when:

1. The deployed PDC team was not administratively prepared to share information – "I do not know the protocol/priorities the PDC office is following regarding support for this operation. Knowing exactly what [are] our resources is key" (p. 1).

2. The deployed PDC team was not administratively prepared to participate in this type of operational environment – "information overflow is rampant on most levels...need organizational tools" (p. 1).

3. The team was not prepared to use known and available GIS analysis tools, and because of the tempo during the response, the "possible use of ... (various applications)... and other tools" was not possible because the team did not "have no time to research these methodologies" (p. 6).

4. These comments indicate that the participants in this tsunami response identified with this theme; that preparation is essential for organizational effectiveness.

US Government Accountability Office - U.S. Tsunami Preparedness: Federal and State Partners Collaborate to Help Communities Reduce Potential Impacts, but Significant Challenges Remain. This document, as an evaluation of tsunami preparations in the United States, named four specific recommendations for continued or further tsunami preparations by the National Oceanic and Atmospheric Administration (NOAA), the federal government's agency of responsibility for these matters. Each of these supports this theme's identification for the need for the responding organization to be properly prepared. This document noted that NOAA should:

1. Take steps to develop software for tsunami loss estimation.

2. Increase high-risk community participation in its tsunami preparedness program.

These two recommendations directly correspond to the tenets of this theme. First, this report recognized the lack of available tsunami damage estimation software for responders, and that this software should be immediately developed. Interestingly, in a commentary on the report, the Department of Homeland Security noted the existence of the HAZUS software previously noted in this research. Secondly, this report recommended rehearsals for all potentially affected communities and their emergency responders. While related to other themes, the preparation aspects of these recommendations correlate with this theme.

United Nations Development Program - The Post-Tsunami Recovery in the Indian Ocean: Lessons Learned, Successes, Challenges and Future Action. This document notes that one of the defined successes in preparation can be seen in the village of Samiyarpettai in India. This village participated in a United Nations Development Program Government Disaster Management program that facilitated it developing a basic level of preparedness in regard to rehearsals and establishing rescue teams. As a result, “only 22 lives were lost in the tsunami as compared to a similar neighbouring village, Pudukuppam, where death toll reached 102. Pudukuppam had not been involved in the programme” (United Nations Development Program, 2005, p. 5). Additionally, this report noted, “the importance of preparedness, early warning and the development of pre-disaster recovery plans (national and community level)” (United Nations Development Program, 2005, p. 5).

United Nations Children's Fund - The 2004 Indian Ocean Tsunami Disaster Evaluation of UNICEF's Response (Emergency and Initial Recovery Phase) - Synthesis Report. This report is one of the most robust documents analyzing any particular organization's response to the Asian Tsunami of 2004. In corroborating the planning theme, this document presents many examples of the recognized importance of preparation for disaster response organizations.

In evaluating UNICEF's response to the tsunami, the document reports "UNICEF's planning processes in the early phase of emergencies lacked definition. There often appeared to be an absence of a Plan of Action to follow...such a … document would provide early objectives and indicators to give direction and structure to the emergency response" (Wiles & Sida, 2007, p. iv). This recognizes that necessary preparations were not in place during this particular response. As a result, this document recommends that UNICEF "strengthen emergency preparedness & response planning," to include developing "standard Operating Procedures to ensure staff understand organisational policy and procedure quickly and maximise support from the wider organisation." This document also recommends that emergency response teams "focus on practical measures to enable rapid response" (Wiles & Sida, 2007, p. 48).

This report stresses that of its in-country offices, the ones that had been operating for longer periods, were the most capable of responding to the tsunami. These offices were also able to provide support for lesser capable offices. The report also points out a specific situation where lack of organizational preparation significantly hindered a particular country's operations. In Indonesia, a robust emergency plan had been developed, but had not been mainstreamed or otherwise rehearsed.

Finally, the report notes that in general, UNICEF was generally not prepared for the scale of the tsunami (as were others), and that although directed and required, the emergency response plans for each country varied in quality and currency and were mandatory for success. These are the basis for deliberate actions during the response, and the lack of plans became a lack of action.

United Nations - Global Symposium +5 on Information for Humanitarian Action - Final Report. The final report corroborates the planning theme in regard to the general preparedness of responders. Overall, of this document's eight emergent themes, their preparedness overlaps with this document's planning theme. Specifically, this document notes,

> There needs to be greater organizational commitment, investment and collaboration across the community in information preparedness to allow for more effective data and information collection, management and analysis to support strategic and operational response. This should include investing in appropriate technologies, in ... equipment as well as in (information management) training within and across humanitarian organizations. It also should include integrating (information management) concepts and practice into the working cultures of organizations and into the priorities of senior management. (Haggarty, 2008, p. 13)

In recognition of a need for preparedness, the report provides the following lessons learned and best practices:

> Lessons learned and best practices need to be collected and integrated into training, but they also need to be actively promoted and applied in the early phases of an operation. The outcomes from training and simulation exercises should not be forgotten, but also need to be reinforced and promoted when an emergency occurs...Conduct simulation exercises for relevant staff prior to emergencies in order to test plans, reinforce best practices, and promote teamwork and coordination. Simulation exercises are also a good opportunity to test (information management) procedures and new and unproved technologies and systems. (Haggarty, 2008, p. 14)

US Agency for International Development - Annual Report Fiscal Year 2005 Office of U.S. Foreign Disaster Assistance. The US Agency for International Development (USAID) recognized long ago that preparedness is essential to facilitate a proper disaster response. In this report, the agency specifically states, "[US Agency for International Development] views preparedness as an essential counterpart to disaster response." Moreover, the organization's strategy emphasizes "building local disaster management capabilities" (p. 86). One particular program, the Regional Disaster Assistance Program (RDAP), "was initiated in 1989 to provide training for disaster managers and technical assistance to affected countries throughout the region. Through RDAP's multi-course instruction program in disaster management concepts, training methodology, and technical skills, OFDA has helped strengthen national and regional disaster management agencies" (p. 86).

United Nations - Regional Workshop(s) on Lessons Learned and Best Practices in the Response to the Indian Ocean Tsunami – Indonesia, Sri Lanka, Thailand, Maldives. During the course of these regional workshops, there were many ideas that corroborate with the planning theme that emerged from this dissertation's interviews. These ideas include both observations as well as proposals for future activities, but all are based in recognized need for response team preparedness.

In the Sri Lanka workshop, the following observations emerged:

1. As part of disaster preparedness planning, ensure that an adequate number of personnel receive training and other development opportunities, so that they are available in times of emergency (p. 5).

2. There was no plan to make effective use of available trained people" (p. 12).

3. There was no authoritative system where decisions could be made quickly (p. 12).

4. There was no information sharing or awareness among organizations and institutions (p. 12).

In the Thailand workshop, the following observations and recommendations emerged:

1. The scale of the disaster exposed certain weaknesses at the local level, particularly regarding preparedness planning and general awareness, during the very first few days of the response" (p. 2).

2. Need for national preparedness plan: Participants stressed the urgent need for a comprehensive national preparedness and response plan that would bring all relevant ministries, the armed forces, local government, and other entities together under a common set of principles and agreed practical arrangements (p. 4).

In the Indonesia workshop, the following observations and recommendations emerged:

1. Build contingency plan based on disaster experiences and expertise of people involved in the response, including the affected communities (p. iv).

2. Develop a rapid response team of persons experienced in disaster management (p. iv).

In the Maldives workshop, the following observations and recommendations emerged:

1. No national or local level institutional structure for disaster management was in place" (p. 4).

2. There were no personnel trained to deal with a disaster of this magnitude (p. 4).

3. Training and rehearsals had been conducted for disasters of a smaller scale such as airplane crashes and oil spills, but not for a disaster of this magnitude" (p. 4).

4. At the time the tsunami struck, there were no emergency operations centers and no persons designated as information focal points (p. 4).

5. Need for a national institution or national operations center (p. 5).

6. A national institutional framework or mechanism for disaster management which links individual islands and atolls to a national institution or national Operations Center is needed. The establishment of such a center must be augmented with a comprehensive disaster management capacity building effort. Just as an institutional framework must extend from the national level throughout the islands, human capacities at all levels must be developed (p. 5).

In a summarizing session attended by representatives from each of the affected nations, participants noted that preparedness on all levels was important to the success of the response. (United Nations Development Program, 2005).

United Nations - Humanitarian Response Review. This document relates several observations that endorse the planning theme, but generally recommend an increased level of preparation. Specifically, one of the key findings related to decision-support is that "A number of tools for coordination such as contingency planning and preparedness, joint needs assessment, CAP/Appeals need to be developed as growing areas of collaboration between the UN, Red Cross/Red Crescent Movement, NGOs and IOM" (Adinolfi et al., 2005, p. 11). Another observation was that there was a general lack of adequately trained personnel, no matter what the organization. This gives more weight to this theme, as this lack directly affects an organization's ability to contribute trained teams to a disaster response.

US Agency for International Development - Field Operations Guide. Within this document, the US Agency for International Development sets forth doctrine for the employment of its teams in the field. One of these types of teams, the Response Management Teams, is responsible for the coordination of the US Agency for International Development response, as well as directing subordinate Disaster Assistance Response Teams. Within both of these teams (or within a specific Geographic Information Unit), it is possible to find Geographic Information Officers who are responsible for providing geospatial information to decision-makers during the course of a disaster response. This guide presents a high level of details in instructions for geographic information officers regarding information that normally is needed by the team in order to complete its mission. Implicit in these instructions are the need for training and experience in the use of geospatial data, namely in the use of satellite imagery. It was also noted that technical experts in geospatial technologies are necessary and thus always available to deployed teams.

This guide also provides procedures and instructions for team members to provide feedback in regards to response team performance, including:

1. Lessons learned.
2. Individual performance of unit personnel.
3. Concerns.
4. Future training needs.
5. Recommended changes.

This further indicates the US Agency for International Development's acknowledgement of the importance of preparation of their teams.

United Nations Office for the Coordination of Humanitarian Affairs - Disaster Preparedness for Effective Response: Guidance and Indicator Package for Implementing Priority Five of the Hyogo Framework. The guidance included in this document directly pertains to the disaster response teams formed and deployed to disaster areas by responders of all types. It recognizes that "contingency planning is a management tool used to analyze the impact of potential hazard events so that adequate and appropriate arrangements are made in advance to respond in a timely, effective and appropriate way to the needs of the affected population(s)" (p. 5). As such, the document provides clear guidance as to what is necessary to be ready to respond effectively. Specifically, the document notes: "A plan in and of itself is not enough. The plan needs to be tested and exercised by the people and organizations that will use it. Classroom or actual field simulation exercises, based on specific scenarios, are an effective means to determine how realistic the plan is and to assess the capacity of the different actors. Based on the results and lessons learned during such exercises, plans (procedures, responsibilities, etc.) can then be modified accordingly" (UN/ISDR & UN/OCHA, 2008, p. 22). As part of a preparedness regimen, an organization's training is also part of its self-improvement processes.

Simulations were noted as being particularly effective in assisting response teams in their preparation for deployment. These types of training exercises "can help to identify strengths and weaknesses, as well as what training is required so that all participants are able to meet their identified responsibilities. The use of simulation exercises also serves to maintain the plan 'fresh' in the minds of all the actors and to keep knowledge and skills up to date" (UN/ISDR & UN/OCHA, 2008, p. 22). In this document's conclusions, it notes that one of the primary outcomes of adhering to this document's guidance is that "all organizations, persons and volunteers responsible for maintaining preparedness are equipped and trained for effective disaster preparedness and response" (UN/ISDR & UN/OCHA, 2008, p. 39).

Corroboration of Theme: Current Information about Affected Populations and Displaced Persons is Critical to Effective Disaster Response

The Response Targeting Theme, *Current Information about Affected Populations and Displaced Persons is Critical to Effective Disaster Response*, is corroborated by multiple documents and archives as follows:

Pacific Disaster Center Tsunami Notes. As reported in an internal PDC email on 6 January 2005 (less than two weeks after the disaster), the most pressing information requirements for decision makers include:

1. Looking for areas with high populations in the "impact zones," areas that are now holding water (p. 1).

2. Suitability models for relief camps in these areas, transportation options to these areas (p. 1).

Additionally, the PDC document observes that the main shortfalls for geospatial information requirements are "...main supply routes, hospital locations, (internally displaced person) camps, ...helicopter landing zones, hospital locations, etc.," further speculating that the lack of this information was costing time, money and lost lives. (Pacific Data Center, 2008, p. 5).

United Nations Children's Fund - The 2004 Indian Ocean Tsunami Disaster Evaluation of UNICEF's Response (Emergency And Initial Recovery Phase) - Synthesis Report. While inherently concerned about its role in protecting children, the report noted that approximately 1.8 million people were displaced by the 2004 Asian tsunami. In its executive summary, this report is specifically critical on the point that displaced persons were of critical importance to the tsunami disaster response. It states, "that UNICEF, in common with other humanitarian agencies, should have paid more attention to internally displaced persons..." (p. iii) Significantly, this document uses displace persons and their status as indicators of response effectiveness to this tsunami. Examples of this include access of persons to water and sanitation, as well as their mortality.

United Nations - Global Symposium +5 on Information for Humanitarian Action - Final Report. In the keynote speech for this symposium, John Holmes, who was at the time United Nations Emergency Relief Coordinator and Under-Secretary-General for Humanitarian Affairs, noted that information was a critical aspect of disaster relief. He specifically identified information about displace persons as part of a general need for information that disaster responders need to have in order to have "really good information and really good analysis" (Haggarty, 2008, p. 41).

In the report, there are eight sets of lessons learned and recommendations regarding the management of information during a disaster.

There are many observations that corroborate this theme as well as others. These lessons and recommendations include:

> Humanitarian information products, services and tools should be designed and developed based on identified user needs and decision-making requirements, and should support analytical processes. Further, they should be easy to use, access and retrieve, and presented in formats that highlight the strategic relevance of the information.
> Use of a common, agreed-upon geo-referencing system standard (e.g., decimal latitude/longitude, P-Code schema, authoritative gazetteer of place names, ISO abbreviations) facilitates the exchange and use of information from different sources. Geospatial data that uses the same geo-referencing standard can be easily shared and used for GIS applications. (Haggarty, 2008, p. 41)

US Agency for International Development - Annual Report Fiscal Year 2005 Office of U.S. Foreign Disaster Assistance. This report presents some clear examples of the focus of US Agency for International Development on displaced persons during a disaster response. While reflecting on the tsunami response, the report notes that the US Agency for International Development's Disaster Assistance Response Teams were initially responsible for on-the-ground assessments in order to focus US government efforts during the response to the tsunami. Overridingly, these assessments focus on the displaced population locations and statuses. For example, the report recounts that one of the top priorities for the US government's relief efforts was the provision of water and sanitation to displaced persons, with the obvious requirement being to know where these people were or were predicted to be. In another clear example of the importance of this information, the knowledge of the displacement of 500,000 people in Sri Lanka led to a prioritization of US efforts to fulfill this significant need. (US Agency for International Development, 2006).

United Nations - Regional Workshop(s) on Lessons Learned and Best Practices in the Response to the Indian Ocean Tsunami – Indonesia, Sri Lanka, Thailand, Maldives. During these workshops, participants recognized the importance of displaced persons. In the context of a session in Indonesia, session participants noted that there was a need for improved registration of such persons. In addition, observations showed that during the course of the disaster response, a lack of information about displaced persons resulted in "aid being sometimes provided regardless of the actual needs" (p. 3). As part of the recommendations of the Indonesia report, it was suggested that in the future, accommodations for displaced persons be more promptly established (United Nations Development Program [Indonesia], 2005). In addition, the lack of visibility on what information had been already collected on displaced persons resulted in the same information being repeatedly asked of the same people.

United Nations - Humanitarian Response Review. This document contains a remarkable amount of discussion about displaced persons in regard to the tsunami and other disasters. This review includes contemplations about the role of the disaster response community in the context of this group, as well as includes proposed benchmarks for all those organizations that respond to disasters such as the Asian tsunami. These process and impact benchmarks include "access and coverage of population in need" (e.g., internally displaced persons) (Adinolfi et al., 2005, p. 16).

US Agency for International Development - Field Operations Guide. This document contains an entire chapter on the information that is required by disaster decision-makers about populations at risk, which includes mostly displaced persons. There is also a chapter with information on the types of assessments performed by the US Agency for International Development, the elements of those types of assessments, as well as the actual checklists that are used to perform those assessments.

The chapter on populations at risk, to include displaced persons, clearly shows the US Agency for International Development's focus on displaced persons as part of disaster response. In addition to the inherent need for information about the location of displace persons, their condition in regard to "the general condition of the affected population, the immediately available resources (e.g., unfamiliar food may have to be used if nothing else can be found), and the normal customs of the affected population" (US Agency for International Development, 2005, p. III–6).

The information on assessments and the checklists used to perform those assessments closely corroborates this theme in regard to the condition of displaced persons. This guide provides assessment checklists that prompt disaster assessment teams to look for comprehensive information about the demographics of displaced persons, as well as their ability to access food, their levels of nutrition, their health, and their access to water, sanitation and shelter.

Corroboration of Theme: Current Information about Conditions in the Disaster Area is Required

Response Targeting Theme, *Current Information about Conditions in the Disaster Area is Required*, is generally referring to situational awareness by disaster decision-makers, about their operational environment. This theme is corroborated by the following documents and archives.

Pacific Disaster Center Tsunami Notes. The PDC deployed team reported in internal emails to its headquarters that the primary request of their team during the first two week on the ground in support of the recovery effort was for satellite imagery, either legacy or newly flown after the disaster had happened. This satellite image was used to supporting mapping requirements, both for pre-existing facilities as well as information about their post-tsunami conditions. This imagery was also used to support relief-related analysis, to include analysis of transportation related facilities for use during relief efforts.

Another interesting aspect notation in this document is the reference to classified imagery. During the course of the disaster response, imagery was reported by this document to be available through United States national intelligence systems much sooner than commercial systems. However, because of security classification issues, it appears that this imagery was not generally releasable to all the other responding participants.

United Nations - Global Symposium +5 on Information for Humanitarian Action - Final Report. Based on assessments for tsunami response performance, this symposium, which focused on disaster information, found that Common Situational Analysis was essential for evidence-based decision-making during a disaster response.

In addition to a general recognition for the need for information about the disaster area, the symposium recognized the need for a common approach to gathering that information, one that would assist decision-makers in interpreting the situation. The symposium recommended the development and use of a Field Assessment Summary Template, specifically:

> Develop a one-page FAST to be completed for each field assessment by collaborating UN, NGO, government and/or academic organizations. The FAST should be a simple and brief format to describe the assessment's methodology, key findings and detailed (geo-referenced) location of assessed areas. This will address OCHA's role of managing a survey of surveys, in an effort to reduce duplication and overassessment. (Haggarty, 2008, p. 10)

In support of developing situational awareness capabilities within the disaster response community, the symposium noted that:

> Visualization is an effective strategic information technique for representing complex data and information, displaying patterns, trends and relationships, and depicting a common situational awareness. In this

regard, satellite-imagery-derived analysis and GIS are valuable tools to support humanitarian action. (Haggarty, 2008, p. 17)

US Agency for International Development - Annual Report Fiscal Year 2005 Office of U.S. Foreign Disaster Assistance. In the report that includes the US Agency for International Development's response to the Asian tsunami of 2004, there are many instances where this theme's stated ideas are corroborated. In a summary presentation about the tsunami response, the report makes clear that the US Agency for International Development used its awareness of the situation on the ground in order to make decisions about resource allocation. For example, the US Agency for International Development "placed top priority on the provision of safe drinking water and sanitation facilities due to the large number of displaced people living in conditions without these essentials" (US Agency for International Development, 2006, p. 19).

United Nations - Regional Workshop(s) on Lessons Learned and Best Practices in the Response to the Indian Ocean Tsunami – Indonesia, Sri Lanka, Thailand, Maldives. These workshops provided a set of short observations about a variety of tsunami response topics, to include discussions about the impact of situational awareness and knowledge about conditions on the ground.

In Sri Lanka, the following was noted:

1. Prior to the tsunami, there were no mechanisms for "sharing awareness among organizations and institutions" (p. 12).

2. In light of this, a recommendation was made to "have stand-by pre-disaster information collection and maintenance mechanism in place" (United Nations Development Program [Sri Lanka], 2005, p. 19).

In Indonesia, it was noted that one of the causes for the lack of situational awareness during the disaster response was the lack of a commonly used and efficient method for field officials and teams to assess and report what they had found. As such, this report recommends the "improvement of methodology (incl. using common format) in conducting sectoral assessments, lack of understanding the importance of framework" (p. xi). In another section of the report there is a recommendation to "set up system that allows access to common needs/services/resources/ information, assets" (United Nations Development Program [Indonesia], 2005, p. xii).

In Maldives, the following was noted:

1. The development of a disaster management plan is essential. One of the key components of the disaster plan is the development of "an information management plan and system" (p. 5) that can provide the type of situational awareness required by disaster decision-makers to do their jobs properly.

2. There was an "absence of coordinated assessment and unclear targeting of communities has led to a lack of clarity about what kinds of relief assistance were needed by whom and what was not" (p. 7).

3. "Disaster and damage assessments must be better coordinated and communities more clearly targeted" (United Nations Development Program [Maldives], 2005, p. 9)

US Agency for International Development - Field Operations Guide. This operating guide presents many corroborating illustrations of how information about the disaster is important to decision-makers within the US Agency for International Development. The preponderance of the document gives guidance on managing the assessments and disaster area information that are important for managing disasters.

Assessments are explained in the second chapter of this document as being central to both preparation for and response to disasters. Detailed information is provided as to what is expected to be in an assessment, how the information is to be collected, and what the disposition of the contents of the assessment is supposed to be. This includes:

1. "information on the purpose, types, and elements of an assessment" (p. II-2).

2. "collecting and analyzing data; preparing recommendations for U.S. Government (USG) response and submitting assessment reports to … Washington" (p. II-2)

3. "It also provides basic assessment checklists by sector" (US Agency for International Development, 2005, p. II-2).

In the third chapter of this document, the information on affected populations that is required by the US Agency for International Development disaster decision-makers is presented. Specifically, this chapter provides "reference information for dealing with populations that are at risk" (US Agency for International Development, 2005, p. III-2). Part of this chapter includes definitions, terms and other proper uses of lexicon in a disaster response.

In Appendix E, the guidelines for Location Referencing and Mapping Resources provide field team members a "basic reference to assist in that (assessment) effort and provides guidance on references and resources available to assist field teams with geographic information including, but not limited to, maps, satellite imagery, and locations of humanitarian points of interest" (US Agency for International Development, 2005, p. E-2).

United Nations Office for the Coordination of Humanitarian Affairs - Disaster Preparedness for Effective Response: Guidance and Indicator Package for Implementing Priority Five of the Hyogo Framework. This complex document provides several instances of corroboration with this theme. In one instance, the guide notes in a section discussing emergency services:

> In many cases, much of the loss of life during a hazard event occurs in the first 24-48 hours. Maximising the speed and efficiency of the response effort, and particularly of search and rescue teams, in this initial phase is critical. As specialised search-and-rescue and medical teams are limited and costly resources that will likely be in high demand during the first hours of an emergency, it is essential that their movements are well coordinated to make sure they reach those in greatest need. (UN/ISDR & UN/OCHA, 2008, p. 33)

Corroboration of Theme: All Decision-Making Methods Have Similar Data Requirements

Response Targeting Theme, *All Decision-Making Methods Have Similar Data Requirements*, is difficult to corroborate directly, as the potentially corroborating documents do not necessarily provide information as to how the organizations described make decisions. However, there is enough information about data being used to establish a link to the three key sets of information needed by disaster decision-makers: location and condition of affected populations and displaced persons, conditions on the ground, and resource locations. The following documents and archives provide corroboration for this theme.

Pacific Disaster Center Tsunami Notes. In this archive, the PDC team on the ground observed that no matter whom the supported organization is and what their activities are, their information requirements are essentially the same. They need:

1. Location and condition of affected populations and displaced persons.
2. Conditions on the ground (not just physical conditions, but political and security conditions, too.)
3. Resource locations. (Pacific Disaster Center, 2008)

The PDC team noted that this information was not forthcoming for many reasons, two of which are information release policy, as well as availability. Regardless, the needs for information across all types of organization appear to be very similar.

United Nations Children's Fund - The 2004 Indian Ocean Tsunami Disaster Evaluation of UNICEF's Response (Emergency and Initial Recovery Phase) - Synthesis Report. UNICEF, as an organization specialized in providing relief to children, makes decisions with a focus and bias as such. Even with a bias, UNICEF seeks out and uses the same three key sets of information that most others do: location and condition of affected populations and displaced persons, conditions on the ground, and resource locations.

In regards to affected populations and displaced persons, UNICEF documented in this report about the necessity for having this information in order to properly response to the disaster. This report noted in the particular case of Indonesia that:

> Generally UNICEF, in collaboration with governments and other agencies, was able to meet the needs of the majority of children in the affected population groups, particularly where it had good preexisting relationships with governmental and nongovernmental agencies and a network of established field offices. The report notes that UNICEF, in common with other humanitarian agencies, should have paid more attention to internally displaced persons (IDPs) and host families in Indonesia on the east coast of Aceh and IDPs and host families in general. (Wiles & Sida, 2007, p. iii)

In addition to describing this shortfall, this report described a potential reason for this shortfall – a lack of situational awareness about affected populations:

In Indonesia, assessments by all agencies were constrained at the start by the difficult operating context. All organizations, including UNICEF, "were operating without accurate numbers of affected people and their locations. UNICEF's monitoring systems could not provide definitive information on the numbers of affected persons assisted or the allocation of expenditure between programme and overhead expenditure" (Wiles & Sida, 2007, p. 3).

In response to this identified shortcomings, UNICEF determined that the following recommendations need to be fulfilled in order to better respond to the information deficit:

1. Deploy rapid assessment teams with standardized tools and methods; Continue to standardize assessment methods for each sector/area and ensure that training support is provided; Develop rapid regional assessment capacity using sector specialists.

2. Develop a system for rapidly providing affected communities with information about UNICEF's activities, intentions and available resources with regular updates (Wiles & Sida, 2007, p. 49).

In regard to resource locations, UNICEF noted that resource location information was essential to some of its successes, as well as being a primary contributor to some of its shortcomings:

> One area where UNICEF has been successful in terms of efficiency is in the use of local solutions. This works on two fronts: it increases the appropriateness of programmes (and thus makes them more likely to achieve outcomes) and often reduces cost. In Sri Lanka, UNICEF designed local *gully suckers* (machines to empty pit latrines), saving considerably on expensive imports. Here as in other examples, UNICEF

> appropriately achieved a balance between speed and cost – initially importing some high-cost machines whilst the low-cost local solutions were designed and built. Local school kits in Indonesia, temporary schools in Sri Lanka and widespread use of local partners where possible are other good examples of this approach. Sometimes this was not the case – in the Maldives UNICEF flew in reverse osmosis water purification units (ROWPU), which were subsequently not used, or used only sporadically in the following weeks. The cost of the air-freight was not justified in relation to the outcome. (Wiles & Sida, 2007, p. 22)

These anecdotes, related through this report, provide ample corroboration for this theme's tenet that these three categories of data are used by types of decision-makers identified in this research.

United Nations - Global Symposium +5 on Information for Humanitarian Action - Final Report. This report produced two recommendations that are significant in regard to the discussion of similar data requirements. One of the recommendations is for the development of a common situational analysis template for disaster responders. This recommendation stated that this should be developed "in consultation with stakeholders and taking into account existing tools for application in forthcoming emergencies to provide key evidence-based information to decision makers to further humanitarian action, performance benchmarking and accountability" (Haggarty, 2008, p. 8).

Furthering this theme, this report recommended the development of a Common Humanitarian Classification System:

> Develop the concept of a common, multi-sectoral humanitarian classification system, building upon the Integrated Food Security and Humanitarian Phase Classification Scheme (IPC), but explicitly including analysis of other humanitarian sectors and indicators. The CHCS would form a platform where different information systems and assessments are linked together and analyzed with the aim to inform decision makers on the degree of severity of crises. (Haggarty, 2008, p. 8)

The implementation of these recommendations would directly support the acquisition of the appropriate data during a disaster response. In this report, John Holmes summarized the need for these three types of information:

> I am delighted to have this opportunity to give you all something of my own perspective in the role of information and knowledge management in the better provision of humanitarian relief...What I have learned in my first months is that while some facts are obvious – the flood, the earthquake, the conflict, the exodus of refugees and IDPs – and some consequences are all too visible – death, destruction, despair – as soon as you start to dig deeper you run into the central and glaring need for really good information and really good analysis. In other words: decent knowledge. Without that you can't really get off first base. You don't know what people really need or where or how urgently. You can't make sensible decisions about priorities – whether within or between emergencies. (Haggarty, 2008, p. 41)

United Nations - Regional Workshop(s) on Lessons Learned and Best Practices in the Response to the Indian Ocean Tsunami – Indonesia, Sri Lanka, Thailand, Maldives. These workshops all reported a shortfall in the capability to identify needs during the disaster response. In the Sri Lanka workshop, the following recommendations were made by the participants:

1. Explore the establishment of a regional disaster coordination mechanism, to share lessons and resources regionally.

2. Identify potential buffer stocks and resources that can be drawn on.

3. Have stand-by pre-disaster information collection and maintenance mechanism in place.

4. Carry out decentralized mapping of available resources.

5. Evaluate what each agency can offer in case of disasters; maintain and regularly update this information within the main coordination body at the central and district levels. (United Nations Development Program [Sri Lanka], 2005, p. 19)

These recommendations support and corroborate the use of the three types of information by disaster decision-makers.

In the Thailand workshop, it was noted that there was a general need to improve the utilization of resources and management of contributions. The participants at the Thailand workshop were clear that the lack of visibility on where relief supplies were impeded effective disaster decision-making (United Nations Development Program [Thailand], 2005).

The Indonesian workshop revealed that the responders there was adequate information (of the three types of information discussed previously in this theme), specifically that the "assessment provided sufficient information to implement response;" however, "access to up-to-date information, assessments, and centralized data from a variety of sources" needed to be improved" (United Nations Development Program [Indonesia], 2005, p. ii). The workshop also recorded that there was a general need to better record the location and disposition of internally displaced persons.

The report of the Maldives workshop showed that this theme is corroborated in their findings. They report that:

1. The absence of coordinated assessment and unclear targeting of communities has led to a lack of clarity about what kinds of relief assistance were needed by whom and what was not.

2. The 'thematic approach' (provision of specific kinds of assistance) applied by some donors led to a mismatch between demand and supply in some sectors.

3. In some cases, conflicting information was collected by donor and government agencies.

4. There was no coordination among individual donor and international agency personnel visiting islands during assessment procedures. The same kinds of questions were repeatedly asked. Some of these personnel made commitments to local communities that have, thus far, not led to a lot of

recognizable actions at least from the perspective of many IDPs. (United Nations Development Program [Maldives], 2005, p. 7)

US Agency for International Development - Field Operations Guide. This document, as the primary for US Government officials who respond to foreign disasters, is clear as to what information is required to support disaster decision-making. For initial assessments, the information to be gathered is categorized by US Agency for International Development into two types of information:

1. What has happened as a result of the disaster.

2. What is needed to save lives, alleviate suffering, and mitigate negative economic impacts.

This includes identifying populations that need assistance, identifying available resources, and determining what requires more in-depth assessments (US Agency for International Development, 2005).

Corroboration of Theme: In the Absence of Current Data, a Predictive Model is Useful

Response Targeting Theme, *In the Absence of Current Data, a Predictive Model of Required Information Would Be Useful*, is corroborated by the following documents and archives.

Pacific Disaster Center Tsunami Notes. In a situational report e-mail, the PDC team noted that there were several areas of concern where no data sets were available and that a predictive model would be useful. As with most disasters where both public health and sanitation systems break down, there was a need for predictive modeling of what diseases would likely emerge and when they would emerge. These diseases include mosquito-borne and other vector-borne illnesses, such as malaria, but also include water-borne illnesses such as typhus and cholera. Predicating the locations of outbreaks would, in the absence of actual ground data (as was the case during the early phases of tsunami response) be immensely valuable to disaster decision-makers in regards to allocating resources.

Another model that the PDC noted would be useful was that for appropriately locating displaced persons camps. There camps have requirements and considerations that are amenable to using geospatial technologies to analyze and predict the best locations. These considerations include proximity to transportation networks as well as the adequacy of available water supply. The ability to narrow camp locations allows disaster decision-makers to focus efforts on locations that have the best possibly for successful camp development and operation.

US Government Accountability Office - U.S. Tsunami Preparedness: Federal and State Partners Collaborate to Help Communities Reduce Potential Impacts, but Significant Challenges Remain. As previously related, it can be difficult for disaster decision-makers to know what the conditions are in a tsunami-affected area. However, it is possible to use software, geospatial data and hydrographic data to estimate the impact of any given tsunami event. This is exactly what the GAO noted in this report when it recommended that the US National Oceanographic and Atmospheric Administration develop a software modeling software of performing this function. As one of the four recommendations made by the GAO, the use of predictive modeling software can be useful for decision-makers in the early stages of disasters when little or no information is available about the extent of the disaster.

Corroboration of Theme: The Most Effective Relationships with External Supporting Organizations are Already be in Place When the Disaster Occurs

Coordination Theme, *Relationships with External Supporting Organizations Must Already be in Place*, is corroborated by the following documents and archives.

Pacific Disaster Center Tsunami Notes. The PDC team noted several instances where the lack of coordination with other organizations severely impeded their ability to provided support for disaster decision-makers. In one instance, a geospatial-related organization within a particular country in the response area would not share geospatial data with the PDC team on the ground. Therefore, instead of efforts being made to provide useful information to disaster decision-makers, the PDC team spent time trying to secure access to already existing information that could be used to support those efforts. The reasons for this are unclear, but regardless, an existing relationship with this entity would have eliminated all surprises in this regard. The PDC team noted that similar, if not so severe issues existed with US government organizations (which is particularly interesting know that the PDC is a US government sponsored organization). The PDC personnel appear to have been expected that the US organizations would have been more coordinated than they were.

US Government Accountability Office - U.S. Tsunami Preparedness: Federal and State Partners Collaborate to Help Communities Reduce Potential Impacts, but Significant Challenges Remain. This GAO noted that relationships are very important for proper response to disasters, and particularly tsunamis. They noted that:

> Prior to the Indian Ocean tsunami in December 2004, NOAA's various tsunami-related activities, such as warning center operations, the TsunamiReady program, and tsunami-related research, were not managed as a formal, integrated program. NOAA combined the activities in 2005 into a single program and is currently strengthening and expanding certain elements of the program. However, NOAA has not yet adopted a comprehensive, risk-based strategic plan to guide its expanded tsunami program into the future. (Mittal, 2006, p. 8)

Additionally, this need for prior coordination was reflected in the recommendation by the GAO for NOAA to develop a comprehensive, strategic plan that "help(s) agencies set specific program goals and objectives, define(s) performance measures for assessing program effectiveness, ensure(s) coordination of existing activities and establish(s) risk-based priorities" (Mittal, 2006, p. 8).

United Nations Development Program - The Post-Tsunami Recovery in the Indian Ocean: Lessons Learned, Successes, Challenges and Future Action. This reported noted that, as with all disasters, coordination remains a challenge. Specifically for this tsunami, the magnitude of the disaster had correlation to the magnitude of number of responders. Many new players (besides those who normally operated in the Indian Ocean region) joined into the response effort, and the report mentions "much attention will need to be placed on extending coordination arrangements with new partners" (United Nations Development Program, 2005, p. 3).

United Nations Children's Fund - The 2004 Indian Ocean Tsunami Disaster Evaluation of UNICEF's Response (Emergency and Initial Recovery Phase) - Synthesis Report. In this report, UNICEF explicitly describes the benefits of relationships that preceded the tsunami. Comments within the report include:

1. "Generally, UNICEF was able to respond well using its pre-existing partnerships with governments."

2. "The partnerships with local NGOs worked best where there were pre-existing relationships and were less successful where UNICEF worked with smaller and newer NGOs after the emergency, essentially as contractors."

3. "UNICEF played an important and meaningful role in all the countries where it responded, particularly when it drew on its pre-existing relationships with governments and other partners" (Wiles & Sida, 2007, p. iv).

United Nations - Regional Workshop(s) on Lessons Learned and Best Practices in the Response to the Indian Ocean Tsunami – Indonesia, Sri Lanka, Thailand, Maldives. These workshops revealed that the practitioners on the ground recognized the importance of pre-existing relationships. In Sri Lanka, there was an existing relationship between the National Disaster Management Centre and UN disaster relief organizations. A positive result of this was recognized in that "pre-existing dialogue and cooperation between UN agencies and NDMC proved to be critical and indispensable in the first 8 weeks" and, in fact was "indispensable" particularly in regard to the magnitude of the disaster (United Nations Development Program [Sri Lanka], 2005, p. 7). In Indonesia, the impact of weak relationships was acknowledged in a discussion of coordination. It was accepted that "existing inter-agency coordination arrangements should be further strengthened, particularly concerning the sharing of information in the early phases of disaster response" (United Nations Development Program [Indonesia], 2005, p. 5).

Corroboration of Theme: The Internet is an Important GIS Data Distribution Tool during Disaster Response

Coordination Theme, *The Internet is an Important GIS Data Distribution Tool during Disaster Response*, is corroborated both generally (about sharing information) and specifically (about using the internet to share geospatial information) in the following documents and archives.

Pacific Disaster Center Tsunami Notes. The PDC document notes that a positive bias existed for the use of the internet and its status as a key enabler for disaster relief efforts. They expressed a need for internet access in order to function properly, for both sending and receiving data and information. Data from existing sited posted to the internet provided much needed geospatial data in the absence of new data. The PDC team specifically noted that the use of the internet to deliver data via web-based applications was severely inhibited by the lack of adequate internet capacity.

United Nations - Global Symposium +5 on Information for Humanitarian Action - Final Report. During this symposium, the concept of using the internet to communicate geographic information was shown to be under investigation by several disaster relief organizations. Additionally, the World Wide Web was discussed as a collaboration tool for the use, maintenance and distribution of geospatial data. In this report, the authors concluded:

> Geographic information and mapping at all phases of humanitarian action have advanced significantly. Web-based mapping tools, such as Google Earth, have opened map-making to the larger public, and enhanced access to satellite imagery has provided a window for information on vulnerable populations in remote areas. The NGO community in particular is designing initiatives looking to the future, Humaninet's "Maps 2.0" initiative is building a community of practice for NGO GIS experts, and OneWorld has developed OneClimate.net, using Web 2.0-based space aimed at tackling climate change. (Haggarty, 2008, p. 28)

Two other organizations are recognized by the symposium for their pioneering web-based geospatial work. The United Nations Geographic Information Working Group has taken the lead in establishing the UN Spatial Data Infrastructure Project, which has a significant focus on use of the web. Additionally, the UN Institute for Training and Research Operational Satellite Applications Programme (UNOSAT) beginning to use the internet to provide "enhanced access to satellite imagery and Geographic Information System (GIS) services and products, for humanitarian relief, disaster prevention and post crisis reconstruction" (Haggarty, 2008, p. 28).

United Nations - Regional Workshop(s) on Lessons Learned and Best Practices in the Response to the Indian Ocean Tsunami – Indonesia, Sri Lanka, Thailand, Maldives. During the final workshop that was attended by responders from all the affected countries, one of the lessons learned recorded was that there was a general need for improved information sharing. This need included "information about ongoing and planned programmes among all actors, and the dissemination of information about the relief operation to the affected populations." (United Nations Development Program [Summary], 2005, p. 4). There were several mechanisms recommended for improving this communication, to include systems to be developed by the UN, national military and police forces, as well as non-governmental organizations acting independently or as part of regional networks (United Nations Development Program [Summary], 2005, p. 4).

Corroboration of Theme: Current Information about Resources Available in the Disaster Area Supports Better Decision-Making

This theme provides insight into resource information being a key enabler for disaster decision-making. The Resource Mapping Theme, *Current Information about Resources Available in the Disaster Area Supports Better Decision-Making*, is corroborated by the following documents and archives.

Pacific Disaster Center Tsunami Notes. The PDC team noted in its archive that the need for information about where resources were (no matter what the controlling organization was) very important. However, the team also noted that information about the accessibility of those resources is also important. The team noted that geospatial information about "supply routes, hospital locations, Displaced Persons camps, helicopter landing zones, hospital locations, etc." (p. 4). were needed but not regularly available during their response support for the tsunami. Current information is required in order to effectively plan for the use of those resources.

United Nations Children's Fund - The 2004 Indian Ocean Tsunami Disaster Evaluation of UNICEF's Response (Emergency and Initial Recovery Phase) - Synthesis Report. UNICEF's response to the tsunami was recognized both within the organization as well as externally as one of the best. Much of this success has to do with the robustness of UNICEF as an organization, and that it has dedicated specialists such as logisticians. However, UNICEF did note in this assessment that there were areas for improvement of supply management. Specifically, the report notes that the management of pre-positioned stocks requires further refinement. The report details that the initial response of UNICEF's supply chain was excellent, but that during the course of the response the supply chain slowed down significantly enough to hamper effective and timely response. The health and nutrition program's "effectiveness ... was challenged" by "delays in ... supply delivery" and "poor field monitoring" (p. 100). Significantly, the report noted a cumulative and compounding effect of lack of awareness of resources locations:

> After the first six weeks, UNICEF's response slowed considerably, due to complex procedures, bureaucracy and operational issues... For example, in Sri Lanka hygiene kits were delivered late and thus after other organisations had distributed such items, toilets were built weeks after homes had been constructed and, in one case, a play area was approved for a camp that no longer existed. (Wiles & Sida, 2007, p. iii)

United Nations - Regional Workshop(s) on Lessons Learned and Best Practices in the Response to the Indian Ocean Tsunami – Indonesia, Sri Lanka, Thailand, Maldives. These workshops produced some of the widest varieties of lessons' learned and recommendations of all the corroborating documents. From Sri Lanka, these include:

1. A general recommendation that all resources necessary to respond to a disaster be mapped.

2. "Identify potential buffer stocks & resources that can be drawn on (e.g. food through WFP)."

3. "Carry out decentralised mapping of available resources" (United Nations Development Program [Sri Lanka], 2005, p. 19).

In Indonesia, the workshop revealed that logistics and prioritization needs to be improved (United Nations Development Program [Indonesia], 2005).

In the Maldives, the workshop produced several lessons and recommendations, to include:

1. "Disaster response efforts must be managed to assure a match between demand and supply of relief items" (p. 8).

2. “A general list needs to be compiled of the kinds of supplies that are needed and those that are not needed in an emergency” (p. 8).

3. “Aid contributions must be properly documented. A formalized system needs to be put in place to manage the influx of donor representatives who arrive to provide assistance to the country. Linked to this is the need for greater coordination between line ministries, the National Disaster Management Committee and international donors” (United Nations Development Program [Maldives], 2005, p. 9).

In the general workshop that was conducted after all of the country specific workshops were conducted, it was recommended that:

> As part of the national preparedness plan, governments should ensure that emergency supplies can be readily made available to disaster-stricken areas. This may include the setup of emergency stockpiles, the analysis of procurement options where commodities are available on the local markets, or the mapping out of already existing resources. (United Nations Development Program [Summary], 2005, p. 4)

Additionally:

> A regional contingency plan should be developed, which would map out existing stockpiles of relief supplies and procurement options, spell out mechanisms for the deployment of experienced personnel for assessment and early relief, and establish systems for sharing logistics capacities and emergency telecommunications. (United Nations Development Program [Summary], 2005, p. 7)

United Nations - Humanitarian Response Review. In discussing its world-wide review of disaster responses, the authors of this review recognized the importance of understanding resource logistics issues. In considering the issue of stockpiles of supplies, the UN discerned that:

> A fundamental problem exists in the lack of a global stock positioning system. This applies to quantity, quality, geographical location, and ownership. Given the difficulty in determining actual figures experienced by the review team, it is clear that this would be impossible during an emergency. One result has, in all likelihood, been a number of unnecessary and costly moving of goods based on incomplete and less than timely information. (Adinolfi et al., 2005, p. 41)

This recognized shortfall corroborates this theme as noted by the interview participants.

United Nations Office for the Coordination of Humanitarian Affairs - Disaster Preparedness for Effective Response: Guidance and Indicator Package for Implementing Priority Five of the Hyogo Framework. This guidance clearly describes the necessary actions for improving disaster response as part of the Hyogo Framework. The UN has recognized that proper management and situation awareness of relief supplies is essential to effective disaster response. The UN describes the requirement as such:

> The contingency planning process should lead to the development of systems to track both the likely needs and actual availability of essential goods, services and human resources that could be immediately deployed

> in an emergency, (for example, medical resources, food, water, emergency shelter, body bags and other materials; and human resources including search and rescue, communication, engineering etc. that are immediately deployable for a given scenario). These systems should track not only Government resources, but also those of other organisations, such as the Red Cross/Red Crescent, UN organisations or others that may be in the country and earmarked for response. This information should be immediately available to those coordinating responses, and staff must be trained and able to update them regularly during a response. (UN/ISDR & UN/OCHA, 2008, p. 33)

Summary of Corroborating Evidence

As presented, each of the themes observed from the interview responses is corroborated by evidence found within operational documents of world-class relief organizations. Each piece of corroborating evidence supports the contention that these themes feature valid observations from disaster responders who observed the use of geospatial technologies to respond to the Asian Tsunami of 2004. As such, they corroborate the emergent themes and provide an answer to the research question: *What happened when geospatial information was used to support disaster decision-making during the humanitarian response to Asian Tsunami of 2004?* Based on the research conducted here, these themes provide answer to that and further address the theoretical proposition: *there is common, best practice use of GIS that best supports disaster management decision making.*

Uncorroborated Theme

There is one theme that is not corroborated and therefore is not included in the final set of themes for this dissertation.

Disaster Decision Makers Are Prepared to Share Geospatial Data. This theme was identified based on one of the interview questions (Does your organization have a data distribution policy?) Several interviewees noted that their organization had data distribution policies that support the sharing of data. Additionally, they stated that this function was necessary for the smooth operation of GISs as part of disaster relief. There were, however, no documents that supported this contention as it is. Thus uncorroborated, this theme does not carry forward in this dissertation.

Ratings of Theme Corroborations

By the nature of this study, each of the emergent themes must be evaluated separately as far as the strength of proofs provided as part of corroboration. Additionally, the strength of this dissertation's validity is directly tied to the evidence that supports the themes the emerged during the conduct of interviews. This section evaluates each theme's corroborating evidence and provides an overall rating of 1, 2 or 3 to each set of evidence, with 1 being the strongest rating. This rating is based on a relative comparison of evidence provided to support each theme. This section also reviews the number of documents that evidence was found within. Within each supporting document, the amount of evidence provided to support each theme is rated as 1, 2, or 3, with 1 being the strongest rating. Finally, each document is given a credibility rating of 1, 2 or 3, with 1 being the strongest. The credibility rating is based on the relative credibility of the document compared to the other documents used to substantiate each theme. The credibility of the document is related to the formality of its publication process. An unpublished document that inherently has not been through a review and editing process is held to be less credible than a document that has been formally published.

Preparation is Essential for Organizational Effectiveness during Disaster Response:

1. Overall corroboration rating: 1.
2. Number of document in which evidence was found: 10 of the 16.
3. Amount of evidence found in corroborating documents: 1.
4. Credibility of evidence: 1.

This is the most strongly corroborated among the themes that emerged from the interviews. Substantiated by a broad spectrum of documents, organizational preparedness is clearly a pervasive problem among disaster relief organizations. At the highest levels of United States Government, at various levels of the United Nations, and on the ground, the issue of organizational preparedness is undoubtedly present with all disaster response organizations.

Current Information about Affected Populations and Displaced Persons is Critical to Effective Disaster Response:

1. Overall corroboration rating: 1.
2. Number of document in which evidence was found: 7 of the 16.
3. Amount of evidence found in corroborating documents: 1.

4. Credibility of evidence: 1.

Second only to organizational preparedness theme, this theme has very strong corroboration in the same ways of that theme's corroboration. On the ground, the responders from the Pacific Disaster Center were clear in their recognition of need regarding information about displaced persons. UNICEF and other UN organization were unambiguous – find out what the status of the affected population is. The Office of US Foreign Assistance reported in its after action reviews that its top priorities are displaced persons, and the US Agency for International Development put so much interest in this theme that there is an entire chapter in its field operating guide devoted to the information that is required by disaster decision-makers.

Current Information about Conditions in the Disaster Area is Required:

1. Corroboration rating: 2.
2. Number of document in which evidence was found: 6 of the 16.
3. Amount of evidence found in corroborating documents: 1.
4. Credibility of evidence: 2.

In comparison to other themes, the evidence presents an average amount of corroboration for this theme. Much of the discussion regarding this theme concerns the use of satellite imagery. While many of the documents that support this theme are formally published, much of the supporting documentation comes from a set of regional workshops that are a collection of anecdotes from disaster relief participants. While valuable, these anecdotes are not as credible as the information found in other, formally published documents.

All Decision-Making Methods Have Similar Data Requirements:

1. Corroboration rating: 2.

2. Number of document in which evidence was found: 5 of the 16.

3. Amount of evidence found in corroborating documents: 1.

4. Credibility of evidence: 1.

While only a third of the documents in this dissertation were used to corroborate this theme, there is a depth of evidence from that limited set that provide substantive proof of the validity of this theme. This discussion includes direct, positive assessments regarding the observation that no matter the background or apparent methodology of the disaster decision-maker, they all require essentially the same sets of information to do their work. Additionally, the multiple sets of United Nations documents all recommend or otherwise annotate this need.

In the Absence of Current Data, a Predictive Model is Useful:

1. Corroboration rating: 3.

2. Number of document in which evidence was found: 2 of the 16.

3. Amount of evidence found in corroborating documents: 3.

4. Credibility of evidence: 2.

This theme has the least amount of evidence, yet still provides substantial arguments that support the interviewee's observations that a predictive model used by disaster decision makers provides a positive benefit during a disaster response. The on-the-ground reports by the Pacific Disaster Center team relates the clear need for some mechanism for providing information to disaster decision-makers when actual conditions on the ground are not know. This internal archive is backed up by a US Government Accountability Office that recommended that the National Oceanographic and Atmospheric Administration create a model that performs this function for tsunami response. As one of only four recommendations, this is a significant corroboration for this theme.

<u>The Most Effective Relationships with External Supporting Organizations are Already be in Place When the Disaster Occurs:</u>

1. Corroboration rating: 3.
2. Number of document in which evidence was found: 5 of the 16.
3. Amount of evidence found in corroborating documents: 2.
4. Credibility of evidence: 2.

The lack of coordination between organizations is obvious in any study of disaster response, and was noted by both the interviewees and the documents and archives that are used to provide proof of the validity of their observations. With a recognized rigorousness, the US Government Accountability Office revealed that the National Oceanic and Atmospheric Administration had recognized the lessons of the 2004 Asian Tsunami and incorporated the lesson of a need for existing coordination and relationships into its new strategic plan. While not as robust, the evidence provided by the United Nations' organizations supports this contention with their observations of the same phenomena.

<u>The Internet is an Important GIS Data Distribution Tool during Disaster Response:</u>

1. Corroboration rating: 3.

2. Number of document in which evidence was found: 3 of the 16.

3. Amount of evidence found in corroborating documents: 3.

4. Credibility of evidence: 2.

This theme is a less corroborated than others, but is significant as an indicator of an emerging issue that may not yet be fully documented. The United Nation's documents presents that the use of the Internet for the distribution of geospatial information is under investigation. Most of these investigations are in the initial stages.

Current Information about Resources Available in the Disaster Area Supports Better Decision-Making:

1. Corroboration rating: 1.

2. Number of document in which evidence was found: 5 of the 16.

3. Amount of evidence found in corroborating documents: 1.

4. Credibility of evidence: 1.

Current information was identified by the United Nation's documents as an equally important set of information as information about the affected population. While not recognized in many of the evidentiary documents, the depth of information provided by those documents is sufficient to provide the highest rating of corroboration. Additionally, the scope of the documents (from on-the-ground to strategic) gives greater credence to evidence provided that supports interview statements regarding the importance of resource locations.

Conclusions on the Corroboration of Themes

In this chapter, corroborating documents and archives were introduced and described as to their pertinence to this dissertation. Initially, the sources of these documents and archives were shown to be viable and germane to the discussion found here. While the United Nations and its component organizations provide a significant amount of the documentation used for corroboration, several other organizations provide governmental context to the research by way of a variety of documentation.

As an important component of this triangulated research, these documents and archives provide substantiation to the themes that were observed in the interviews of disaster decision-makers. For each theme that was identified during the analysis of the results of the interview, there were multiple documents that provided substantiation to that particular theme. Thus triangulated, these documents confirm that the themes that emerged during the analysis of the interviews have a high level of validity and are of a quality that they will significantly contribute to the base of literature regarding this topic.

CHAPTER VII

MODEL OF DISASTER DECISION SUPPORT GIS

With the information revealed by this research, it is possible to design a geographic information system (GIS) that fulfills the needs presented by interviewees and corroborated by the documents of the most effective and influential disaster response organizations in the world. This logical design describes the functions and interrelationships of the basic elements of a GIS that, within the parameters of this research, provides the tools to best support disaster decision-making.

These functions are presented in the context of the themes previously addressed in this research; however, some of the themes do not directly contribute to the design of a GIS. The themes that do not pertain to the design of a GIS and thus are excluded from this model include the following:

- Preparation is Essential for Organizational Effectiveness during Disaster Response.
- All Decision-Making Methods Have Similar Data Requirements.
- The Most Effective Relationships with External Supporting Organizations are Already be in Place When the Disaster Occurs.

The data and functional design of this model corresponds to the themes revealed during the interviews of disaster responders and subsequently corroborated by the various documents previously described. Additionally, details about specific data types and functions are derived from the results of the interviews, as well as from the literature. The description of the data design of this model is organized by the functions that are necessary to fulfill the requirement presented by the theme.

It is important to note that the core functions of a GIS are not described in detail here. These include such functions as pattern, cluster and proximity analyzes, and measuring. These inherent functions are described previously in this dissertation and do not warrant subsequent discussion, except to note that they are inherently present in any GIS and thus are so here, too.

Functions

The results of this research suggest that there are three general functions that support disaster decision-making. These three functions support requirements found both within the disaster decision-making team as well as that team's external information consumers. These specified functions are in addition to the inherent functions of a GIS previously described in this document. Each of the following functions is described in the context of the pertinent themes that emerged from the interviews with the disaster decision makers.

Mapping

One of the key functions of a disaster decision-making GIS is the ability to produce maps of the area within the area of concern for the disaster decision-making team. The area of concern includes both the affected area as well as the areas surrounding the disaster affected that influence the affected areas. Within the function of mapping, there are two categories: general and thematic.

General mapping is the ability of the GIS to produce hardcopy and digital products that represent the surface of the earth. This type of mapping includes road maps, topographic maps, and other types of maps that are used generally for non-specialized purposes.

Thematic mapping is the graphic display of processed information about current and specific conditions, as well as specialized information, all in a map form. Typically, thematic maps are constructed by superimposing the thematic information onto a regular map. For example, in the case of a thematic map that shows current road conditions, a regular road map is used as the base. Superimposed on this hypothetical map would be roads that have different colors based on their condition status. In this way, a thematic map accentuates the concerned theme by emphasizing the information graphically that supports that theme. In addition, thematic maps display the results of any geospatial analyses. Thus, the thematic maps available via this function include (among others):

1. Displaced Persons Locations and Status.
2. Transportation Network Status.
3. Comparison of Pre- and Post- Tsunami Imagery.
4. Areas of Inundation by Tsunami Surge.
5. Digital Terrain Models.
6. Damage Assessments.
7. Population Densities.

The content of the map information can be distributed as a paper map or a digital file, with the potential to distribute the file in a variety of ways, to include e-mail and posting on an internet web page.

Modeling

Modeling is an important capability for the disaster GIS, as there are times when accurate information about actual conditions and effects in the disaster zone are unknown. The modeling functions for a tsunami response GIS must be able to predict conditions for the disaster decision-maker when not all required information is present. The types of models that fulfill this requirement include the following described below in two categories: disaster effects and operational support.

Disaster effects. Disaster effects are those conditions on the ground that are changed, either permanently or temporarily, by the impact of the disaster, this case being a tsunami. Disaster effect models include:

1. Tsunami Impact Prediction – The tsunami disaster response GIS evaluates weather and bathometric readings from point locations and produce an estimate of where and to what extent a tsunami has affected the shore. This includes the level of inundation and amount of time that water covered any particular point on land.

2. Tsunami Damage Prediction – Based on the impact location and extent of the disaster, this GIS predicts the level of damage to structures, infrastructure and the landscape.

3. Population Movement Prediction – Taking into account all known or predicted damage to the disaster area, the GIS predicts when where affected populations will move.

4. Disease Outbreak Prediction – With actual or predicted information on population locations, levels of inundation, climate and weather, the GIS will predict the time and areas that particular diseases will break out.

Operational support. In order to best support decision-making, the operational support models provide predictive assessments of the effects of disaster decision-making, giving the disaster decision maker the ability either to simulate a decision and a set of environmental conditions and see the impact, or let the GIS provide a recommended course of action.

1. "What if" Predictions – based on known variables, this model allows the disaster decision maker to change variables such as weather, security situation, use of different modes of transportation, as well as other variables, to determine a predicted outcome if those variables were actually in place.

2. Infrastructure Placement – based on the known or predicted information about the conditions on the ground and the affected populations, this model provides optimal locations for required infrastructure. This infrastructure can be either newly required construction, such as camps for displaced persons, or maximization of use of existing infrastructure, such as airfields.

3. Transportation Configuration – based on known or predicted conditions on the ground, the GIS will provide recommendations for what transportation routes should be used for any given purpose.

Collaboration, Coordination and Awareness

Providing a disaster decision maker a way of understanding a complex situation during a response to a disaster is an essential tool for this GIS and one of the most critical functions. A GIS provides a capability to track current events in the disaster area, apply information from modeling predictions, and make decisions with an awareness of all available information. It is important to note that each of these functions can be viewed in either an integrated or an isolated manner. The components of this function are described below:

1. Current Conditions – condition information about conditions on the ground can be displayed in a variety of ways. One example of conditions on the ground is displaying graphically the extent of where the land was inundated by the tsunami.

2. Resource Locations and Conditions– resources can include static and mobile items. Static resources include such things as buildings, while mobile resources can include food and water stockpiles, motorpools of available vehicles, and fuel.

3. Affected Population's Location and Conditions – this essential information provides a disaster decision maker with a location to focus resources and other efforts.

4. Assessment Information – this includes the locations of particular needs and damage.

5. Change Detection – show the location where changes have occurred to the landscape.

Data Required to Support Functions

This section addresses the data requirements for the implementation of this disaster decision support GIS model. Not only are the types of data addressed, but how the data is acquired or otherwise updated is included.

Base Map Information

The following are the categories of information that are used to provide the basic background information for the GIS:

1. Demography.
2. Ground Transportation Networks – roads, railroad tracks.
3. Overhead Imagery - satellite imagery or aerial photography with adequate resolution to be able discern most buildings and roads on the ground.
4. Critical Infrastructure – major facilities that are of local, regional or national importance, to include those related to transportation, energy and security.
5. Political divisions.
6. Major Land Use – parcels of land categorized by how they are used.
7. Hydrography.
8. Elevation.

This information is considered relatively static for the purposes of disaster response and should thus be acquired prior to a disaster.

Disaster Information

Disaster information is the information about the disaster that, by its very nature, must be collected after the onset of the disaster. This data is also dynamic in nature, so it must be regularly updated during the course of the disaster response. This data design is primarily based on the information required to support a USAID disaster assessment (USAID, 2006). The data types include:

1. Mass care locations.
2. Area affected by the disaster (location and size).
3. Number and location of people affected by the disaster.
4. Mortality and morbidity rates.
5. Types of injuries and illnesses.
6. Characteristics and condition of the affected population.
7. Groups within the population that may be disproportionately affected or require special attention.
8. Emergency medical, health, nutritional, water, and sanitation situation.
9. Level of continuing or emerging threats (natural/human-caused).
10. Damage to infrastructure and critical facilities.
11. Damage to homes and commercial buildings.
12. Damage to agriculture and food supply system.
13. Damage to economic resources and social organization.

14. Vulnerability of the population to continuing or expanding effects of the disaster over the coming weeks and months, and whether vulnerability varies among different groups.

15. Level of response by the affected country and internal capacities to cope with the situation.

16. Potential constraints or roadblocks to assistance efforts.

17. Level and nature of ongoing or anticipated response from other donor countries and PVOs/NGOs/IOs.

In order to support the acquisition of this data, the GIS is enabled to accept data in a variety of ways, to include:

1. User input from field locations using field devices, cell phones, or other similar devices.

2. Analyzed post-disaster satellite imagery or aerial photography.

3. Web-based user update of data.

Summary of Model

The preceding chapters of this dissertation have identified, defined and answered the principal research question: *What happened when geospatial information was used to support disaster decision-making during the humanitarian response to Asian Tsunami of 2004?* This chapter assimilates this information and proposes new theory based on that information in the form of a model. As qualitative research, this dissertation is also exploratory and confirms the research proposition; *there is a common, best practice for the use of GIS to support disaster management decision making.* This model is the description of how the pertinent themes that emerged from the corroborated research can be used as the foundation for a model of *this best practice.*

In describing the functions that they described as best practice, the interviewees provided robust description of what a GIS has to do in order to best fulfill the needs of disaster decision-makers. These functions, included in the logical design, provide robust description of the required activities of a GIS as well as the expected outputs of the activities. As GIS functions, the interviewees report that mapping; modeling disaster effects and operational support; and collaboration, coordination and awareness fulfill the needs of disaster decision support GIS.

In addition to defining the functions found in a best practice disaster support GIS, this chapter describes the data required to support those functions. Based on corroborated interview data, the data sets determined to be needed in order to support a disaster decision support GIS include base map data, as well as disaster information data. As a whole, these functions and data sets represent a logical design for a best practice GIS for supporting disaster decision-making.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

This dissertation examines a principal research question: *What happened when geospatial information was used to support disaster decision-making during the humanitarian response to Asian Tsunami of December 2004?* While investigating this dissertation's research proposition (that *there is a common, best practice for the use of GIS to support disaster management decision making*), this dissertation constructs a proposition that fulfills this dissertation's hypothesis: that the data collected via interviews of disaster decision-makers and examination of documentation and archives are sufficient to generate theory in the form of a model. The hypothesis is affirmed by a set of themes that emerged from the results of interviews of disaster decision-makers who participated in the response to the Asian tsunami of December 2004.

Literature

A review of the literature related to this research reveals that there has been some limited research into the topic using GIS to support disaster decision-making, and that the results of this research was being used in a practical manner in the field. The limited body of research on this dissertation's research topic generally supports the idea that GIS as a decision-support tool would be beneficial to disaster decision-makers if the system was appropriately designed, implemented and utilized. The limits of the literature prescribed the identification and analysis of corollaries of disaster response, during which pertinent literature was found to provide enhancing and correlating information as to how GIS could be expected to be used to support disaster decision-making. However, the literature is more purposeful in recommending that future research be conducted on how GIS is used by disaster decision-makers in order to more fully develop the theoretical foundation for the expanded use of GIS as a disaster decision-making support tool.

Theoretical Basis

The lack of directly pertinent literature is reflected in the dearth of available theories that directly support this research. However, two categories of theories emerged as pertinent and were examined in order to evaluate their applicability to this dissertation. In the first set of theories evaluated, this research considers typical methods for decision-making during disaster response in order to identify characteristics of those theories. These characteristics were used to develop the interview instrument so that the likely decision-making methodologies used by disaster decision-makers during the response to the Asian tsunami could be elicited during the interview phase of this research. In addition to being examined for identification purposes, the decision-making methodologies were appraised in order to determine what types of information each method would require in order to be effective. In the end, however, an evaluation of how each of the responding interview participants' organizations made decisions indentified no discernable difference in the geospatial information required by any of them to make decisions during the response to the tsunami.

Methodology

Based on an evaluation of the literature and available theoretical basis, the available methodologies for conducting this research narrowed considerably. As a little known phenomenon, the use of GIS to support disaster decision-making lends itself at this point in time to an exploratory method of research. An additional condition that prescribed a qualitative method of research was the nature of the data available (or lack thereof). No volumes of existing data presented themselves, thus driving the effort of this dissertation toward primary data collection. Given the nature of the research being conducted and the subjects of that research, a snap-shot case study was selected as the research strategy, with the initial data collection being interviews of subjects who participated in the response to the Asian tsunami. In order to mitigate bias and enhance validity, the results of the interviews were evaluated against corroborating evidence from the documents and archives of organizations that had also participated in the response to the tsunami.

Interviews

The interviews of disaster decision-makers who participated in the response to the Asian tsunami of 2004 revealed eight themes as to how disaster decision making took place during the disaster response to tsunami, what factors were important to effective decision making, and how geospatial technologies supported those efforts. Additionally, the disaster decision-makers were queried as to what they saw as the best practices for using GIS to support disaster decision-making, all within the context of their experiences responding to the tsunami. The responses to the interview questions provide an initial set of answers the research question by providing details as to what the 19 participants in this study observed as they fulfilled their disaster leadership duties during their response to the Asian tsunami of December 2004.

Emergent Themes

The interview participants observed that, during the response to the tsunami, the most effective disaster response teams were those that showed up to the disaster prepared to immediately begin operations, to include having the appropriate training, education, and equipment. In the context of GIS, this includes team-training, training and experience with GIS software on hand, and access to appropriate geospatial data.

In order to make the best decisions about providing relief, the interview participants observed that disaster decision-makers should have current information about where the populations that were affected by the tsunami are located, as well as information about their conditions. These populations include those who remained in place after the disaster, as well as those who migrated to locations other than their homes in order to seek safety and better living conditions.

In addition to information about the location and condition of affected populations, the interview participants reported that the conditions in the affected area are also important. Specifically, they said that satellite imagery or other types of overhead imagery gave indicators that supported better decisions about what resources were needed, where they might be needed, and how those resources would be transported to the appropriate location.

Not only is it important to know where the affected people are during a disaster response, it is important to know where the resources are that are going to be used to address problems caused by the disaster. During the tsunami response, interview participants observed that there were many times information about resources was lacking, which resulted in significant misallocations of critical relief supplies.

When current information is not available, the interview participants presented that models of the effects of the disaster would be useful in making decision. Models of all types and phenomena and behaviors would allow disaster decision-makers the ability to make intelligent estimates of the conditions on the ground, thus making a better decision.

Corroboration

As part of maximizing validity while answering the research question, this dissertation corroborates the observations of interview participants with data from multiple pertinent documents and archives from credible and recognized international organizations and national governments that participated in this particular disaster response. A collection of documents and archives was reviewed in the context of each theme. Evaluated in that context, each theme was found to be corroborated by multiple documents, this giving these findings significant validity. Thus corroborated and validated, the following themes are used to provide the basis for a GIS model that can be applied to other similar situations in the future:

1. Preparation is Essential for Organizational Effectiveness during Disaster Response.

2. Current Information about Affected Populations and Displaced Persons is Critical to Effective Disaster Response.

3. Current Information about Conditions in the Disaster Area is Required.

4. All Decision-Making Methods Have Similar Data Requirements.

5. In the Absence of Current Data, a Predictive Model is Useful.

6. The Most Effective Relationships with External Supporting Organizations are Already be in Place When the Disaster Occurs.

7. The Internet is an Important GIS Data Distribution Tool During Disaster Response.

8. Current Information about Resources Available in the Disaster Area Supports Better Decision-Making.

In all respects, and particularly in regard to the use of geospatial technologies, having cooperative relationships in place prior to a disaster response is essential for a disaster response organization to be effective. Interview participants imparted that dealing within existing relationships is difficult enough; trying to work effectively within new relationships is much more challenging. In regard to producing geospatial information, or otherwise sharing it, interview participants noted that the use of the internet has become an essential tool. The movement of large sets of data, particularly imagery, can provide decision-makers with data in a quick and responsive manner. In addition, the use of the internet to distribute finished products to other information users, with by e-mail or other means such as web-based mapped, magnifies the positive impact of those products.

Decision-Making

Decision-making during the response to a disaster is what geospatial information is intended to support, as data without purpose is intellectual. Certainly, there are limitations to the tool that is GIS in support of decision-making, as there is with any application you would find GIS supporting. The literature revealed several identifiable decision-making methodologies that support disaster. The literature, however, did not focus on information requirements for supporting those decision-making methodologies. So, each of the three (*recognition-primed*, *edge of chaos*, and *progression of multiple options*) were used as a filter to analyze the information requirements that interviewees determined were needed to support their efforts during the tsunami. The results of the analysis are that, no matter what each interviewee presented as their manner of decision-making, the information requirements were the same. Thus, the emergent themes are pertinent to, at least, disaster decision-makers who use any of those three models. One additional benefit of the use of GIS is to mitigate the negative effects in regards to coordination that some of the decision-making techniques incur (specifically, *progression of multiple options*). In all, decision-making methodologies as identified do not have significant impact on the outcome of the study.

Model

Based on the themes that emerged during the interviews, and were subsequently corroborated, a logical design for a model of a disaster decision support GIS emerged that can be considered a best practice based on the observations of the interview participants. This model addresses the functions that a disaster decision support GIS would require, as well as the data to support those functions.

The modeling function provides the ability for disaster decision-makers to predict events and outcomes when limited information is available. Modeling can be performed on natural phenomena, as well as those that have human inputs. The output of a model in a disaster situation can be used to make the best decisions about a likely state of events while there are still many unknowns. Information from models can enhance an organization's operational agility by allowing the organization to reliably predict and subsequently decide.

Collaboration, coordination and awareness functionality provides disaster decision-makers the capability to more readily understand and comprehend the situation surrounding the disaster to which they are responding. A common operational picture can be used to support the sharing of a shared mental model of the event. As described when discussing the theories of decision-making as well as the literature discussing lessons' learned, the lack of a shared mental model is significant impedance to multi-organizational responses to disasters. A common operating picture a significant capability that can mitigate that frequently observed phenomenon.

The mapping function is the most used function of any GIS, and provides graphic information about the disposition of all information, to include information provided by the two other essential functions of this model. Even though common and inherent to GIS functionality, mapping cannot be ignored. These functions are all supported by regular base map data (such as road data), as well as appropriate disaster related data.

Hypothesis Validity

The results of this research provide validity for this dissertation's hypothesis: that the data collected via interviews of disaster decision-makers and examination of documentation and archives will be sufficient to generate theory in the form of a model. The results of this study provided significant and robust enough information that is used to develop the previously described model. Logically and coherently developed, this body of research objectively provides the observations of people who participated in making decisions during the disaster response to the Asian tsunami of December 2004 as themes of observable phenomena.

Although acquired as part of a snapshot case study, these themes are corroborated by after action reviews, analyses and other documents prepared by organizations that participated in the response to the tsunami. Overwhelmingly, the emergent themes provide an expertly identified logical model that defines what a disaster decision support GIS should look like.

Contribution to the Literature

This dissertation provides an uncommon addition to the literature regarding the use of GIS to support disaster decision-making. It provides a model of GIS use that is directly tied to primary research findings from direct participants in a major disaster. This formal assessment of GIS performance in a field environment begins to fill the gap in the literature observed previously in this dissertation. Additionally, this research provides a consolidation of GIS-oriented concepts as oriented toward disaster-decision making. This dissertation also reveals information that is usually unavailable to the public, as it contains internal after action reviews and unpublished discussions. Taken as a whole, this dissertation provides a building block in the literature and is a significant contribution to the existing body of academic knowledge.

Future Research

While comprehensive in nature, there are several areas for future research into the use of geospatial technologies to support disaster decision-making that are revealed by this dissertation and should be considered as candidate research topics for future research. These potential research topics were not fully explored, as they exceeded the limits of the scope of this dissertation in regards to the development of a logical GIS model. However, they would provide significant contributions to the body of academic knowledge if explored.

Impact of inter-organizational relationships on the use of GIS to support disaster decision-making

One of the primary themes that emerged during this research was that existing inter-organizational relationships were much more effective in supporting any particular disaster decision making team's efforts. This theme was observed in the interview evidence, and was corroborated by pertinent documents. However, this dissertation did not definitively define the relationships on the details of how geospatial systems were specifically impacted by this observable trend. The uncovering of how this interaction works could be used to more effectively define inter-organizational relationships for organizations that respond to disasters.

Investigation into the reliability of distributed user-updated geospatial information.

An emerging trend in disaster decision-support GIS is the employment of end users to provide updates to a consolidated geospatial data repository, for the subsequent use of all other users who are responding to the same disaster. However, there are not clear metrics as to how often this is occurring, and when it does, how reliable this information is. Another question applies to the validation of data as it is input into the GIS: do vetting procedures exist and what other procedures can be used to ensure adequate quality control?

Observations and Final Comments

In this exploratory research into the use of GIS to support disaster decision-making during the response to the Asian tsunami of December 2004, the research proposition is validated: *there is a common, best practice for the* *use of GIS to support disaster management decision making.* These best practices, extracted from the field decision-makers and validated by substantiating documentation, are consolidated in a model that describes a design for a GIS that is the best available for supporting disaster decision-making. Although developed in the context of a tsunami response, this GIS model provides a basis for all disaster decision makers to use in establishing and operating a geospatial system in support of their operations, no matter what type. This dissertation represents the next step forward for disaster decision-makers, who can use this research to implement an effective disaster decision-support GIS without having to learn these lessons the hard way: through making mistakes that potentially cost lives and squandered resources. Ultimately, this allows for the best chance for those in need during a disaster to get the resources they need to survive, and ultimately recover from that disaster.

APPENDIX A

SELECT DEFINITIONS

As part of exploring the use of GIS during the resolution of disaster management, it is important to set a base of definitions. This refinement of terms makes some seemingly familiar terms become more appropriate for this problem.

Application. An application is the use of a GIS to solve problems, automate tasks, or generate information within a specific field of interest. For example, a GIS application that was used during the management of the attacks of September 11, 2001 was that of the "spatial status of lifelines" that showed, with daily updates, the extent of availability of common services in Manhattan (such as electricity and telephone) (Cutter, 2003).

Disaster. Oxford English Dictionary (1989) describes a disaster as "anything that befalls of ruinous or distressing nature; a sudden or great misfortune, mishap, or misadventure; a calamity." A disaster in the context of this research is a humanitarian crisis, either man-made or natural, that causes or has the potential to cause the significant loss of human life, or cause the significant loss of human habitat or sustainment that, over the course of a short period of time, can cause the loss of human life.

Disaster Management Operations. Disaster management operations are those activities that are performed in order to relieve the negative effects on human lives that are caused by a disaster. These activities can include providing one or more of the following: food, water, shelter, medical care and economic aid. According to FEMA, response is one of four categories of emergency management, the others being mitigation, preparedness and recovery (Gunes et al., 2000).

Geographic Information System. A Geographic Information System, or GIS, is a collection of computer hardware, software, and geographic data for capturing, managing, analyzing, and displaying all forms of geographically referenced information (ESRI, 2006). Also termed geospatial systems.

Geospatial Data. A general definition of data is any collection of related facts arranged in a particular format; often, the basic elements of information that are produced, stored, or processed by a computer. (ESRI (GIS Dictionary), 2006). In the case of geospatial data, it is that which includes both a tabular component and a geo-location component, and that is properly formatted for use in a GIS.

APPENDIX B

INSTITUTIONAL REVIEW BOARD APPROVAL

The University of
Southern Mississippi

Institutional Review Board

118 College Drive #5147
Hattiesburg, MS 39406-0001
Tel. 601.266.[illegible]
Fax 601.266.5509
www.usm.edu/irb

HUMAN SUBJECTS PROTECTION REVIEW COMMITTEE
NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Human Subjects Protection Review Committee in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the "Adverse Effect Report Form".
- If approved, the maximum period of approval is limited to twelve months.
  Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: **27092003**
PROJECT TITLE: **Investigation Into the Use of Geospatial Technologies as Part of Disaster Management Efforts Related to the Asian Tsunami of 2004**
PROPOSED PROJECT DATES: **10/01/07 to 10/31/08**
PROJECT TYPE: **Dissertation or Thesis**
PRINCIPAL INVESTIGATORS: **Robert Redding**
COLLEGE/DIVISION: **College of Arts & Letters**
DEPARTMENT: **Political Science**
FUNDING AGENCY: **N/A**
HSPRC COMMITTEE ACTION: **Expedited Review Aprpoval**
PERIOD OF APPROVAL: **10/15/07 to 10/14/08**

Lawrence A. Hosman
Lawrence A. Hosman, Ph.D.
HSPRC Chair

10-17-07
Date

APPENDIX C

INTERVIEW QUESTIONS

Disaster Decision-maker Demographics and Organizational Information
Within this module, the questions are developed in order to develop a demographic description of the sample. The categories of demographic information to be collected include: Occupation and Employment, Education Attainment, Experience in Decision Making, and Age.

What is your age?

(Pick list)

- 18 – 25 years
- 26 – 35 years
- 36 – 45 years
- 46 – 55 years
- 56 – 65 years
- 66 – 75 years
- Greater than 75 years

What is your level of education?

(Pick list)

- Doctoral degree
- Professional degree
- Master's degree
- Bachelor's degree
- Associate degree
- Some college, no degree
- High-school graduate
- Less than a high school diploma

What was the primary role that you had when you responded to the Asian Tsunami of 2004?

(Pick list)

- Official Responder (police, firefighter, emergency medical services, etc.)
- Decision Maker (incident commander, unified command, Government officials, community leaders, etc.)
- Support Personnel (logistics, planning, and operational staff; GIS specialists, hospital staff, etc.)
- Volunteer (church groups, non-government organizations, social services, search and rescue, etc.)

- Media Personnel (local and national news reporter, information officer, etc.)
- Other:

(text box)

At the time, how long had you been serving in this position?

(text box)

Prior to the Asian Tsunami of 2004, had you ever been personally involved in disaster response and recovery operations?

(Pick list)
- Very Involved
- Somewhat involved
- Not at all involved
- Other

(text box)

Have you attended any seminars, conferences or other professional gatherings that primarily dealt with disaster response and recovery?

(Pick list)
- Never
- At least once
- Two or more

Do you participate in GIS user groups or other organizations to coordinate data development, data sharing/exchanging or application development activities?

(Pick list)
- Yes
- No

To the best of your knowledge, how many dedicated GIS staff were employed within that organization at the time of the disaster?

(text box)

To the best of your knowledge, please select how many other staff within that organization used GIS on a casual or periodic basis?

(text box)

As far as you know, how long had your organization been using GIS at the time of the tsunami?

(text box)

At the time of the tsunami, what were the GIS software packages that your organization used?

(text box)

What were the primary uses of GIS within your organization at the time of the tsunami (i.e. what were your major GIS applications)?

(text box)

How would you categorize your organization?

(Pick list)
- Academic/educational
- Government
- Non-governmental
- Commercial
- Other (please specify)

  (text box)

Please describe the mission of your organization:

(text box)

Does your office adhere to a certain set of moral codes, principals, or ethics?

(Pick list)
- Yes
- No

If yes, please describe these principals and how this applies to your use of GIS:

(text box)

In what country or countries does your organization operate?

(text box)

Decision-support Information Requirements
For this module, the instrument questions relate to the topical program areas as described in the following sub-modules.

Planning
This sub-module of the instrument focuses on data requirements that support disaster management planning prior to an incident. GIS can be used to analyze terrain, evaluate population locations and status, and determine hazards and opportunities. Newkirk (1993) said that a GIS, when properly designed and implemented, is an excellent tool for risk and hazard analysis. In addition, a GIS can be a powerful integrator of varied, non-geospatial data that can be used for planning.

Please check the box next to the type of GIS data that your organization currently has on hand:

(check box)

- Geodetic control
- Orthoimagery (aerial photography, satellite images, etc)
- Elevation (topography)
- Transportation (street center lines or ROWs, rail/transit lines, airports, etc)
- Hydrography (rivers, streams, lakes, wetlands, watersheds, etc)
- Governmental boundaries/political units (cities, counties, election districts, etc)
- Population
- Cadastral information (parcels, property lines, etc)
- Environmental (soils, habitats, etc)
- Land use/ zoning
- Utilities (water, gas, telecom)
- Public safety/public health

Please describe any other GIS data that you have on hand currently to support disaster response.

(text box)

Does metadata exist for any of this GIS data?

(Pick list)

- Yes
- No

Is the format of this GIS data convertible for use outside of your office?

(Pick list)

- Yes
- No

Please describe the capabilities of your organization's GIS.

(text box)

What role do senior leaders in your organization play in making sure the organization is best prepared for disaster response?

(text box)

If yes, please describe:

(text box)

Does your organization serve, share, or provide GIS data or maps on-line? If so, how (GIS web server, FTP site, on-line metadata, etc)?

(text box)

Does your organization have a data distribution policy?

(Pick list)
- Yes
- No

If yes, please describe the policy:

(text box)

Has the use of your organization's GIS ever been subject to a legal proceeding?

(Pick list)
- Yes
- No

If yes, please describe (in brief) those legal actions:

(text box)

Response Targeting

This sub-module is related to planning, but focuses on the use of data that is immediately available after the start of a disaster event to support the implementation of a plan. High payoff locations can be targeted during disaster recovery for many reasons. For a food provider, locating population concentrations can be very effective for maximizing efforts. For organizations that are focusing their efforts on de-mining, a geospatial application can help them determine which minefield, when removed, can benefit the most people. Gentile et al. (1997) stated that GIS was of great value to the humanitarian demining efforts that were conducted in Bosnia after the civil war that erupted during the disintegration of Yugoslavia.

Please describe any data that you have the capability and plans for accumulating during the course of a disaster response. An example of this would be plans for keeping updated locations of food warehouses during the course of a disaster response.

(text box)

Please describe any data that you accumulated during the course the response to the Asian Tsunami of 2004.

(text box)

Coordination

The coordination sub-module asks questions that support information requirements for synchronizing the efforts of the many different organizations that typically participate in disaster management. Typically, there are many relief organizations working on any particular disaster. The ability of one organization to coordinate with others would allow for a maximization of effort, an enhanced capability to deconflict operations, and a general reduction in the redundancies that plague these types of operations. One of the recommended changes from the White House (2006) for post-Katrina disaster management is the implementation of a common operating picture between agencies. A properly configured and distributed GIS can provide a tool that facilitates coordination by showing where activities are occurring for multiple agencies.

How are decisions normally made in your organization during a disaster response?

(text box)

How were decisions normally made in your organization during the response to the Asian Tsunami of 2004?

(text box)

During your disaster experience and while in your particular role as part of the response to the Asian Tsunami of 2004, what types of vital information did you receive that directly supported your organizations mission?

(text box)

During your disaster experience and while in your particular role as part of the response to the Asian Tsunami of 2004, was there any essential information missing that you needed?

(Pick list)
- Yes
- No

If yes, please list all essential information you needed but did not have:

(text box)

Please describe any bureaucratic problems that your organization had in regards to GIS during the response to the Asian Tsunami of 2004.

(text box)

Documentation
This sub-module focuses on archive requirements. For a variety of reasons, disaster relief operations must be documented. It is important to track where work has been done so that it can be properly evaluated later or repeated if necessary. It is also important to document disaster relief operations because virtually all of the organizations that conduct disaster relief are donor beneficiaries. The donors that contribute must be informed as to how their money was spent. In an article from March 2003, Lewis expands upon this theme by explaining that without visibility on field operations; major donors to relief operations are not as likely to provide funds to support future operations.

What reporting requirements during your response to the Asian Tsunami of 2004 that involves GIS data? For example, do you produce maps that depict your organization's response to disasters?

(Pick list)
- Yes
- No

If yes, please describe:

(text box)

During the response to the Asian Tsunami of 2004, were you able to properly fulfill these requirements?

(Pick list)

- Yes
- No

If no, please describe what happened:

(text box)

Resource mapping

This sub-module focuses on information related to locating pre-placed or existing resources, or the places that they can arrive, which can really help to bring efficiency to a recovery effort. As with any organization that manages resources, asset visibility can enhance decisions about allocation of these resources by giving additional information about resource locations, proximity to priority efforts, and information about the proximity of resources to transportation assets.

Future

List three improvements in order of importance that you would like to see made to your GIS to provide better support for disaster management

(text box)

Are there any other GIS data layers that you do not currently have that you would like to have?

(text box)

Would you use or deploy a GIS that users could sign up to, add and update themselves?

(Pick list)

- Yes
- No

Are you currently conducting any major data gathering or data creation activities, or will you be doing so within a year? Please describe.

(Pick list)

- Yes
- No

If yes, please describe:

(text box)

Document Collection:

If you are interested in providing archives, policies or other documents for research purposes, briefly describe these documents and provide the URL link or transmit an electronic copy of your documents to robert.w.redding@usm.edu

(text box)

REFERENCES

Adinolfi, C., Bassiouni, D., Lauritzsen, H., and Williams, H. (2005). *Humanitarian response review: An independent report commissioned by the United Nations Emergency Relief Coordinator & Under-Secretary-General for Humanitarian Affairs, Office for the Coordination of Humanitarian Affairs (OCHA)*. Retrieved October 12, 2008, from http://ochaonline.un.org/

Audisio, C., Nigrelli, G., & Lollino, G. (2009). A GIS tool for historical instability processes data entry: An approach to hazard management in two Italian alpine river basins. *Computers & Geosciences, 35*(8), 1735-1747.

Bell, D., & Carens, J. (2004). The ethical dilemmas of international human rights and humanitarian NGOs: Reflections on a dialogue between practitioners and theorists. *Human Rights Quarterly*, *26*(2), 300-329.

Boyle, S. (1998). Developing geographic information systems for land use impact assessment in flooding conditions. *Journal of Water Resources Planning and Management*, *124*(2), 89-98.

Chen, X. (2002). Using remote sensing and GIS to analyse land cover change and its impacts on regional sustainable development. *International Journal of Remote Sensing*, *23*(1), 107-124.

Comfort, L. (1993). Integrating Information Technology into International Crisis Management and Policy. *Journal of Contingencies & Crisis Management*, *1*(1), 15.

Comfort L. (1999). *Shared risk: Complex systems in seismic policy.* Amsterdam and Oxford: Pergamon.

Comfort, L. (2005). Risk, security, and disaster management. *Annual Review of Political Science, 8*(1), 335-356.

Comfort, L. (2007). Crisis management in hindsight: cognition, communication, coordination, and control. *Public Administration Review, 67*, 189-197.

Comfort, L., Ko, K., & Zagorecki, A. (2004). Coordination in rapidly evolving disaster response systems: The role of information. *American Behavioral Scientist*, *48*(3), 295-313.

Comfort, L., Sungu, Y., Johnson, D., & Dunn, M. (2001). Complex systems in crisis: Anticipation and resilience in dynamic environments. *Journal of Contingencies & Crisis Management*, *9*(3), 144.

Cova, T., Dennison, P., Kim, T., & Moritz, M. (2005). Setting wildfire evacuation trigger points using fire spread modeling and GIS. *Transactions in GIS*, *9*(4), 603-617.

Craik, K. (1943). *The nature of explanation*. Cambridge: Cambridge University Press.

Crichton, M., Flin, R., & Rattray, W. (2000). Training decision makers – tactical decision games. *Journal of Contingencies & Crisis Management*, *8*(4), 208-217.

Cutter, S. (2003). GI Science, Disasters, and Emergency Management. *Transactions in GIS*, *7*(4), 439-446.

Disaster Tracking Recovery Assistance Center. (2007). *2004 tsunami response participant list*. Retrieved September 3, 2007, from http://www.d-trac.org/en/home.

Environmental Systems Research Institute (ESRI). (2006). GIS.com homepage. Retrieved August 3, 2006, from http://www.gis.com/whatisgis/index.html

Environmental Systems Research Institute (ESRI). (2006). GIS dictionary home page. Retrieved August 3, 2006, from http://support.esri.com/index.cfm?fa=knowledgebase.gisdictionary.gateway

Feagin, J., Orum, A., & Sjoberg, G. (Eds.). (1991). *A case for case study.* Chapel Hill: University of North Carolina Press.

Federal Emergency Management Agency (FEMA). (1997). *Multi hazard identification and risk assessment.* Washington DC: U.S. Government Printing Office.

Federal Emergency Management Agency (FEMA). (2008). HAZUS-MH overview. Retrieved on May 4, 2008, from http://www.fema.gov/plan/prevent/hazus/hz_overview.shtm

Federal Emergency Management Agency (FEMA). (2009a). About FEMA. Retrieved on April 8, 2009, from http://www.fema.gov/about/index.shtm

Federal Emergency Management Agency (FEMA). (2009b). Hurricane Katrina flood recovery maps (Mississippi). Retrieved on April 8, 2009, from http://www.fema.gov/hazard/flood/recoverydata/katrina/katrina_ms_gis.shtm

Flin, R., & Slaven, G. (1995). Identifying the right stuff: Selecting and training on-scene emergency commanders. *Journal of Contingencies & Crisis Management*, *3*(2), 113-123.

Flin, R. (Ed.). (1997). *Decision making under stress: Emerging themes and applications*. Aldershot, UK: Ashgate.

Foresman, T. (Ed.). (1998). *The history of geographic information systems: Perspectives from the pioneers*. Upper Saddle River, NJ: Prentice Hall.

Gall, M. (2004). Where to go? Strategic modelling of access to emergency shelters in Mozambique. *Disasters*, *28*(1), 82-97.

Gillham, B. (2000). *Case study research methods.* London: Cassell.

GIS gains ground as disaster mitigation tool. (1996). *Civil Engineering, 66*(9), p. 19.

Glantz, M., & Jamieson, D. (2000). Societal response to Hurricane Mitch and intra- versus intergenerational equity issues: Whose norms should apply? *Risk Analysis: An International Journal, 20*(6), 869-882.

Global positioning systems gaining use in humanitarian emergencies. (2003, August 13). *Biotech Week*, p. 89.

Gomez-Fernandez, F. (1998). Development of a volcanic risk assessment information system for the prevention and management of volcanic crisis: stating the fundamentals. C. Brebbia & P. Pascolo (Eds.) *Geographic Information System Technologies and their Environmental Applications (First International Conference on Geographical Information Systems in the Next Millennium)* (pp. 111-120). Southampton, UK: Computer Mechanical Publications.

Grier, P. (2006, February). Dueling officials slowed storm response. *Christian Science Monitor,* February 24, 2006. p. 3.

Gunes, A., & Kovel, J. (2000). Using GIS in emergency management operations. *Journal of Urban Planning & Development, 126*(3), 136-149.

Haggarty, A. (Ed.) (2008). *Global symposium +5 on information for humanitarian action - Final report.* New York: United Nations.

Helsloot, I., & Ruitenberg, A. (2004). Citizen response to disasters: a survey of literature and some practical implications. *Journal of Contingencies & Crisis Management, 12*(3), 98-111.

Jaiswal, R., Mukherjee, S., Raju, K., & Saxena, R. (2002). Forest fire risk zone mapping from satellite imagery and GIS. *International Journal of Applied Earth Observation & Geoinformation*, *4*(1), 1-10.

Janelle, D., & Gillespie, A. (2004). Space-time constructs for linking information and communication technologies with issues in sustainable transportation. *Transport Reviews*, *24*(6), 665-677.

Juhl, G. (1993). Federal Emergency Management Agency develops prototype disaster planning and response system. *American City & County, 108*(3), p. 38.

Kaempf, G., & Klein, G. (1996). Decision making in complex naval command-and-control environments. *Human Factors*, *38*(2), 220-232.

Kaiser, R., Spiegel, P., Henderson, A., & Gerber, M. (2003). The application of geographic information systems and global positioning systems in humanitarian emergencies: Lessons learned, programme implications and future research. *Disasters, 27*(2), 127-140.

Kar, B., & Hodgson, M. (2008). A GIS-based model to determine site suitability of emergency evacuation shelters. *Transactions in GIS, 12*(2), 227-248.

Katoch, A. (2006). The responders' cauldron: the uniqueness of international disaster response. *Journal of International Affairs, 59*(2), 153-172.

Kauffman S. (1993). *The origins of order: Self-organization and selection in evolution*. New York: Oxford University Press.

Klein, G. (1989). Recognition-primed decisions. In W. Rouse (Ed.), *Advances in Man-Machine Systems Research* (pp. 47-92). Greenwich, CT: JAI Press, Inc.

Klein, G. (1997). Developing expertise in decision making. *Thinking & Reasoning, 3*(4), 337-352.

Kharif, O. (2003, August 21). Plotting the war on terror and disease. *Business Week Online*. Retrieved on July 7, 2005 from http://www.businessweek .com/technology/content/aug2003/tc20030819_8703_tc126.htm

Kistemann, T., Munzinger, A., & Dangendorf, F. (2002). Spatial patterns of tuberculosis incidence in Cologne (Germany). *Social Science & Medicine, 55*(1), 7-19.

Kovel, J. (2000). Modeling disaster response planning. *Journal of Urban Planning & Development, 126*(1), 26.

Laefer, D., Koss, A., & Pradhan, A. (2006). The need for baseline data characteristics for GIS-based disaster management systems. *Journal of Urban Planning & Development, 132*(3), 115-119.

Laefer, D., Pradhan, A. & Koss, A. (2006). GIS-based disaster management systems: Cogent data framework. *TRB 85th Annual Meeting Compendium of Papers CD-ROM*, Paper #06-2076.

Lee, S., & Choi, J. (2004). Landslide susceptibility mapping using GIS and the weight-of-evidence model. *International Journal of Geographical Information Science, 18*(8), 789-814.

Lewis, T. (2003). Environmental aid: Driven by recipient need or donor interests. *Social Science Quarterly, 84*(1), 144-161.

Li, X., & Yeh, A. (2000). Modelling sustainable urban development by the integration of constrained cellular automata and GIS. *International Journal of Geographical Information Science, 14*(2), 131-152.

MacEachren, A. (2000). Progress reports, cartography and GIS: facilitating collaboration. *Progress in Human Geography, 24*(3), 445-456.

MacEachren, A., Cai, G., & Sharma, R. (2005). Enabling collaborative geoinformation access and decision-making through a natural, multimodal interface. *International Journal of Geographical Information Science, 19*(3), 293-317.

Maktav, D., Erbek, F., & Jürgens, C. (2005). Remote sensing of urban areas. *International Journal of Remote Sensing, 26*(4), 655-659.

Maniruzzaman, K., Okabe, A., & Asami, Y. (2001). GIS for cyclone disaster management in Bangladesh. *Geographical & Environmental Modelling, 5*(2), 123-131.

Matthew, R., & McDonald, B. (2006). Cities under siege. *Journal of the American Planning Association, 72*(1), 109-117.

Mittal, A. (2006). *U.S. tsunami preparedness: Federal and state partners collaborate to help communities reduce potential impacts, but significant challenges remain.* (Publication No. GAO-06-519). Retrieved April 28, 2007, from GAO Reports: Main Page via GPO Access: http://www .gpoaccess.gov/gaoreports/index.html

Montoya, L. (2003). Geo-data acquisition through mobile GIS and digital video: An urban disaster management perspective. *Environmental Modelling & Software*, *18*(10), pp. 869-875.

Nellis, M. (2005). Geospatial Information Technology, Rural Resource Development, and Future Geographies. *Annals of the Association of American Geographers, 95*(1), 1-10.

Newkirk, R. (1993). Extending Geographic Information Systems for Risk Analysis and Management. *Journal of Contingencies & Crisis Management*, *1*(4), 203-207.

Noji, E. (2005). Estimating population size in emergencies. *Bulletin of the World Health Organization*, *83*(3), 164.

Oxford English Dictionary (2nd ed.). (1989). Oxford: Oxford University Press.

Pacific Disaster Center. (2007). Pacific Disaster Center home page. Retrieved March 8, 2008, from http://www.pdc.org/

Pacific Disaster Center. (2008). Tsunami notes. Unpublished internal document.

Pettit, C. (2005). Use of a collaborative GIS-based planning-support system to assist in formulating a sustainable-development scenario for Hervey Bay, Australia. *Environment & Planning B: Planning & Design*, *32*(4), 523-545.

Potter, M., Sweeney, P., Thomas, C., Miller, T., & Gourley, T. (2005). Connecting silos: The legal bases for public health emergency response in Pennsylvania. *Journal of Public Health Management & Practice, 11*, 50-56.

Preliminary Results from the World Trade Center Evacuation Study -- New York City. (2003). *MMWR: Morbidity & Mortality Weekly Report*, *53*(35), 815-817.

Preuss, J. (2005). Why 'tsunami' means wake up call. *Planning*, *71*(8), 4-7.

Puder, A. (2004). MICO: An open source CORBA implementation. *IEEE Software*, *21*(4), 17-19.

Ross, K., Klein, G., Thunholm, P., Schmitt, J., & Baxter, H. (2004). The recognition-primed decision model. *Military Review, 84*(4), 6-10.

Salazar, R., & De-Vries, W. (2001). Towards a geospatial information infrastructure in Ecuador. *GIM-International, 2001*; *15*(9), 44-47.

Schwartz, D. (2005). The NIEHS responds to Hurricane Katrina. *Environmental Health Perspectives*, *113*(11), p. A722.

Shankar, K. (2008). Wind, water, and wi-fi: New trends in community informatics and disaster management. *Information Society*, *24*(2), 116-120.

Silver, J. (1996, June 10). Federal Emergency Management Agency's geographic information system coordinates disaster aid efforts among various helpers. *Government Computer News*, p62.

Smith, W., & Dowell, J. (2000). A case study of co-ordinative decision-making in disaster management. *Ergonomics*, *43*(8), 1153-1166.

Stake, R. (1995). *The art of case research*. Newbury Park, CA: Sage.

Stein, S., & Okall, E. (2005). Speed and size of the Sumatra earthquake. *Nature, Issue 434*, 581-582.

Steinitz, C., Faris, R., & Flaxman, M. (2005). A sustainable path? *Environment, 47*(6), 24-38.

Thayer, W., Griffith, D., Goodrum, P., Diamond, G., & Hassett, J. (2003). Application of geostatistics to risk assessment. *Risk Analysis: An Official Publication Of The Society For Risk Analysis*, *23*(5), 945-960.

Tumay, A., Dincer, K., & Tanyer, S. (2002). Usage of geographic information system and RS technologies in disaster management. In L. Hanzo (Ed.), *2002 IEEE International Geoscience and Remote Sensing Symposium Proceedings* (pp. 2447-2449). Piscataway, NJ: Institute of Electrical and Electronics Engineers.

UN/ISDR & UN/OCHA. (2008). *Disaster preparedness for effective response guidance and indicator package for implementing priority five of the Hyogo framework.* Geneva, Switzerland: United Nations Secretariat of the International Strategy for Disaster Reduction (UN/ISDR) and the United Nations Office for Coordination of Humanitarian Affairs (UN/OCHA).

United Nations Development Program [Indonesia]. (2005). *Post-tsunami lessons learned and best practices workshop, report and working groups output, Jakarta, Indonesia, 16-17 May 2005.* Unpublished internal document, United Nations Development Program.

United Nations Development Program [Maldives]. (2005). *Post-tsunami lessons learned and best practices workshop, report on main findings, Maldives, 17-18 May, 2005.* Unpublished internal document, United Nations Development Program.

United Nations Development Program [Sri Lanka]. (2005). *National post-tsunami lessons learned and best practices workshop, Colombo, Sri Lanka; 8-9 June 2005, Report.* Unpublished internal document, United Nations Development Program.

United Nations Development Program [Summary]. (2005). *Regional workshop on lessons learned and best practices in the response to the Indian Ocean tsunami, report and summary of main conclusions, Medan, Indonesia, 13-14 June 2005.* Unpublished internal document, United Nations Development Program.

United Nations Development Program [Thailand]. (2005). *National workshop on tsunami lessons learned and best practices in Thailand, report and summary of main conclusions, Bangkok, 30-31 May 2005.* Unpublished internal document, United Nations Development Program.

United Nations Development Program. (2005). *The Post-Tsunami Recovery in the Indian Ocean: Lessons Learned, Successes, Challenges and Future Action.* Retrieved on March 6, 2008 from http://www.humanitarianinfo .org/sriLanka/catalogue/Files/ Info%20Centre/TEC/TEC019_UNDP_Recovery_Lessons_Learned.pdf

United Nations Environmental Program. (2005). After the Tsunami. Rapid environmental assessment. Retrieved on March 6, 2008 from http://www.unep.org/tsunami/tsunami_rpt.asp

United Nations Environmental Program. (2008). UNEP Glossary. Retrieved on March 6, 2008 from http://www.grid.unep.ch/product/publication /freshwater_europe/glos.php#s

United States Geological Survey. (2004). Spatial Data Transfer Standard homepage. Retrieved on March 6, 2008 from http://mcmcweb.er.usgs .gov/sdts/

United States Government. (2006, February). The federal response to Hurricane Katrina, lessons learned. Retrieved on January 8, 2008 from http://georgewbush-whitehouse.archives.gov/reports/katrina-lessons-learned.pdf

US Agency for International Development. (2005). *Field operations guide for disaster assessment and response.* Version 4.0. Bureau for Democracy, Conflict, and Humanitarian Assistance - Office of U.S. Foreign Disaster Assistance.

US Agency for International Development. (2006). *Annual report for fiscal year 2005 - Office of U.S. Foreign Disaster Assistance.* Retrieved on March 6, 2008 from http://www.usaid.gov/our _work/humanitarian_assistance/disaster_assistance/publications /annual_reports/pdf/AR2005.pdf

VanLooy, J., & Cova, T. (2007). GIS-based indices for comparing airline flight-path vulnerability to volcanoes. *Professional Geographer, 59*(1), 74-86.

White, C., Plotnick, L., Addams-Moring, R., Turoff, M., & Hiltz, R. (2008, January). *Leveraging a wiki to enhance virtual collaboration in the emergency domain.* Paper presented at the Hawaii International Conference on System Sciences, Honolulu, Hawaii.

Wiles, P. & Sida, L. (2007). *United Nations Children's Fund - The 2004 Indian Ocean tsunami disaster: Evaluation of UNICEF's response (emergency and initial recovery phase) - synthesis report.* Retrieved on March 6, 2008 from http://www.unicef.org/evaldatabase/files/UNICEF_Tsunami _Synthesis_Report_2006.pdf

Williams, T. (1995). Object-oriented CASE tools carve a path from concept to code. *Computer Design's: Electronic Systems Technology & Design, 34*(10), 63-71.

Wong, F., Geist, E., & Venturato, A. (2005). *Probabilistic tsunami hazard maps and GIS.* 2005 ESRI International User Conference, San Diego, California. Retrieved on May 4, 2008 from http://proceedings.esri.com/library /userconf/proc05/papers/

pap2000.pdf

Xue, Y., Cracknell, A., & Guo, H. (2002). Telegeoprocessing: The integration of remote sensing, geographic information system (GIS), global positioning system (GPS) and telecommunication. *International Journal of Remote Sensing, 23*(9), 1851-1893.

Yin, R. (2003). *Case study research* (3rd ed.). Thousand Oaks, CA: Sage.

Zaitchik, B. (2003). Applying a geographic information system slope-stability model to site-specific landslide prevention in Honduras. *Journal of Soil and Water Conservation, 58*(1), 45-53.

Zerger, A., & Smith, D. (2003). Impediments to using GIS for real-time disaster decision support. *Computers, Environment & Urban Systems*, *27*(2), 123-142.