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Knowledge Management, Emergency Response, and Hurricane Katrina

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Abstract- **This paper explores the use of knowledge management with emergency information systems. Two knowledge management systems that were utilized during Hurricane Katrina response are described and analyzed. The systems specified were developed by both federal agencies as well as grass root efforts without the support or mandate of government programs. These programs, although developed independently, were able to share data and interact in life saving capacities, transcending traditional geo-political boundaries. We conclude that emergency information systems are enhanced by incorporating knowledge management tools and concepts.**

***Index Terms*— Crisis Response, Knowledge Management, PeopleFinder, ShelterFinder**

1. INTRODUCTION

It is clear from the 9/11 terrorist attacks, the anthrax events, the Slammer worm attack on the Internet, the London subway bombings, the 2004 tsunami, and now Katrina that terrorist attacks and/or disasters (henceforth referred to generically as emergencies) are increasingly involving the necessity to coordinate activities and responses by a much broader host of organizations involving the private sector, nonprofits and volunteer organizations. While some of these organizations are always involved in emergency response; the total span of organizations depends very much on the type of emergency, its location, and scale of impact. As a result one can not completely predict where and who are the people and units that will be gathering and supplying information as well as who will be responding and contributing resources. The most likely way this will be done effectively is by utilizing a centrally organized but fully distributed command and control center that can add functional nodes and linkages as needed and trigger by the occurring events [34]. Additionally, we need to become aware that we need Emergency/Crisis Response systems that guide responders in the correct response actions and which facilitate communications between the various responding groups and managers.

Emergency response in the United States of America, US, is evolving from something that was locally handled to something that is standardized under Federal control. The US implemented the National Incident Management System, NIMS, in 2004 to accomplish this. NIMS established standardized incident management protocols and procedures that all responders are to use to conduct and coordinate response actions [33]. However, hurricane Katrina has shown some weaknesses in this approach.

It was expected that on August 27th, 2005, when President George W. Bush declared a state of emergency for three coastal states days before the August 29th landfall of Hurricane Katrina that this approach would be sufficient to handle necessary emergency response. However; Mississippi, Alabama, and Louisiana would be the site of the worst natural disaster in U.S. history, stretching government resources far beyond their ability to respond to the instantaneous and growing number of casualties. Running out of shelter and supplies for the growing number of victims, the government became logistically overwhelmed and under-equipped. Private citizens and companies (all Non-Government) responded immediately. Power [25] describes how decision support systems, DSS, can aid in disaster response and as predicted, multiple independent systems were developed and implemented for immediate use to help victims find housing, medical supplies, post requests for immediate evacuation, as well as help find those separated in the storm. Some of these systems were designed using knowledge management, KM, collaboration techniques and many captured knowledge as part of their database. This paper describes how two of theses systems, PeopleFinder and ShelterFinder, were developed, implemented, and used. We will describe the situation that led to the need of these systems, how these systems were created, the resources required for each, how KM was used to create the system and if the system serves as a knowledge management system, use of the systems by the end users, and finally describe the end result of these systems.

2. BACKGROUND

Emergency Response Systems are used by organizations to assist in responding to an emergency situation. These systems support communications, data gathering and analysis, and decision-making. Emergency Response Systems are rarely used but when needed, must function well and without fail. Designing and building these systems requires designers to anticipate what will be needed, what resources will be available, and how conditions will differ from normal. A standard model for an Emergency Response System is from Bellardo, Karwan and Wallace [3] and identifies the components as including a database, data analysis capability, normative models, and an interface. This model is only somewhat useful as it fails to address issues such as how the Emergency Response

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System fits into the overall emergency response plan, Emergency Response System infrastructure, multiple organization spanning, knowledge from past emergencies, and integrating multiple systems. Additionally, many organizations do not address the need for an Emergency Response System until an emergency happens, and then, only for a few months until something more pressing comes up [11]. The result is that many organizations have an Emergency Response System that may not be adequate.

To address the weaknesses of the Bellardo, Karwan, and Wallace [3] model, Jennex [12] summarized the literature and used findings from Y2K to generate an expanded emergency information response system model. These systems are more than the basic components of database, data analysis, normative models, and interface. A more complete emergency response system model includes these basic components plus trained users (where users are personnel using the system to respond to or communicate about the emergency and consist of first responders, long term responders, the emergency response team, and experts), dynamic, integrated, and collaborative (yet possibly physically distributed) methods to communicate between users and between users and data sources, protocols to facilitate communication, and processes and procedures used to guide the response to and improve decision making during the emergency. The goals of the emergency information response system are to facilitate clear communications, improve collaboration between users needing to collaborate, improve the efficiency and effectiveness of decision-making, and manage data to prevent or at least mitigate information overload. Designers use technology and work flow analysis to improve system performance in achieving these goals.

Before discussing the hurricane Katrina systems that are the subject of this paper and how knowledge manage, KM, it is important that we establish what we mean by knowledge, KM, and a KMS as well as provide a framework for how KM fits into disaster and/or emergency response.

2.1 Knowledge

Davenport and Prusak [7] define knowledge as an evolving mix of framed experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information. Knowledge often becomes embedded in documents or repositories and in organizational routines, processes, practices, and norms. Knowledge is also about meaning in the sense that it is context-specific [9]. Jennex [14] extends the concepts of context to also include associated culture that provides frameworks for understanding and using knowledge. A simpler definition of knowledge is that it is the how and why of something. It is the insight into why something happens that creates knowledge. To be useful though, this knowledge needs to be framed in context and culture, the information and data that explain how the knowledge was generated, what it means, and how it should be used.

2.2 Knowledge Management

Jennex [13] defines knowledge management, KM as the practice of selectively applying knowledge from previous experiences of decision-making to current and future decision making activities with the express purpose of improving the organization's effectiveness. KM is an action discipline; knowledge needs to be used and applied for KM to have an impact. Inherent in KM is communication between knowledge creators and/or possessors and knowledge users. KM supports using knowledge in two ways, directly by linking knowledge of a task to those performing the task and indirectly by supporting knowledge sharing and collaboration between knowledge users and experts. A knowledge management system, KMS, is the system developed to aid knowledge users in identifying, sharing, retrieving, and using knowledge they need. Per Alavi and Leidner [1, p. 114] a KMS is the "IT (Information Technology)-based systems developed to support and enhance the organizational processes of knowledge creation, storage/retrieval, transfer, and application." Maier [21] expanded on the IT concept for the KMS by calling it an ICT (Information and Communication Technology) system that supported the functions of knowledge creation, construction, identification, capturing, acquisition, selection, valuation, organization, linking, structuring, formalization, visualization, distribution, retention, maintenance, refinement, evolution, accessing, search, and application. KMS use a variety of technologies designed to enhance knowledge storage and knowledge communication/transfer.

A recent development in KMS technology is the use of the wiki. A wiki is a website or similar online resource which allows users to add and edit content collectively and/or collaboratively [23] [36] [38]. The wiki originated in 1994/1995 [6], but has only recently come become popular as a content management system [22]. Very recent research has found that wikis are useful for KM as they provide content management combined with knowledge exchange/communication and collaboration capabilities. Additionally, Wagner [36] found wiki technology to be useful in supporting knowledge creation and sharing by providing a group collaboration environment. Vazey and Richards [35] found improved decision making and knowledge acquisition while Raman, et al. [29] applied a wiki as a tool for improving emergency response planning.

Jennex, Smolnik, and Croasdell [17] defined KM success as reusing knowledge to improve organizational effectiveness by providing the appropriate knowledge to those that need it when it is needed. KM is expected to have a positive impact on the organization that improves organizational effectiveness using the dimensions of impact on business processes, strategy, leadership, efficiency and effectiveness of KM processes, efficiency and effectiveness of the KM system, organizational culture, and knowledge content. Jennex and Olfman [16] summarized and synthesized the literature from 17 studies on over 200 KM projects on KM/KMS critical success factors (CSF) into an ordered set of twelve KM CSFs. The following CSFs were found applicable to this paper:

- A knowledge strategy that identifies users, sources, processes, storage strategy, knowledge, and links to knowledge for the KMS
- Integrated technical infrastructure including networks, databases/repositories, computers, software, and KMS experts
- A common enterprise wide knowledge structure that is clearly articulated and easily understood
- A clear goal and purpose for the KMS
- The search, retrieval, and visualization functions of the KMS support easy knowledge use

2.3 Knowledge Management and Emergency Response

Jennex [12] identified an expanded model of an Emergency Information System, EIS. This model considers an EIS as more than the basic components of database, data analysis, normative models, and interface outlined by Belardo et al. [3]; adding trained users, methods to communicate between users and between users and data sources, protocols to facilitate communication, and processes and procedures used to guide the response to and improve decision making during the emergency. The goals of the EIS are to facilitate clear communications, improve the efficiency and effectiveness of decision-making, and manage data to prevent or at least mitigate information overload. EIS designers use technology and work flow analysis to improve EIS performance in achieving these goals. Power [26] [27] discuss how knowledge based DSS can be used to improve disaster planning and response and communications between response participants. Turoff, et al. [34] expanded the expanded EIS model by introducing the concept of a dynamic EIS and identifying design requirements that expanded EIS capabilities in group communication and data/information/knowledge management. The result is that the focus of an EIS is on communication and facilitating decision making; both are also key attributes of a KMS.

Additionally, in recent years, disaster managers have realized the potential of KMS for faster and more organized response to natural disasters. The large number of groups that respond to a disaster all need access to a wide range of real-time information, requires coordination. Groups have proposed and created KMS that allow for more efficient use of data and faster response. One example that has been proposed is the Information Management System for Hurricane disasters (IMASH) [10]. IMASH is an information management system based on an object-oriented database design, able to provide data for response to hurricanes. IMASH was designed with the premise that the World Wide Web is the medium of choice for presenting textual and graphical information to a distributed community of users. This design is much more effective in the fast-changing environment of a natural disaster than the historical use of static tools which, out of necessity, have been the tools used in disaster response. Kitamato [19] describes the design of an information management system, Digital Typhoon, designed to provide a hub of information on the Internet during a typhoon disaster. The Digital Typhoon provides access to information from official sources (news, satellite imagery) as well as a forum for individuals to provide information (local, personal). It effectively became a hub of information, but created questions about organization, filtering, and editing. Systems used for Hurricane Katrina response realized the benefits and difficulties of these systems. Like IMASH, the systems described below use the Internet to distribute data to a community of users, and like the Digital Typhoon, the knowledge management systems described for Hurricane Katrina response became hubs of information that required data management to reduce repetition and allow for editing.

Another application of KM to emergency response is in identification of the decision/hand off points [25] [26] [27]. KM is applied through the generation of guidelines, rules, and procedures that govern these points. As experience is gained and lessons learned, the criteria guiding the declaration of these points is modified to incorporate this experience. The benefit to emergency responders is that decision making with respect to these points is simplified and guided, reducing the stress on the decision maker.

A last application of KM to emergency response is in enhancing collaboration between experts and responders. Turoff et al. [34] and Power [26] discusses the need for improved communication and collaboration between emergency response participants. KM technologies such as Wikis, web portals, and peer to peer networks create this communication and collaboration infrastructure. Wagner [36] discusses the use of wiki technology to enhance knowledge creation and sharing within a group, this can be applied to knowledge creation and collaboration between expert and first responder groups.

Finally, future trends into emergency response systems were demonstrated during the Strong Angel III civilian-military integrated disaster response demonstration held in San Diego, California during August 2006. Demonstrations were held integrating knowledge bases into visualization systems resulting in smart displays. In particular, the use of knowledge bases within a GIS as demonstrated by the San Diego State University Visualization Laboratory illustrated the power of tying social and demographical data and knowledge to images and maps. This integration created an emergency response system that could be ad hoc queried with results displayed visually. This facilitated knowledge creation and knowledge transfer among emergency response personnel.

In summary, there is a fusion of Emergency Response systems with KM. This is because decision makers, when under stress, need systems that do more than just provide data, they need systems that can quickly find and display knowledge relevant to the situation in a format that facilitates the decision maker in making decisions. It is expected that Emergency Response System evolution will continue to utilize KM concepts and approaches as experience in responding to disasters is showing that these systems are more effective than traditional Emergency Response Systems. Examples of how KM aids emergency/crisis response includes using knowledge of past disasters to design communication and data/information capture protocols and templates, capturing emergency response knowledge in procedures and protocols; incorporating lessons learned into response team training, interface and display design, and the generation of heuristics guiding decision making; and using knowledge to guide the creation of experience knowledge bases that responders can use to generate emergency response actions.

3. PEOPLEFINDER

3.1 Problem Emerges & Information Overload Occurs

During the first days after Hurricane Katrina hit the Gulf Coast, the Gulf Coast News website (http://www.gulfcoastnews.com) had setup a webpage for people to talk about their hurricane stories. Obviously geared for stories talking about how New Orleans spent a few days without power, the site quickly became an online repository for people to look for victims and post requests for help. Posts on the website ranged from asking for directions out of town, to people from other states asking if someone can check on or save their family members at flooded addresses. This trend grew, and quickly 23 different websites had people posting that they survived, as well as people looking for information on victims that had not been found. Anyone looking for loved ones would have to check each website as there was, at that time, no central repository for information. There also lacked a way to leave contact information should your search query be matched. As Table 1 indicates, many websites hit upon the same idea at the same time to host servers for survivors to post their status to. Although this was a terrific response from mostly civilian Internet companies, it created confusion on which sites to post to and search at, which created the need for a site like PeopleFinder [24].

3.2 Proposed Knowledge Management Solution

David Geihufe of the Social Software Foundation had been working on an open source Customer Relationship Management, CRM, system called CiviCRM [8]. During the intelligence phase [18], David envisioned using his CRM system to create a web based, data driven Decision Support System, DSS, [28] form of KMS that would be a central repository for victims and people looking for them (an application described by Power [26] as appropriate for DSS). The website would accept data in an open standard from other websites, as well as allow people to post information directly to the server. Not having the resources necessary to use this system, David received corporate support from the Salesforce Foundation. In 24 hours, the Salesforce servers were accepting PFIF (PeopleFinder Interchange Format). Twenty-four hours after that, sixty thousand records had been inputted by global volunteers to the PeopleFinder knowledge management system Some inputs were parsed (‘scraped’) from sites such as Craigslist, and the Gulf Coast News. . Ultimately, over 620,000 records were searchable and over 500,000 searches processed. Tables 2 and 3 show the database schema.

Table 1: Websites and the number of survivor records in each [24]

Website	**No. of Entries**
http://www.msnbc.msn.com/id/9159961/	143,000
http://www.familylinks.icrc.org/katrina/people	135,222
http://wx.gulfcoastnews.com/katrina/status.aspx	42,477
http://www.publicpeoplelocator.com/	37,259
http://www.katrina-survivor.com/	9,071
http://www.lnha.org/katrina/default.asp	4,500
http://connect.castpost.com/fulllist.php	2,871
http://www.findkatrina.com	2,474
http://www.katrinasurvivor.net	2,400
http://theinfozone.net	1,300
http://www.cnn.com/SPECIALS/2005/hurricanes	1,120
http://www.wecaretexas.com/	200,000
http://www.scribedesigns.com/tulane/	1,933

Table 2: Note Schema [20] Note_record_id is the primary key

string	**note_record_id**
string	person_record_id
string	linked_person_id
date	entry_date
string	author_name
string	author_email
string	author_phone
bool	found
string	email_of_found_person
string	phone_of_found_person
string	last_known_location
text	text

The note table is necessary as it is a lesson learned from the September 11th World Trade Center attacks [20]. Entries may be updated multiple times, and syncing data between servers can become very difficult. The notes table solves this problem by keeping a log of who has made what change, and what changes were made. The timestamp on each file can be used as a quantitative metric on which entry is the most recent.

Table 3: Person Schema [20] Person_record_id is the primary key

string	**person_record_id**
date	entry_date
string	author_name
string	author_email
string	author_phone
string	source_name
string	source_date
string	source_url
string	first_name
string	last_name
string	home_city
string	home_state
string	home_neighborhood
string	home_street
int	home_zip
string	photo_url
text	other

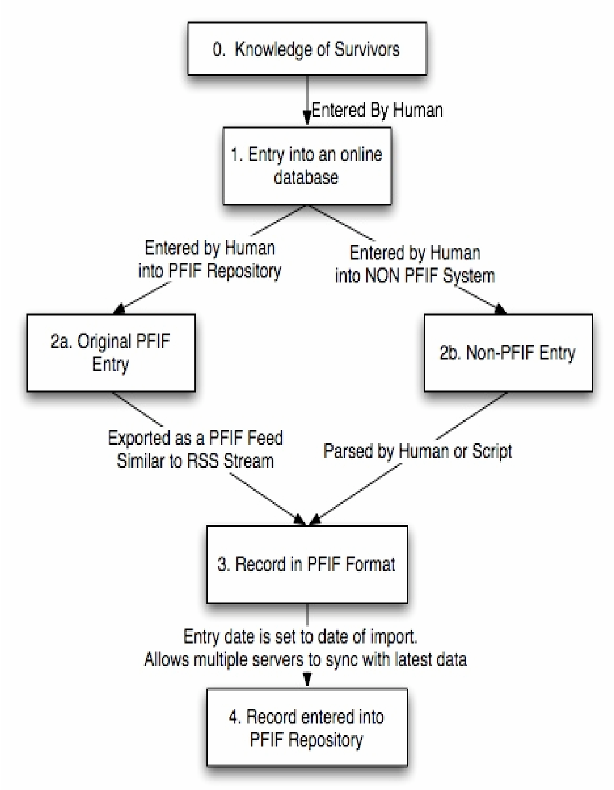

Fig. 1. Sharing Data Flow Diagram [20]

Integrity of data, a key component of a successful DBMS (Database Management System), while syncing between multiple servers was non-trivial. Multiple approaches were considered, and the decision was made to keep all data sets as read-only throughout the entire transaction process, except for the field entry_date, which would indicate when that entry had been posted to the server. [20]

Figure 1 shows the data flow diagram depicting how the data transverses the system. Table 4 details the decision table providing a rule set for when to manually enter the data into the PFIF repository, and when to request to have a parser written.

Table 4: Decision Table for assessing how to proceed with new websites discovered.

Potential Conditions	Actions to be performed		
	Manual entry	Task a parser for later development	Task a parser for immediate development
If (postings) <25	X		
If (postings) <25 but anticipate growth	X	X	
If (postings) > 25		X	
If (postings) > 100			X

3.3 Leaderless Development

To facilitate design and development of the system a wiki was used to enhance collaboration, knowledge creation, and knowledge sharing by coordinating tasks and development for the PeopleFinder system. Anyone wanting to make changes to the wiki had to register on it. Similar to public bulletin board websites, registration was automated and required no formal approval [2]. When a developer found bugs or noticed new features that needed to be added to the system, they could post a task that needed to be completed. One of the other developers could assign themselves to the task to complete it, give status on its development, and clear the task upon completion. Sites to be scraped were handled like this as well. Sites that had information to share could be listed on the wiki, and people could either manually transfer the information record by record, or coders could write parsers to grab the information and repost it into the Salesforce server in PFIF. The determination on whether to manually parse the site, or write a parser for it was determined by the number of entries on the site, the number of entries expected on the site, and whether or not the author of the original site had made safeguards to prevent scripts from parsing the site [24].

With any website that can be modified by the general public, vandalism is an immediate and valid concern. For example, there was nothing to keep political protestors from registering and defacing the website with a political message that has nothing to do with the purpose of the website. Fortunately, editors on the website kept vandalism suppressed by monitoring the Recent Changes page [32].

3.3 PeopleFinder Analysis

PeopleFinder went from an idea to operationally functioning within a 72-hour window. Due to the nature of the website, few users would be inclined to leave feedback to make the site more helpful. Therefore, features may have been incorrectly prioritized based on what the developers thought would be helpful, rather than what the user base needed. Future concerns about this type of project will most likely include privacy rights. When someone wants their online entry removed from the database, perhaps to avoid any risk of identity theft, there is currently no feature that allows them to be removed. In fact, the data network is setup to maintain the entries at all cost. It is also difficult to have an easy-to-use website that allows distraught people to find their family and friends, while making sure that those with criminal intentions are filtered out. Regardless of the security downfalls, PeopleFinder was a success as soon as the first person was able to quickly ascertain the status of a loved one.

KM in PeopleFinder is reflected in its construction and in the captured knowledge. The system design reflects the capture of lessons learned from previous disasters. The use of a leaderless development process reflects the use of KM to facilitate collaboration between experts. Knowledge capture is reflected in the capture of notes and the history of notes for each person plus the context information that makes the knowledge useful. KMS features implemented in the system include a knowledge strategy with a clear purpose for the captured knowledge, integrated technical infrastructure including knowledge repositories and a web based interface; and the implementation of good search and retrieval functions. As stated it was not expected that feedback would be left by users, this needs to be compensated by researchers who need to collect some system satisfaction data so that future systems can learn from mistakes in this system.

KM use in PeopleFinder is considered successful. The use of KM collaboration technologies, in this case Wiki, to facilitate design collaboration and knowledge sharing is considered to be very successful. The system was designed, built, and implemented in 72 hours and reflected the application of lessons learned from previous disasters and the development process. Also, given the large number of system accesses, it is inferred that the system was very successful with respect to capturing the right knowledge and making it usable (searchable and retrievable) in providing the right knowledge to the right people at the right time. View sharing means that a system provides the facility which allows each co-author to have the same interface copy to work on as shown in Fig. 1. In Fig. 1, there are four copies of the same interface. A collaborative system should provide facilities to support the roles. This means a centralized server managing the shared document and numerous distributed user interfaces which clients use directly as shown in Fig. 1. By this architecture, each attribute or service is implemented. each attribute or service is implemented. Each attribute or service is implemented. Each attribute or service is implemented. Each attribute or service is implemented. Each attribute or service is implemented. Each attribute or service is implemented. Each attribute or service is successfully implemented. View sharing means that a system provides the facility which allows each co-author to have the same interface copy to work on as shown in Fig. 1. In Fig. 1, there are four copies of the same interface. A collaborative system should provide facilities to support the roles. This means a centralized server managing the shared document and numerous distributed user interfaces which clients use directly as shown in Fig. 1. This means a centralized server managing the shared document and numerous distributed user interfaces directly.

4. SHELTERFINDER

FEMA estimated that over 500,000 people were left homeless, and another 500,000 jobless [4] by Hurricane Katrina. With that many people residing in such a close proximity to each other, finding a new place to live, even for a temporary amount of time, can be near impossible. Employment in other cities could be located online through already existing jobs databases; however there was no way to find somewhere to live for free during the victims' rebuild from devastation. At the same time, hundreds of thousands of people across the nation offered up their homes to let Katrina victims have somewhere to stay until they could find permanent housing. The problem was how to coordinate information so that people who were in the affected areas could find housing across the nation. Like PeopleFinder, multiple websites began to popup to offer housing, but there was no organized meta search, allowing users to check one centralized location.

4.1 Collecting Shelter Data for Hosting

ShelterFinder [30] was set to solve similar problem as PeopleFinder. Continuing with open standards for the systems data formats, ShelterFinder maintained a means for a single server to stream new data feeds to multiple servers, while simultaneously being ready to respond to requests for data from other servers. Rather than PFIF that was designed for victims, ShelterFinder used standard formats such as CSV (Comma Separated Values) and XML (Extensible Markup Language) [37]. These formats allowed an independent team of developers to write database search systems as well as another independent team to build the GIS front end for more efficient use of the database system. Like PeopleFinder, a wiki was used for distributed management of the project. ShelterFinder would become a web based, data driven DSS [28] form of knowledge management system.

4.2 ShelterFinder Development

ShelterFinder, in addition to being a distributed development group, had three constant managing members for promoting collaboration, managing the direction, and development of the system. Despite the fantastic strides made in such a short period of time, in reflection, the team has discussed that there exist some key aspects of their implementation strategy that could have been executed differently to get more attention to the system and users. While PeopleFinder was a more evolutionary approach to software development, ShelterFinder attempted to maintain a quality of service by not releasing code until it had been thoroughly tested by the users, and implemented by the lead developer. Keeping the system offline until specific milestones were met kept ShelterFinder unavailable during potentially critical periods of time. A different software development methodology could have helped garner more resources, and get more users while attention was still focused on the amazing open source efforts emerging.

4.3 ShelterFinder Analysis

ShelterFinder gained huge acceptance due to two major components. First, it was a combined search engine that hosted records for more homes or shelters than most housing search engines. Letting the victims choose a specific city, even if it is on the opposite side of the United States away, allowed victims to try to find temporary housing near family or in areas they might be able to get jobs. This helped the families find shelter near helpful social resources, while decreasing the stress that the increased number of people could inadvertently cause on the resources of an area. When large amounts of people have been displaced, any opportunity to place them in different geographic areas helps the relief effort.

Second, the GUI was uniquely easy to use and made finding homes or shelters near specific addresses incredibly easy and intuitive. The GUI was a result of the recent introduction of Google Maps (http://maps.google.com/). Using built-in Google Maps XML parsing engine, it provided a graphical front-end allowing users to see where in America homes were available, as well as an intuitive graphical representation on the map of how many spaces were free at each shelter based on icon color. At a community level, Google Maps has developed a means for conventional GIS developers to become web-based GIS developers and create web-based applications, quickly and cheaply.

KM use in ShelterFinder is also reflected in its construction and capture of knowledge. The system design reflects the capture of lessons learned from previous disasters. The use of a leaderless development process reflects the use of KM to facilitate collaboration, knowledge sharing, and knowledge creation between experts. Knowledge capture is reflected in the capture of knowledge on available housing; however, some critical context information that makes the knowledge useful was not captured. The system should have also captured knowledge and data on location maps and survivor preferences and housing and service characteristics to obtain better fits of survivors to available housing other than fits based on location. Allowing searchers to pick locations that they thought best is convenient, but not ideal as reflected in reported dissatisfaction with survivors in a number of communities that took in and housed survivors. A key issue was the widespread dispersion of current or former criminals to locations who did not know what they were getting. Better knowledge capture could have mitigated these issues. KMS features implemented in the system include a knowledge strategy with a clear purpose for the captured knowledge, integrated technical infrastructure including knowledge repositories and a web based interface; and the implementation of good search and retrieval functions.

KM use in ShelterFinder in response to Katrina is considered minimally successful but has subsequently improved. The use of KM collaboration technologies, in this case Wiki, to facilitate design collaboration, knowledge sharing, and knowledge creation is considered to be successful but not as successful as for PeopleFinder. ShelterFinder required updating that removed it from operation at critical times during Katrina recovery [30] this reflects that key lessons learned from previous disasters that were applied to PeopleFinder were not applied here. This probably reflects that the designers were not as aware of what was needed as subsequent additions using the Wiki have resulted in incorporation of key lessons learned from Katrina for application at disasters since and the incorporation of key features such as Google maps during Katrina [31]. This subsequent use of KM collaboration technologies is considered very successful. Knowledge capture is also considered minimally successful as the matches were not as good as desired. Additionally, since use data was not provided for ShelterFinder like it was for PeopleFinder (and both can be accessed from the same websites and ShelterFinder was started by many of the same team that did PeopleFinder [30]) it is inferred that the captured knowledge and data was not as useful as that provided by PeopleFinder as it is apparent that the right knowledge was not provided to the right people at the right time.

4.4 Leaderless Development Approaches

The alternative software development approach taken by ShelterFinder shows that leaderless development systems can still explore the same variety of software development approaches, as well as share the same need for system requirements as their traditionally managed counterparts. The non-traditional leaderless system does have the hindrance of not necessarily being able to replace the traditional roles that a managed software development project would identify at the start of the project. In a leaderless system, this role is replaced by a group of personnel who claim and execute the publicly obtainable tasks, which would typically be reserved for a specific role.

This type of open task claiming, allows willing members of the development team to attempt and execute tasks that they wouldn't normally be aware of, if the task isn't normally assigned to the traditional role they would play. When a task is overburdened and risks holding back the other parts of the project, team members that wouldn't normally characterize themselves within a specialty, can claim tasks that they are capable of accomplishing.

4.5 Critical Mass Requirement

Distributed, by definition, requires capability to be stretched across large redundant numbers. Leaderless development worked especially well for the PeopleFinder project, given the varying expertise available to the project by the massive number of constantly changing contributors. PeopleFinder was fortunate to have some early members that specifically spent their time advertising PeopleFinder, which in turn helped attract more development personnel, feeding the leaderless system. ShelterFinder, relying on a lesser quantity of members to oversee these tasks, were partially overwhelmed with the amount of work and the pressing timeline, and was unable to advertise the site in the same way as PeopleFinder. This identifies a weakness in the leaderless system that if sufficient numbers of personnel are lacking, necessary functions can go without execution. Without other team personnel able to identify underperforming tasks within the project, the lacking tasks will continue until noticeable system degradation occurs, if noticed at all. For example, without team members persistently advertising the systems capability, users won't know about the site and the site won't be used to it's maximum capacity. Non-marketing groups, perhaps isolated from usage statistics, might not know that the site isn't being used or factors that might be keeping the site from being used. In a rapid application development with a critical timeline such as disaster response, this can be a fatal system flaw.

5. Conclusions

As recently as the Sumatra-Andaman earthquake of 2004, disaster management response required printed maps, and specially trained disaster management personnel to coordinate the deployment of resources. Military groups such as the US Army's Civil Affairs branch and Non-Government Organizations, NGOs, such as the American Red Cross, have specially trained personnel to sort through the overwhelming amounts of information that arrives and interact directly with victims. The incoming information arrives in a variety of formats, inconsistent for the operations center, but usually in a consistent format from each source. This type of work usually requires specialized operations centers, a specialty staff to manage the data, and requires significant time to sort through the paper records submitted from the disaster area. Everyday citizens that would like to contribute are unable to, not only because they are not inside the physical operations center but also because there was no way for responders to reach out to the community to look for resources. Knowledge management systems, such as IMASH and the Digital Typhoon, have been researched and developed to help coordinate response to disasters. However, only by assessing how these types of systems actually worked in a disaster can improvements be made and resources like these used most efficiently in the future.

Wide spread emergencies such as Katrina and the 2004 Tsunami have shown the difficulty of building stand alone Emergency Response Systems (systems whose sole purpose is to respond to emergencies). These systems are expensive and it is difficult to not use them for routine activities when resources are low. Exercises preparing for a possible avian flu pandemic and for a pandemic coupled with a terrorist attack on critical infrastructure (Operation Chimera and Strong Angel III) are focusing on training large numbers of people in emergency response while using and developing open source emergency response systems [15]. Strong Angel III in particular focused on creating and using an emergency response system based on open source development and commercial off the shelf components. The goal is to reduce the cost, time, and effort involved in building and implementing an emergency response system while maintaining system security, especially when using the Internet and other commercial, civilian communication networks, and providing a structure for integrating diverse data and knowledge sources and bases. Additionally, Raman, et al. [29] discusses the use of wiki technology to facilitate KM for emergency response systems. It is expected that open source technologies such as wiki technology will be used to improve connectivity, knowledge sharing, knowledge creation, and communications between diverse groups needing to communicate during an emergency. It is expected that increased use of knowledge based systems and KM will continue for emergency response. Improved KM technologies for storing, searching, and retrieving knowledge will be used to integrate KM into emergency decision making.

The above also suggests the major conclusion of this paper, that KM needs to be applied to the development of Emergency Response Systems. Lessons learned from each disaster and exercise need to be captured and disseminated to those responsible for creating formal or ad hoc emergency response systems. Social networks, such as the International Society for Crisis Response and Management, ISCRAM, and their annual conference, where an early version of this work was presented, are the KMS for emergency response personnel. They provide the knowledge repositories, communities of practice, and knowledge transfer opportunities for the emergency response community.

The technologies discussed here are changing the traditional approach to disaster response. Conventional, expensive, and isolated operations centers are morphing into a series of scalable, cheap, distributed, and highly networked information portals that can be used wherever a computer and Internet access are available. The more wireless options that become available to people in disaster struck areas, from WiMax to satellite, the more options this new breed of distributed systems will have for helping people in real-time wherever tragedies strike. Strong Angel III demonstrated the effectiveness and adaptability of many of these technologies in a real world laboratory environment. This demonstration showed that disparate data and knowledge sources could be integrated and visualized; additionally, communication networks were established from a cold site using a variety of systems from various vendors.

The social approach of these two projects is fairly unconventional in comparison to both commercial America as well as traditional disaster response. Leaderless cells performing specific actions are historically more comparable to terrorist networks than they are humanitarian operations. The concept of groups self-determining their order of operations is counter-traditional management approaches. However, the unsuccessful initial Hurricane Katrina response by the government [5] has shown that a rigid management can become overwhelmed when emergencies are too geographically widespread, or too many people have been affected. Distributed teams that can utilize knowledge management systems and can dynamically call upon the continually growing user base of the Internet for expert resources and manpower have a better chance to respond to the myriad of future emergencies.

Finally, the use of KM and KMS functions is shown to improve the speed and quality of response actions. This is expected and it is our conclusion that future EIS should incorporate KM considerations.

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