INVESTIGATING INFORMATION TECHNOLOGIES IN DISASTERS: THREE ESSAYS ON MICRO-BLOGGING AND FREE AND OPEN SOURCE SOFTWARE (FOSS) ENVIRONMENT

By

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DEDICATION

This dissertation is dedicated to my parents Juying Chen and Guangcai Li, my husband David Guild, and my daughter Sophia Guild,
who always love and support me.

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ABSTRACT

To cope with the high demand for fast-paced response, disaster management often requires a rapid information exchange involving close collaboration among different parties. Advanced information technology plays an important role in this setting. For instance, micro-blogging services provide a platform for people around the world to propagate and exchange information, and they are simultaneously one of the most accessible mediums in difficult times. In the recovery effort, Free and Open Source Software (FOSS) systems have emerged as an ideal platform for cross-organizational joint disaster management given its enormous benefits of low cost, flexibility, and easy customization. This dissertation aims to investigate how advanced information technologies cope with the various demands of disaster response. It consists of three essays on the exploration of micro-blogging and FOSS environments.

The first essay looks at the usage of micro-blogging in the aftermath of the massive 2008 China earthquake and explores the question whether micro-blogging could replace mainstream media information channels or merely supplement them in the manner of distributing disaster information. Twitter is used as a proxy for micro-blogging in general and the mainstream media information channel is used as the benchmark. In this essay, we focused on two sets of theories which are well known in the IS domain: Information Quality and Collective Intelligence. Information quality (IQ) has been defined as a measure of the "fitness for use" of information (Wang and Strong (1996)). Parker et al (2006) has adapted a framework of thirteen information quality dimensions, which includes: accessibility, accuracy, appropriateness and so on. Delone and Mclean (1992; 2003) also incorporated information quality as one of the determinants that affect

the success of information systems in their proposed IS Success Model. In this essay, we focus on four dimensions: *Timeliness*, *Accessibility*, *Accuracy*, and *Completeness*. Regarding collective intelligence, Web 2.0 applications provide a platform or social network to facilitate communication, information sharing, and collaboration between its users. The concept of collective intelligence has been embraced in nearly all areas where extensive collaboration is a necessity. They have become a new means to collect the wisdom of different groups of people to enable greater productivity and facilitate more meaningful decisions than are possible by individuals working in isolation (Gregg 2010). We argue that micro-blogging can provide integrated and speedy information regarding disaster news. It serves as an excellent supplement to the traditional information channels, and if the circumstances of a situation were to render micro-blogging as the only effective communication tool available, it could certainly serve as a replacement in the short period of time after the disaster happens

The second essay is a case study looking at the deployment of FOSS systems through the collaborative efforts of public and private entities in joint disaster response. Much previous IS research has fallen in the FOSS domain. For example, Currion et al. (2007) discussed the significance of FOSS software for disaster management. They also discussed the component-based design in SAHANA with a focus on technological aspects. Sen et al. (2011) conducted an empirical study of the factors of OSS success as measured by the number of subscribers and developers. The determinants from the technical perspective were found to measure the success of an OSS project. Subramaniam et al (2009) used longitudinal data to investigate the success of an open source software project. The determinants include OSS license, user-interest, and developer-interest from

both the time-invariant and time-dependent perspectives. This essay aims to identify the key factors that affect the potentials for response organizations to explore humanitarian FOSS systems as a novel and economically preferable approach for disaster management. From a collaborative system deployment perspective, it also helps to better understand how the government and private organization partnership in this area may be initiated, how to encourage government to better support their deployment, and how to coordinate with different organizations and leverage the FOSS advantage to the maximum extent. Technology-Organization-Environment (TOE) framework developed by Tornatzkey and Fleischer (1990) was the major theoretical foundation adopted in this essay.

The third essay again touches on the micro-blogging environment and explores how communication patterns evolve on twitter in the midst of a disaster. How the public is reacting and responding to a disaster can be seen in the types of messages they choose to rebroadcast to their audience via 'retweeting'. This essay utilizes data from the period after the 2011 Japanese Earthquake and Tsunami with regards to the radiation threat from the Fukushima reactors. Risk communication is the major theory that we used in the third essay. Risk communication has been defined as an interactive process of an exchange of information, involving multiple messages about the nature of risk (Chartier and Gabler 2000). The media plays an important role in risk communication. It not only provides information, but also brings the public's attention to urgent issues. Slovic (1999) examined risk assessment and the relationship to public perceptions and stated "risk is the socially constructed sum of hazards and public perceptions". Even though the most perfect risk communication may not solve all problems or conflicts, a poor one could lead to an overall failure of risk perception and risk management. We analyze the pattern of

alarming, reassuring, and assuring coverage in the different time periods following the event, and check the different conditions under which the communication patterns change. Again tying in to our first paper where we compare Twitter to mainstream media coverage, findings here expand upon prior research regarding the content of traditional media coverage of a 'hot crisis' by looking at how the content of this new communications medium is similar and different. Finally, governmental information is also communicated in the micro-blogging environment. We examine how the public reacts to this information on Twitter under different circumstances.

Essay 1 Twitter as a Rapid Response News Service: An Exploration in the Context of the 2008 China Earthquake

1. Introduction

On May 12, 2008, at 14:28 hours, a magnitude 8.0 (CSB) / 7.9 (USGS May 2008) earthquake struck the Sichuan province in China (Xinhua May 18 2008). This later turned out to be one of the world's largest natural disasters in recent history. This was also one of the first large-scale natural disasters to occur since the social networking website Twitter, which was created in 2006, became a widespread communications channel. In fact, information was being disseminated by Twitter a full 3 minutes before the USGS had the first report of the earthquake (USGS_News (May 12 2008)). Subsequent to the earthquake, cellular networks were overloaded. Communication with channels accessible via text messaging such as Twitter played an enormous role in helping news be communicated from and to the victims of the disaster as it was often the only communication means available.

Micro-blogging services such at Twitter, have the ability to distribute information very quickly, and possess a unique role in assisting victims in numerous ways during the aftermath. This brings about many exploratory questions: What is the role of micro-blogging as a rapid disaster news service? What type of information quality is provided by micro blogging during different timeframes? Due to the fact that the mainstream media channel provides the news casting function for the audience, we will use the existing mainstream media channel as the reference point for comparison in our paper.

The results of our study will have implications regarding whether the modern communication tool – micro-blogging, could replace the mainstream media information channel or merely supplement it in the manner of distributing disaster information. In prior literature, whenever some new information technology has been studied (such as B-to-C commerce), content analysis and comparisons have been used for research purposes (Kim, Song et al. 2005). We will adopt a similar approach in our paper, using the mainstream media information channel as the benchmark.

The concepts of information quality as well as 'collective intelligence' will be utilized to explore micro-blogging in terms of information quality regarding fast disaster news dissemination and understand how effective it is in adding value through the process of collective intelligence. To the best of our knowledge, this is the first research directly examining the information quality of web 2.0 information channel over time subsequent to a major disaster. The implications of this study are that it can allow emergency responders to choose which information channel to focus on at different times during the disaster response.

The remainder of this paper is organized as follows. The background is described in part 2. The literature review is discussed in part 3. Analysis and our findings are shown in part 4. We conclude with discussion and future research in part 5.

2. Background: Twitter in China and the China Earthquake

2.1. Twitter and Micro blogging in China

Created in 2006, Twitter is one of the most popular micro blogging sites in the world. This social networking website allows anyone to create an account and instantly

broadcast their thoughts to the world. Users can both send and receive messages via twitter.com, as well as by other means such as SMS text messaging, and numerous cell phone and desktop applications. 'Twitter has experienced incredible growth in usage, with total time spent on the website increasing 3712% year over year' according to a June 2009 Nielsen Online survey (Nielsen Jun 2 2009). This does not include mobile usage. Twitter includes multiple functionalities such as 'following' other users. This allows people to see a user's comments in nearly real time via the web or an application. While messages are limited to a mere 140 characters, users are able to immediately broadcast anything to the world with any computer or cell phone with internet capabilities.

With ease, and immediacy of use, micro-blogging is a potentially appealing tool in the case of emergency news dissemination. Consuming low bandwidth in an environment where infrastructure may not be fully intact, information can be easily and quickly disseminated for use by those who need it most. As described in USA Today on May 19, 2009, 'a fast-moving network of text messages, instant messages and blogs has been a powerful source of firsthand accounts of the disaster, as well as pleas for help and even passionate criticism of rescue efforts.' Twitter founder Jack Dorsey told AFP in a 2007 interview that "inspiration for the service came from his experience writing software for courier and emergency service dispatchers that need to route people between locations". Twitter designer Biz Stone recalled an instance of receiving notice about an earthquake in California via twitter just before boarding a train last year. It was there that he first envisioned its potential in emergency response as a communications tool(AFP May 12, 2008). Many people use twitter to check the most recently updated news in emergencies and other breaking events.

Approximately a year after Twitter launched and was gaining a small, but growing base, China saw a number of home-grown micro-blogging websites began to appear. This includes sites such as Digu, Sina, and Fanfou. In addition to messages having a small character limit, these sites began to incorporate other features such as embedded video and pictures. These and other chat providers also allow the ability to also update personal microblogs simultaneously. 'The people who run these Twitter clones in China argue the sites employ features which attract Chinese to socialize and share information in an easier and faster way' (CNN Dec 27 2009). A Twitter clone, QQ, 'is the 9th largest web property in the world and has over 570 million registered users for their instant messaging service of its IM service' (www.qq.com). Another micro-blogging service is called TaoTao, and is in direct competition with other Chinese services (CNN Dec 27 2009). According to a study from San Francisco-based Netpop research, while only seventy-six percent of broadband users in the United States utilize social media features, more than 90 percent of Chinese broadband users do so (CNN Dec 27 2009). The Chinese market is highly receptive to these text based web2.0 communications that are now becoming pervasive in society.

On Jun 2 2009, Twitter was blocked in mainland China. Many of the early Chinese micro-blogging pioneers with similar functions were also blocked, yet unlike Twitter which is still blocked; most had soon found their way back online. For instance Fanfou, reached nearly 1 million registered users by the end of June 2009 (Readwriteweb Mar 5, 2010). Meanwhile, China's 'Great Firewall' has enough holes to allow some Chinese netizens to use Twitter itself versus one of the micro-blog

alternatives' (CNN Dec 27 2009). Michael Anti, a Chinese Twitter user with over 10,000 followers notes, "It is a risk of course". Yet, "the Twitter community is booming and is expanding" (CNN Dec 27 2009). According to the 2010 China Microblog Overview by Buzzle.Com (Feb 23 2010), "Twitter is still very popular with a sub-section of Chinese users who are able to cross the Great Firewall of China.'' They additionally make note of various rumors about the possibility that Twitter is attempting to develop technology to allow all users to cross the firewall, allowing them further development in China' (Buzzle.Com Feb 23 2010) .

While twitter only makes up a subsection of the micro-blogging universe in China, at the time of the Sichuan earthquake, it was fully accessible, and still one of the more widely used micro-blogging services in China. As tweetscan was able to provide us an excellent and full historical search ability of the timeframe around the earthquake on twitter, we were able to obtain a rich data source to analyze and use as a proxy for micro-blogging.

2.2. Sichuan earthquake and Twitter

The Sichuan earthquake was China's largest natural disaster in 30 years. Sichuan suffered an enormous loss with 87,587 reported killed or missing and over 374 thousand injured. Further, 5.36 million buildings collapsed and over 21 million were damaged (USGS May 2008). The communication networks completely went down in Sichuan province and were also disrupted in other areas after the quake (AFP May 12, 2008). "Fixed line phone services were heavily damaged in most neighborhoods", Xinhua quoted one of China's largest mobile service providers as saying. Even China's

Earthquake Department website, a key point for information about the earthquake, was inaccessible (AFP May 12, 2008). Information about the massive earthquake was spread through text messages, instant messages, and micro-blogging services, such as 'twitter'. As the cellular networks were overloaded, this text based communications played an enormous role in helping the victims of the disaster.

AFP (May 12, 2008) reported "*the world had real-time news about China's massive earthquake as victims dashed out "twitter" text messages while it took place, in what was being touted that Tuesday as micro-blogging outshining mainstream news. As the earth shook with tragic consequences, people in the parts of China that felt the quake used their mobile telephones to send terse messages using the service provided by the San Francisco-based Twitter Inc. News of the deadly catastrophe reached Twitter devotees such as blogger Robert Scoble in San Francisco even before the massive temblor, which killed more than 12,000 people in Sichuan province, was reported by news organizations and the earthquake-tracking US Geological Survey"*. Xiao Qiang, a journalism professor at the University of California, Berkeley, commented on Usatoday (5/19/2009) : "*All the major online communities, bloggers, all are very eager to help. It's quite amazing. I haven't seen anything like that, the freedom and the participation, how much the average Internet netizen wants to help*."

According to O'Brien, who started a new project aiming to investigate the newsroom of the future, "*The beauty of Twitter is that it enables: An instant, virtual, citizen journalism newsroom that immediately posts thousands of updates*." Twitter is very good at distributing breaking news. It has the potential to improve the overall reporting and flow of information for everyone (O'brien July 30, 2008). It combines

people who are on their computers, the ones on the move with cell phone and PDAs, twitter facilitates real-time group communication that never existed before (Mills et al 2009). That is why one twitter blogger commented that "*This event has the potential to bring mainstream media into the Twitter world*" in an interview given by AFP (May 12, 2008).

3. Literature Review: Information Quality and Collective Intelligence

3.1. Information Quality

Information quality (IQ) has been defined as a measure of the "fitness for use" of information (Wang and Strong 1996). The quality of information depends on who and how the information is being used. Data meeting the needs of a particular user would be high quality. Data which is of high quality for one user may not necessarily be high quality to another depending on their different needs and perceptions. Since it is a very difficult concept to be captured, defined, and measured, over the last decades, many IS researchers have intensively studied the definitions and taxonomies of IQ in different dimensions, contexts and applications. They feel IQ should be treated as a multi-dimensional concept (Wand and Wang 1996; Wang and Strong 1996; Huang et al. 1999; Helfert et al. 2009). Parker et al (2006) evaluated a number of IQ frameworks in order to identify common elements, differences, and missing elements of such frameworks. Parker et al (2006) has adapted a framework of thirteen information quality dimensions, that includes: accessibility, accuracy, appropriateness and so on.

Delone and Mclean (1992; 2003) also incorporated information quality as one of the determinants that affect the success of information systems in the IS Success Model

which they proposed. In their work, information quality was measured by accuracy, timeliness, completeness, and relevance of the information provided. Helfert et al (2009) also concluded that accuracy, timeliness, accessibility (availability), completeness, consistency, and interpretability should be considered as the most important IQ dimensions.

Pipino and Wang (2002) described a subjective and objective assessment of data quality and presented three functional forms for developing objective data quality metrics, which were simple ratio, min or max operation, and weighted average. Simple ratio measures the ratio of desired outcomes to total outcomes (Pipino and Wang 2002). This ratio ranges from 0 to 1. 0 represents the least desirable outcomes and 1 represents the most desirable outcomes (Pipino and Wang 2002). The four main dimensions described in Pipino and Wang (2002)'s research include *timeliness*, *accessibility*, *accuracy*, and *completeness*.

Timeliness was defined as the extent to which the data is sufficiently up-to-date for the task at hand by Pipino and Wang (2002). Only if the information is up-to-date, is it representative of the current states of the situation. In the context of emergency response, timeliness is one of the most important components of information quality. The initial hours following the disaster are the most important for emergency responders. Every single minute counts, since that is when lives will be saved and lost. We are particularly interested in how quickly micro-blogging can distribute information in disaster, thus we will focus on studying the timeliness aspect of information quality. We will look at both of the positives and negatives regarding timeliness as they pertain to both the mainstream information channel and twitter.

Accessibility (availability) was defined as the extent to which data is available, or easily and quickly retrievable (Pipino and Wang 2002). As mentioned by Vandenbosch and Higgins (1995), accessibility is an important dimension of deciding the use of an information channel. Accessibility of information was a major factor in the Sichuan earthquake. In the area around the epicenter, the infrastructure was devastated. It was not until towards the end of the first month where communications were fully restored. Cell phone conversations were impossible. People had no access to television or the internet. The main mode of two-way communication for most people was text messaging, whose low bandwidth did not place as large of a load on the fragile network. Twitter's ability to be used via text message and the 140 character limit which further constrains its required bandwidth, has made it an ideal communication tool in such a situation. Twitter's structure also allows groups of users to be created which directly broadcast information amongst each other in real time. At the same time, other information channels remained inaccessible in the quake zone (such as the Wenchuan County) for weeks.

Accuracy (free-of-error) was defined as the extent to which data is correct and reliable (Pipino and Wang 2002). Accuracy is vitally important in order for resources to be properly and most effectively allocated to quickly assist the maximum number of people. Erroneous information can waste precious minutes and seconds. A mistaken location or incorrect assessment of severity causes resources to be sent to an area in less need of aid, or perhaps where it is not needed at all. The inherent characteristics of micro-blogging allow it to provide information, and simultaneously confirm it through the power of collective intelligence, which will be discussed later in the paper. Single

incorrect reports are bound to occur and will in fact be common. However these erroneous reports will be overwhelmed by repeated reports of the correct information from other sources. This allows for increased accuracy over a short period of time.

Completeness was defined as the extent to which data is not missing and is of sufficient breadth and depth for the task at hand (Pipino and Wang 2002). Completeness is also extremely important in allocating emergency response resources. As in all decision making processes, a more complete picture of the situation allows for better conclusions being drawn. Resources can again be easily misallocated without completeness. In the example of the earthquake, perfectly immediate and accurate information about a situation requiring assistance could have been provided to emergency response, but if that information was incomplete, for example, some areas were completely inaccessible, time and resources could be wasted. Again, the power of collective intelligence allows micro-blogging to provide a superior overview of the situation, and a greater degree of completeness. Similar to a wiki, while a single entry provides but a small sliver of the overall picture, thousands of entries together can provide a grand overview.

3.2. Collective Intelligence

Weiss (2006) indicates that as far back as 1968, computer visionaries foresaw the possibilities of utilizing computers for cooperative purposes in allowing people capable of solving specific problems to share their ideas. (Gregg 2010). “A collective intelligence application is one that harnesses the knowledge and work of its users to provide the data for the application and to improve its usefulness” (Gregg 2010). Web 2.0 is how the most hyped examples of collective intelligence have come to be known as. (Gregg 2010).

These web 2.0 applications provide a platform or social network to facilitate communication, information sharing, and collaboration between its users. The concept of collective intelligence has been embraced in nearly all areas where extensive collaboration is a necessity. While computers were traditionally seen as a mere supportive tool, web 2.0 applications see them as a means to collect the wisdom of different groups of people to enable greater productivity and facilitate more meaningful decisions than are possible by individuals working in isolation (Gregg 2010). For example, anyone can add, supplement, and correct the definition and description of a term in Wikipedia, a free, web-based, collaborative, and multilingual encyclopedia project (www.wikipeida.org). In other words, value is added through the contributions of information from a great number of people. A data collocation and analysis process is performed before the publication of an article in a newspaper or magazine. With twitters'140 character limit, the collective intelligence is performed through multiple tweets that answer, describe, or supplement the same question and topic. In this paper, we also investigate the collective intelligence that tweets provide as compared to mainstream multimedia.

In the following section, we shall focus on the quality of information that micro-blogging can provide in distributing news about a disaster. We will concentrate on the following four well-identified information quality dimensions in the IS area: timeliness, accessibility, accuracy, and completeness. Additionally, we will investigate how effective twitter is in terms of 'collective intelligence'.

4. Analysis and Findings

4.1. Timeliness

4.1.1 Data collecting and sample characteristics

We used the Factiva database to obtain the sample of the mainstream news. We used 'China Earthquake' as the key words and specified the date range as between May 12 2008 to Jun 12 2009. It returned 1836 articles. We enabled the 'identify duplicate' option in order to avoid double counting. Factiva indicated 281 duplicate articles, leaving a sample of 1555 articles. 'Tweet Scan' is a search engine which enables search of Twitter messages in real-time (www.tweetscan.com), which has been given 2008 Web 2.0 Award. TweetScan gave us the access to historical twitter database. We inputted the same search criteria as what we did with the Factiva database. 2130 tweets were found in our specified time period. By inputting similar criteria related to this earthquake, such as Wenchuan Earthquake, Sichuan Earthquake, Disaster, and Chengdu, more than 80,000 tweets were found. However, in order to more precisely be able to compare it with the mainstream information channel serving as the benchmark in this case, 2130 tweets were selected matching the search criteria "China Earthquake" exactly in our specified time period.

We classified the data into five buckets:

1) less than 1 hour after the earthquake
2) between the second hour to the end of first day
3) between the second day to the end of first week
4) the second week
5) between week three to the end of the first month

The statistics are shown in table 1.

Timeliness	Mainstream (#)	Twitter (#)	Mainstream (%)	Twitter (%)
< Hour 1	9	433	1%	20%
Btw Hour 2 to End of Day 1	99	1071	6%	50%
Btw Day 2 to End of Week 1	597	327	38%	15%
The Second Week	448	111	29%	5%
Btw Week 3 to End of 1 month	402	188	26%	9%
Sum	1555	2130	100%	100%

Table 1. Statistics of Mainstream articles and Tweets gathered

4.1.2 Analysis of Timeliness Dimension

We observed 433 tweets in the first hour in contrast to 9 items from mainstream media; 1504 tweets during the first day in contrast to a mere 108 items from traditional media. Immediately after the first day however, traditional media consistently provided more information, with 597 articles the rest of week one compared to 327 tweets, 448 articles week two in contrast with 111 tweets, and then 402 articles the remainder of the month, in contrast with 188 tweets.

Figure 1 shows the comparison of timeliness with the two information channels. Figure 2 interprets the same data in a cumulative manner.

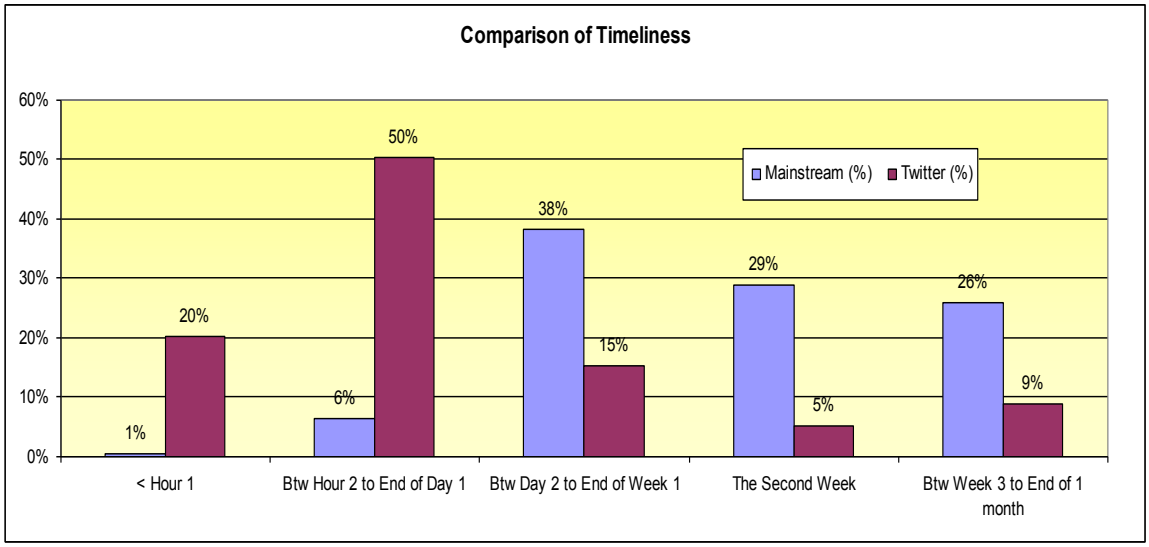
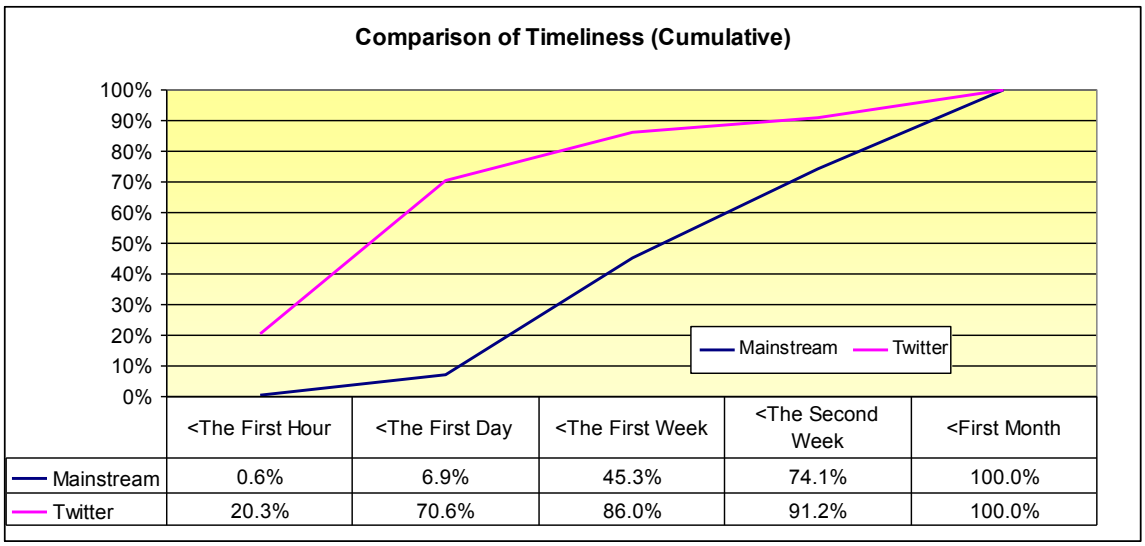


Figure 1. Comparison of Timeliness



	<The First Hour	<The First Day	<The First Week	<The Second Week	<First Month
Mainstream	0.6%	6.9%	45.3%	74.1%	100.0%
Twitter	20.3%	70.6%	86.0%	91.2%	100.0%

Figure 2. Comparison of Timeliness (Cumulative)

The initial minutes and hours following a catastrophe are the most important for emergency responders. These are the moments when lives will be saved or lost. 20% of the total information coming out of twitter was focused in the very first hour of the catastrophe. Meanwhile traditional media has a much more linear relationship between time and coverage of the event with about 1% and 7% of information coming in the first

hour and the first day and it steadily remaining in the news in the weeks that followed. At the time when information knowledge is most critical, traditional media is extremely lacking compared to twitter. In fact, information was coming out of twitter a full 3 minutes before the USGS had the first report of the earthquake (BBC May 12 2008; SearchEngineLand News May 12 2008). Several people in China reported the earthquake via twitter while it was still going on. The US Geological Survey (USGS) has people who work full time to watch for and observe earthquakes and tremors. They have seismometers monitoring movement in the earth in real-time. As noted by Search Engine Land blogger Danny Sullivan called it "absurd" to suggest that Twitter users knew of the Sichuan earthquake before the US Geological Survey, which uses seismic equipment positioned around the world to record such events, and then after a scientist's review sends out notices of the events (SearchEngineLand News May 12 2008). However in terms of this information being broadcast to the world for use by others, this was indeed the case.

Looking at twitter and the traditional media over the four weeks following the Sichuan earthquake, the majority of the media's coverage occurred on day two and later, while over 70% of the information coming from twitter was during the very first day, after which interest rapidly declined. Traditional media has the following drawback with regards to timeliness:

(a) Slow to report.

(b) Have to spend time checking sources before publishing.

(c) More resources devoted to covering the aftermath.

Emergency responders and twitter users in fact have a similar timeframe of interest. While emergency response needs to gather information as quickly as possible, twitter users converse about what is happening immediately around them. They are both most engaged immediately. The following figure from tweetip.com demonstrates the immediate spike and decline in information coming from twitter by plotting in five minute segments, the number of tweets containing 'Earthquake China'. Our data obtained from tweetscan confirmed this behavior.

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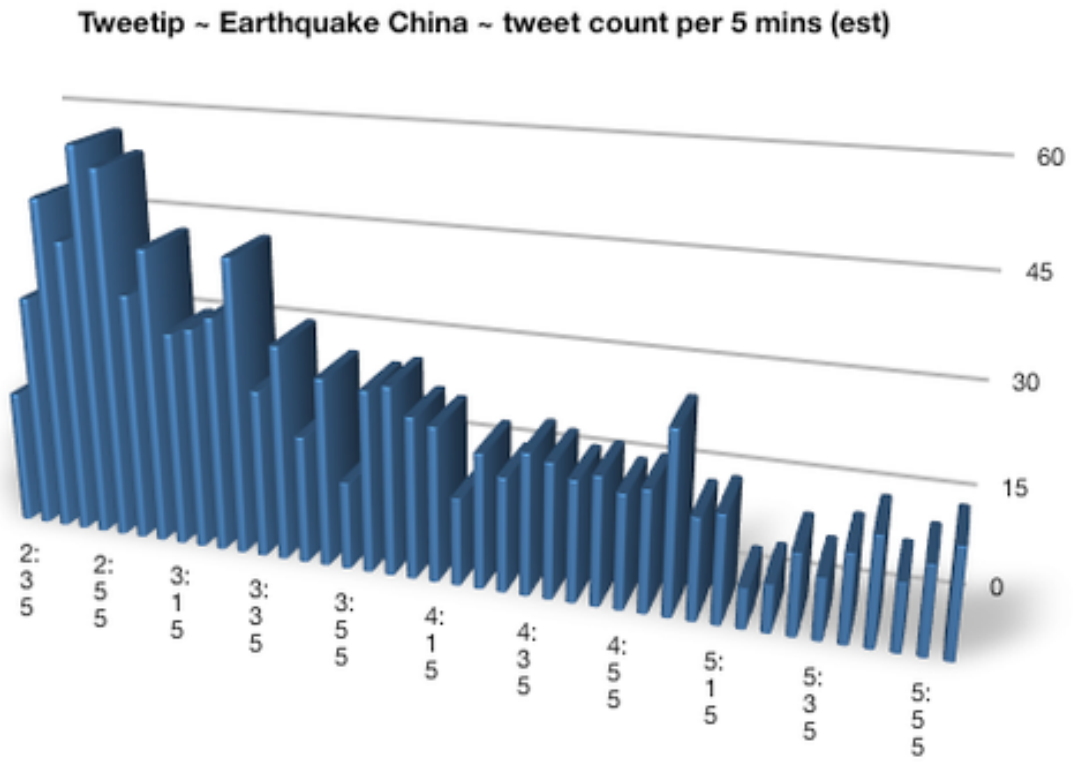

Figure 3. Tweet count per 5 minutes (adopted from Tweetip.com)

In emergency response systems, we should be taking advantage of the immediacy provided by twitter in getting information out to the masses. Such an easily utilized

communication channel which broadcasts the information as quickly as twitter is unknown to us. Just a few minutes difference in getting information out can make an enormous difference in getting resources ready and gathering the response crew. We believe incorporation of twitter can dramatically help improve the information quality in terms of timeliness for emergency response system.

4.2. Accessibility

After the earthquake, the IT infrastructure was seriously damaged in the quake zone. According to EERI special earthquake report (Oct 2008), the electric grid was compromised throughout most of the disaster area. Every city in the surrounding area with the exception of Chengdu suffered power outages. Outages ranged from 10 to 20 days, with remote areas experiencing longer outages due to increased difficulty in accessing the areas in need of repair. Both hydro-electric, and coal powered electric plans experienced extensive damage and remained out of service for up to 60 days after the earthquake. Even the more populated and easier to access areas affected by the earthquake were without power for many days. Very few sources of information were available. Micro blogging and text messages which consume very limited bandwidth were often the only available information resources. Residents in the affected areas were not able to receive information from TV, radio, or Internet. Text based cellular communications were the only remaining ways to retrieve information. Mobile communications were not just beneficial for quake victims; it was also of great assistance to disaster response and recovery.

Steve Inskeep hosted a National Public Radio interview show on May 14, 2008. Some of its transcript is cited below. It once again shows how quake zone victims relied on the new information channel which consumes very limited bandwidth as the only communication way after the quake.

- *Host: People after rushing out in the streets of Chengdu to get out of buildings that they were afraid would fall were all on their cell phones sending text messages. That turns out to be the way that the first word got out about this earthquake, in a country where some 600 million people have cell phones.*
- *Quake Zone Resident: It (text messaging) is a very practical tool, and it's very busy. The user doesn't require any fancy phones, it works on everything, and it's very reliable. It's something like 99.9 percent arrival rates.*
- *Quake Zone Resident: People living in tents can't recharge their batteries. In the meantime it is very difficult to get the call through as the signals are very bad. Text messaging was the only way to go.*

We have gathered some news on the recovery of power, IT infrastructure, and cell towers from the related authorities. It serves as the basis for our following analysis.

- *Mobile service operator China Mobile's branch in Sichuan said about 2,300 local base stations stopped operating due to power shutdowns and transmission failures caused by the quake and three switching stations were overloaded. China Mobile has immediately started repairing affected facilities. Besides power disruptions and a surge in call volumes following the quake could have also slowed the cell phone network, they*

said. Call volumes were 10 times the normal level and the percentage of connections fell by half, China Mobile said (BBC Monitoring Asia Pacific May 12, 2008).

- *According to Wall Street Journal News (May 22, 2008), China Mobile, like many other businesses that operate near the quake epicenter in Sichuan province, was jolted by the May 12 earthquake. At one point, 4,457 of its cell towers were out of service and phone traffic in Sichuan backed up with huge increases in calls. Yet the quick restoration of mobile phone coverage to all but a small portion of the quake zone is one of the hallmarks of China's strong response to the disaster. --- Initially, the mobile phone coverage was OK. A backup power source, designed for just such an emergency, kept the cell phone tower operational, though heavy phone traffic made it tough to get through sometimes. By the third day after the quake, however, the tower had used up all its juice, and cell phone coverage was officially out for the first time since the earthquake.*

- *China Mobile (May 14 2008) said that by 8:00 CST on May 13, it had repaired 1,850 of the 4,457 base stations damaged in the afflicted region.*

- *Update from the Chinese Embassy (May 22 2008), 'So far, 23,117 of the 25,062 damaged telecommunications base stations have been repaired.'*

- *According to the State Electricity Regulatory Commission (SERC_1), as of 12:00 on May 25 (Sunday), electricity power supply had been restored in 12 Counties, including Lixian, but not yet in Beichuan County. According to the Ministry of Industry and Informatization, as of Sunday, May 25, public telecommunications services like mobile phone and fixed-line telephone had been restored in 62 of 109 towns and villages in quake zone, enabling local residents to communicate in different ways.*

- *According to State Electricity Regulatory Commission (SERC_2), as of midday June 9th, electricity power supply had been restored in 114 of the 135 towns and villages (in 7 counties of Sichuan Province) that suffered power outage as a result of the devastating earthquake which struck southwest China on May 12th*

Based on the news provided by the several authorities as shown above, we have conducted the following analysis.

1. Hour 1 and May 12: Once the power reserves of the cell towers were depleted, their ability to facilitate communication via text message and twitter also ended. Per China Mobile, 40% of the downed and damaged towers were back in service the first day. Because the text messages and twitter consume extremely low bandwidth, we make the assumption that if a cell tower is functioning, then both text messages and twitter are accessible. Due to the extremely high traffic where all volumes were 10 times the normal level and the percentage of connections fell by half per China Mobile, we are applying a 0.5 discount factor here to make a very conservative assumption that only 50% of the text messages and twitters go through if the cell tower is functioning. Anecdotal quotes above from quake zone survivors imply functionality of text messaging was far better than 50%, but we will hedge on the conservative side with our estimates.

Initial reports from China mobile indicated that 2300 of their base stations had been damaged. By May 13th, China Mobile was reporting they had already restored service to 1850 of the 4457 base stations which had gone out of service. The increase in base stations going out of service leads from the lack of electricity, and the back up power supplies quickly ran out of electricity. During this timeframe, both China Mobile and China Unicom (May 16 2008) made statements that half of their base stations had

been affected. Not knowing exactly what time these 50% statements were made in reference to, we can estimate that China Mobile would have had between 4600 and 8914 base stations in Sichuan Province at the time of the earthquake. In the worst case, if the 2300 base stations were all knocked out immediately, accessibility would have been between 50% and 74% in the first hour. Multiplying by our 0.5 discount factor, we estimate an accessibility rate between 25% and 37%. For simplicity, and lack of detailed hour by hour numbers, we will assume this accessibility for the rest of the day.

During this period of time, use of traditional mainstream media is virtually impossible due to the complete lack of power.

2. ***May 13:*** It is important to note that the number of failed base stations continued to increase from the first day due to the backup power supplies being exhausted as noted in the Wall Street Journal article above. So while stations were being repaired, new ones were also going offline. Per China Mobile, 1850 of the 4457 damaged base stations were restored on May 13. This means 2607 base stations were still non-functional. This gives us accessibility of between 43% and 71%. Multiplying by our 0.5 discount factor, our estimated accessibility rate is between 21% and 35%. During this period of time, traditional media remains inaccessible.

3. ***May 22:*** The May 22nd update from the Chinese Embassy (May 22 2008) states *'So far, 23,117 of the 25,062 damaged telecommunications base stations have been repaired'* bringing us to 92% of the damaged stations being functional, and accessibility would be between 92% and 96%.Since the demand on cell towers was not as high as during the first couple days, we apply a 0.8 discount factor here, leaving us a range of between 74% and 77% accessibility. As shown by item 5 from the State Electricity

Regulatory Commission, the mainstream accessibility rate is 57% on May 25. By assuming the recovery rate is constant, we can derive a 44% (57%*(22-12)/(25-12)) accessibility rate on the day of May 22.

4. ***May 25***: Public telecommunications services like mobile phone and fixed-line telephone had been restored in 62 of 109 towns and villages in quake zone, enabling local residents to communicate in different ways. Here we can derive a 57% accessibility rate for traditional channels. We make a conservative assumption here that the accessibility rate of text based communication over the cellular network remains in the 74%-77% range of May 22.

5. ***June 9***: On the June 9th update of the State Electricity Regulatory Commission, still 16% of affected towns and villages were without power. We make the assumption that once power is restored to an area, people are once again able to access both twitter, and traditional information channels on an equal basis. Since the high demand on the cellular network is no longer a factor, we will no longer apply the 0.8 discount factor. We simply have an 84% accessibility rate for both communication channels. Cellular communication accessibility could, and likely was higher, but again keeping our estimates conservative, we will assume the 84%.

The detailed comparison of accessibility between the twitter upper and lower bounds and mainstream information channels is shown in figure 4.

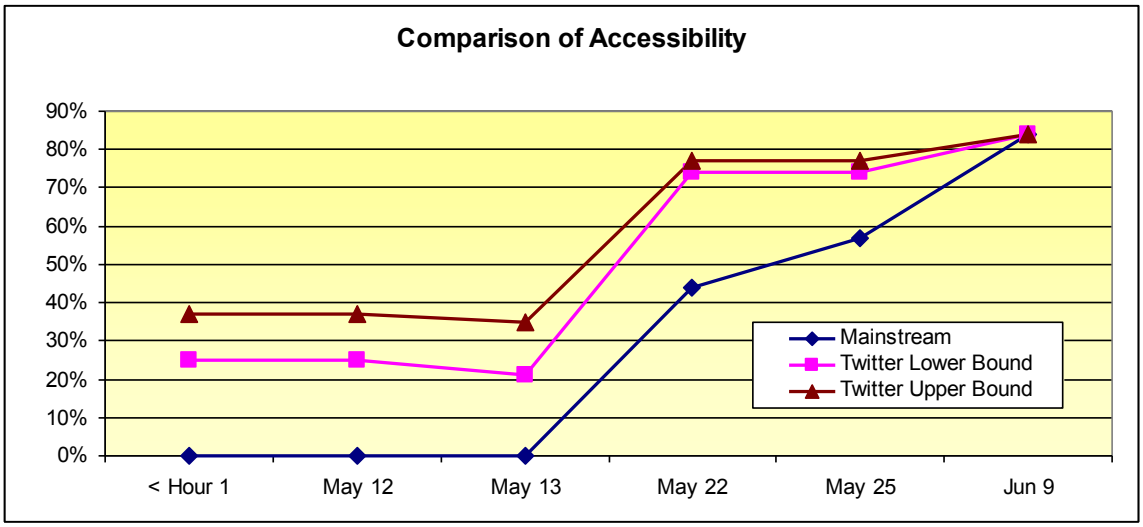

Figure 4. Comparison of Accessibility

From this hypothetical figure, we can see in the emergency response system, twitter is the much more effective tool for information dissemination in the critical moments following the event and its accessibility never falls below that of mainstream media. Regardless of whether we look at the lower or upper bound of our conservative twitter accessibility estimates, they both show twitter to be significantly more accessible in the emergency situation over the entire time period. For emergency response, this is especially the case during the most essential timeframe, immediately after the event, but is also applicable in all following timeframes.

In analyzing the dimension 'timeliness', the focus of analysis is on the actual time information became available to the whole world. How quickly information becomes available has a direct effect on the speed of action by the emergency responders and volunteers. When looking at 'accessibility', our focus is on when that information became accessible to those affected in the earthquake area. This is extremely important in terms of emergency responders being able to find the victims, as well as in allowing the victims to better locate assistance, improve their conditions, and contact loved ones. In

the next two sections, we are going to look at the information quality dimensions 'accuracy' and 'completeness'. As these two dimensions are not as easily quantified as the previous two, content analysis will be used as a proxy to comparatively measure the two information channels.

4.3. Accuracy

A semantic content analysis approach was used to quantify the following two dimensions of information quality: accuracy and completeness. Busch and et al (2005) had an excellent guide to content analysis: Content analysis is a research tool used to determine the presence of certain words or concepts within texts or sets of texts. Researchers quantify and analyze the presence, meaning and relationship of such words and concepts, then make inferences about the messages within the texts, the writer(s), the audience, and even the culture and time of which these are a part (Busch and et al 2005).

CATPAC is the software which we used for the following content analysis. CATPAC is a program that can read any text and summarize its main ideas (www.galileoco.com). This self-organizing artificial neural network computer program has been optimized to read and analyze large amounts of text (Kim, and et al 2005). By reading the text, it can produce a lot of outputs, such as determining the most frequently used symbols and words, identifying the patterns of similarity based on those words' co-occurrences, and providing other different cluster analysis.

In the research conducted by Singh and et al (2009), a list of keywords was created to represent different dimensions of information quality. In order not to underestimate the importance of a concept, they first chose a few synonyms (such as

'available', and 'reachable', and 'accessible'). Furthermore, in order to best cover the relevant words, both synonyms and antonyms (such as 'inaccessible' and 'accessible') were included for each quality dimension in their research. We have adopted their word lists in our research and also assign each word equal 'weight'.

Information Quality Dimension	Keywords
Accuracy	accurate, inaccurate, accurately, confirmed, uncertainty, uncertain, rely, reliable, relied, wrong, false

Table 2. Keyword list for accuracy dimension adopted from Singh et al (2009)

We have included the words in the keyword list in the 'include' file of the CATPAC program to make sure that all the keywords appear in the program's dendogram output. Thus we can easily sum up the frequency of each word in the list. Then we calculated the 'hit density' of sum of the frequency of the keywords within both traditional media and twitter. This allows us a method of measurement with which to compare to two mediums. Efthimiadis (1993) defined hit density as the ratio of the number of 'hits' divided by the number of content-bearing words in an article. Our calculation of hit density is a simple ratio of the number of sum of the frequency of the key words, as identified by CATPAC, to the total number of words appearing in the articles and tweets. We have grouped the articles and tweets by the following five time frames and summarized the content and hit density for each. As Singh and et al (2009) suggested, we also reviewed all the high frequency words in the output to make sure that we did not miss any other high frequency keyword that can possibly represent the

information quality dimension. The summaries of hit density of the 'accuracy' dimension for both mainstream papers and twitters are shown below.

Accuracy: Mainstream Articles	Total number of words	Sum of the appearances of the keywords	Hit Density
< Hour 1	338	1	0.002959
Btw Hour 2 to End of Day 1	28851	63	0.002184
Btw Day 2 to End of Week 1	26020	159	0.006111
The Second Week	20037	110	0.005490
Btw Week 3 to End of 1 month	17069	83	0.004863
Sum	92315	416	0.004506

Table 3. Hit density of the 'accuracy' dimension for mainstream articles

Accuracy: Twitter	Total number of words	Sum of the appearances of the keywords	Hit Density
< Hour 1	2913	4	0.001373
Btw Hour 2 to End of Day 1	7592	2	0.000263
Btw Day 2 to End of Week 1	2438	1	0.000410
The Second Week	891	2	0.002245
Btw Week 3 to End of 1 month	1478	3	0.002030
Sum	15312	12	0.000784

Table 4. Hit density of the 'accuracy' dimension for tweets

The detailed comparison of accuracy between the mainstream information channels and twitter is shown in figure 5. We multiplied the scale of the 'hit density' axis by 10^3 in the figures for ease of viewing.

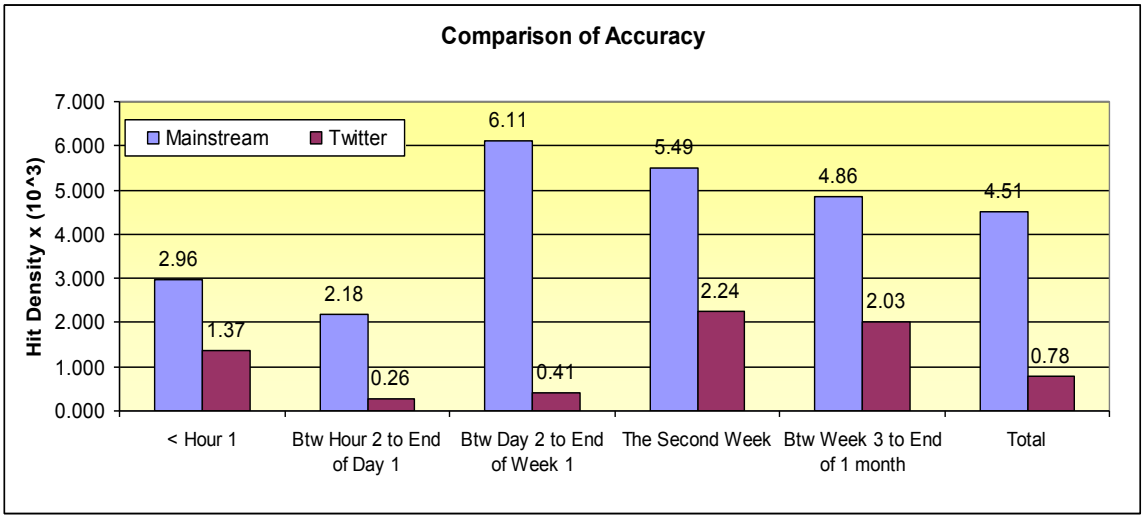

Figure 5. Comparison of Accuracy

As viewed via this method of 'hit density', traditional media is at all times shown to be more effective in communication accuracy. We define the ratio between mainstream and twitter as the mainstream hit density divided by the tweet hit density. It is a low of 2.2 (2.96 divided by 1.37) during the first hour, and a high of 14.9 between day two and the end of the first week. Overall, traditional media has a hit rate 5.8 times that of twitter with regards to accuracy. While still trailing traditional media, twitter does in fact show a higher focus during the first hour on accuracy than it does during the rest of the first week. It is also during this first hour where twitter is closest to traditional media using this measurement of accuracy. While the significance is unclear, it is also interesting to note that traditional media sees a large spike in accuracy starting on day two, which then slowly declines, while twitter shows similar behavior, but does not see the increase until the second week. The accuracy ratio between mainstream and twitter across different time frames is shown below.

Accuracy Ratio: 'Mainstream' Hit Density : 'Twitter' Hit Density	Ratio
< Hour 1	2.2
Btw Hour 2 to End of Day 1	8.3
Btw Day 2 to End of Week 1	14.9
The Second Week	2.4
Btw Week 3 to End of 1 month	2.4
Total	5.8

Table 5. Accuracy ratio between mainstream and twitter

One reason for the higher hit density for mainstream media coverage is twitter's 140 character limit. Combined with the fact then when filtering for the words China, earthquake, and the space take up 16 of these characters, this leaves a mere 124 characters for the key words to appear in. Furthermore, Twitter's built-in character limit encourages the use of abbreviations and more concise words. A twelve-character word such as 'insufficient' is less likely to be used in a twitter message as it consumes such a large percentage of the character limit. Traditional media obviously does not have this constraint.

Another cause for the gap between the hit density of the mainstream and twitter mediums is the large amount of additional noise found in twitter. While the mainstream media is very focused on reporting what has happened, twitter also contains a much higher weight of messages which are merely comments and anecdotes from people. One must filter through many more messages in twitter in order to uncover the information bearing ones. This has largely been done for us in advance by the traditional media.

The Twitter medium is more focused on what is happening immediately around people. There is a misalignment between this focus, and that of the mainstream media. This is particularly evident with the increase in the hit density ratio between mainstream media and twitter in the second day, and the remainder of the first week. While the newspapers and television were busily reporting how big the earthquake was, where it struck, and ensuring this information was accurate for days after it occurred, people on twitter had moved on and were communicating on the big picture of what was happening around them currently. There is a very quick shift in focus from the earthquake to the earthquake's effect. As more time passes, the two mediums interests re-align as the mainstream media's relative focus again more closely mirrors that of the twitter community. We can see the hit density ratio then reverts back to what it was during the first hour.

From the perspective of accuracy, traditional media channels still must play an important roll in emergency response systems. Twitter can be most effectively used in order to gather as much information as quickly as possible in the immediate moments after the disaster event, but traditional media channels need to be used during the entirety of the timeline in order to confirm this information's accuracy. It is very important that the designers of emergency response systems are aware of it.

4.4. Completeness

We used the same methodology as discussed in the 'accuracy' dimension for the content analysis of the 'completeness' dimension. The keywords are listed in table 6.

Information Quality Dimension	Keywords
Completeness	adequate, complete, entire, entirely, inadequate, incomplete, insufficient, integrity, unaware, unknown, wholeness,

Table 6. Keyword list for completeness dimension adopted from Singh et al (2009)

The summaries of the hit density of the 'completeness' dimension for both mainstream papers and twitters are shown below:

Completeness: Mainstream Papers	Total number of words	Sum of the appearances of the keywords	Hit Density
< Hour 1	338	0	0.000000
Btw Hour 2 to End of Day 1	28851	21	0.000728
Btw Day 2 to End of Week 1	26020	72	0.002767
The Second Week	20037	77	0.003843
Btw Week 3 to End of 1 month	17069	57	0.003339
Total	92315	227	0.002470

Table 7. Hit density of the 'completeness' dimension for mainstream papers

Completeness: Twitter	Total number of words	Sum of the appearances of the keywords	Hit Density
< Hour 1	2913	2	0.000687
Btw Hour 2 to End of Day 1	7592	1	0.000132
Btw Day 2 to End of Week 1	2438	2	0.000820
The Second Week	891	1	0.001122
Btw Week 3 to End of 1 month	1478	1	0.000677
Total	15312	7	0.000457

Table 8. Hit density of the 'completeness' dimension for tweets

The detailed comparison of completeness between the mainstream information channels and twitter is shown in figure 6. We multiplied the scale of the 'hit density' axis by 10^3 in the figures for ease of viewing.

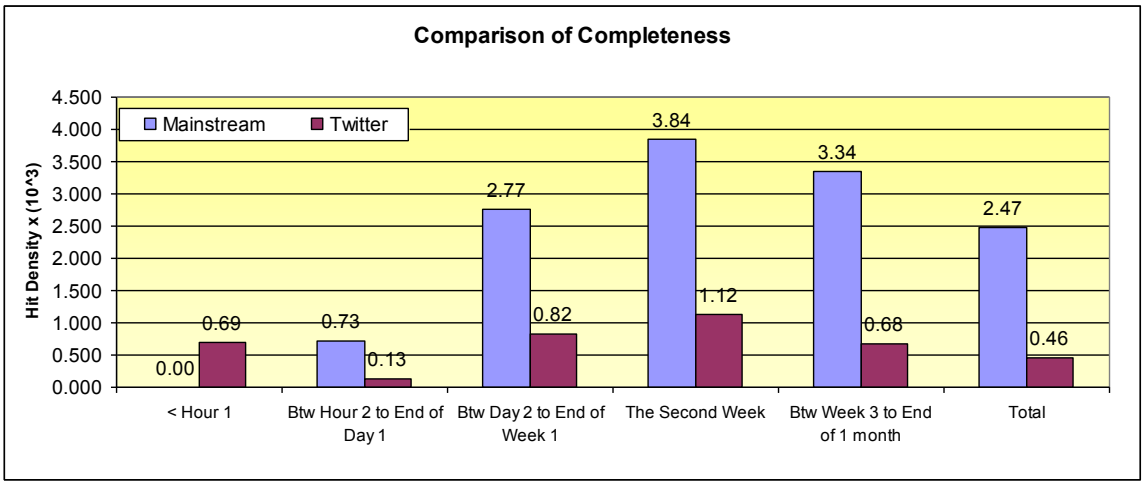

Figure 6. Comparison of Completeness

A comparison of completeness shows that in the first hour, twitter has one of its higher hit rates of the entire time period, while traditional media contained not a single word exhibiting completeness. It scored zero. After hour two, traditional media once

again indicates a higher level of completeness than twitter, with both exhibiting a pattern of increasing to a peak during the second week, and dropping slightly beyond that. The overall hit rate for completeness was 5.4 times greater in the traditional media than twitter. After the first hour, results were much smoother than when we looked at accuracy, with ratios staying within a range of 3.4 to 5.5. The completeness ratio between mainstream and twitter across different time frames is shown below.

Completeness Ratio: **'Mainstream' Hit Density : 'Twitter' Hit Density**	**Ratio**
< Hour 1	0.0
Btw Hour 2 to End of Day 1	5.5
Btw Day 2 to End of Week 1	3.4
The Second Week	3.4
Btw Week 3 to End of 1 month	4.9
Total	5.4

Table 9. Completeness ratio between mainstream and twitter

In looking at completeness, we again have the same instance as we did with accuracy with regards to twitter's 140 character limit, and additional noise contributing to the gap between the hit density of mainstream media and twitter. One thing is very different however. After the first hour, the mainstream media and twitter quickly align with each other in their respective focus on completeness. The hit density ratio remaining within the relatively a narrow range, combined with the lower overall ratio between the hit densities show twitter to be more comparable to the mainstream reporting channel in completeness than accuracy, and infinitely better during the very first hour.

Similarly to as we discussed with regards to the accuracy dimension, with the exception of the moments immediately following the disaster event, emergency response systems still need to rely on mainstream information channels to ensure completeness of information. In the design of emergency response system, we should never overlook that those traditional information channels still serve as a sort of referee to the information coming out of the twitter channel.

4.5. Collective Intelligence[1]

While we studied the 'accuracy' and 'completeness' dimensions of information quality, one of the functions that CATPAC program provides is a summary of all the high frequency words appearing in articles. There are 9 mainstream articles and 433 tweets in the first hour after the earthquake. Since we are primarily interested in the distribution of disaster news, we will focus on this time frame to compare the effectiveness of the collective intelligence provided by both information channels.

First we started with the top 10 frequency words in each of the 9 mainstream articles. Then we went through the tweets following their time stamps, and tried to identify how many tweets were needed to cover those same 10 high frequency words. The average number was 39. So on average, in order to cover the top 10 frequency words appearing in one article, 39 tweets are needed. The detailed data is shown in the table 10.

[1] We thank an anonymous referee for insightful contributions used in this section.

No	Number of words in the article	# of Tweets to cover the top 10 high frequency words in the article
1	276	21
2	643	42
3	325	47
4	576	32
5	298	37
6	407	51
7	587	30
8	412	34
9	542	61

Table 10. Competitive Intelligence

The average number of words those 9 articles contain is 452, while the average number of the words that each of the 433 tweets from the first hour contained is 11. Thus the average word number of one article is 41 times that of the corresponding tweets. Interestingly, only thirty-nine tweets were needed to cover all of the ten most frequently occurring words from one article. Put another way, a mainstream article of a length the equivalent of forty-one tweets has the same information content of only thirty-nine tweets. From this perspective, twitter is slightly more effective and efficient than the mainstream media in terms of collective intelligence. This number is a larger if one excludes the key search phrase 'China Earthquake' from the word counts as it is highly unlikely to appear but a few times in an article, making up just 1-2 % of the content. Meanwhile by the nature of how the data was collected from twitter, the key phrase alone is 18% (2 divided

by 11) of the content for micro-blogging. In this case, twitter will be even more effective in terms of collective intelligence immediately after the earthquake.

The Twitter medium is very focused on what is happening immediately around people. As discussed previously, the inherent characteristics of micro-blogging allow it to provide information, and simultaneously confirm it through the power of collective intelligence. Erroneous reports will be overwhelmed by the repeated reports of the correct information from other sources.

5. Discussion and Conclusion

This paper has been an exploration of Twitter as a rapid response news service as compared to mainstream newspaper media in the context of the China Earthquake of 2008. The China earthquake was the first large scale natural disaster where Twitter was used in a major way. As Homeland security consultant W. David Stephenson demonstrated how to use Twitter in emergencies in the episode of his video series '21st century disaster tips you won't hear from officials', he commented that twitter is not only one of the best tools for citizen reporting in emergencies, its real usefulness is its ability to get messages to users' friends and family and provide evacuation updates. The messages can include information about where the shelters are, distribution sites, and other contact information (Singel R. Oct 24, 2007). Observing twitter's growth, it is worth understanding what role twitter can play in distributing information during emergency response, and what its advantages and disadvantages are as it continues to gain a wider audience. In our analysis, we focus on the five important information quality dimensions: timeliness, accessibility, accuracy, and completeness, as well as collective

intelligence, we have found that micro-blogging is a very effective tool for information dissemination in the critical moments following the disaster. This communication method, which requires extremely low bandwidth, may be the only accessible tool in a fragile communications network after a disaster. Furthermore, it enables not just a two-way communication; micro-blogging's unique structure also allows users to directly broadcast information amongst groups of people, and be seen and referenced by others. This broadcast ability is extremely critical in emergency response. While micro-blogging can contain a good deal of noise and extraneous information, it can be negotiated through in order to find the content with information value.

From our research, we have found that micro-blogging can serve as an excellent supplement to the traditional information channels, and if the circumstances required in a situation where it is the only effective communication tool available, micro-blogging could certainly serve as a replacement in the short period of time after the disaster happens. Based on the well-defined dimensions of information quality, we tried to provide a complete picture of micro-blogging in distributing information in emergency response. We aim to raise the audience's interest in considering further development in utilizing micro-blogging as a new, flexible, and powerful information channel in emergency response. As Mills et al (2009) stated, twitter has the potential to become a centrally-operated tool for crisis management organization (CMOs), municipal, state, and federal government agencies and other organizations involved in disaster response and recovery. We hope to focus on other iterations of the web 2.0 information channel in our future research, including text messaging and mobile voice communications. We hope our research can shed some light in this direction.

Essay 2 A Case Study of Private-Public Collaboration for Humanitarian Free and Open Source Disaster Management Software Deployment

1. Introduction

Natural disasters are characterized by large scale detrimental impacts and devastating consequences. Disaster management in practice is challenged in a number of ways. First, response organizations are often constrained by available resources in the affected regions. In addition, a disastrous event may involve rapidly changing conditions, hence frequently forcing responders to perform un-planned tasks. Furthermore, it involves multiple organizations working in a collaborative and coordinated manner. Free and open source software (FOSS) systems present a means to handle these challenges. It offers system developers the freedom to reuse the software. In recent years, more and more responses to natural disasters have utilized FOSS for disaster management purposes. In general, the use of FOSS systems helps to develop response information systems that help manage humanitarian response resources (e.g. food, shelter, and medical supplies), distribute response intelligence, and coordinate response operations (Morelli, Silva et al. 2010).

The research on FOSS in humanitarian relief operations is still in its infancy. Considering its potential significance on disaster management, (Guo, Yang et al. 2010) called for new research to further our understanding of humanitarian FOSS. To date, a number of imperative research issues have not been thoroughly explored, including the success factors to the joint deployment of disaster FOSS by public and private sectors. The deployment of a FOSS system is a complex process and often involves multiple stakeholders who represent government agencies, non-government organizations, and

volunteers. Without a quick and well-executed deployment, a FOSS system may not achieve its full potential, leaving human lives and properties at risk. The current study fills this research gap by answering the question of: "What are key issues that affect the success of private-public collaborative deployment of humanitarian FOSS systems?" We identify the imperative issues in FOSS deployment through the lens of the Technology-Organization-Environment (TOE) framework (Tornatzkey and Fleischer 1990). To elaborate our understanding of the issues, we collect qualitative data about humanitarian FOSS collaboration projects . The data was collected from key informants in private and public sectors, who participated in recent disaster management operations worldwide. Based on the previous literature and our data, we present a set of research propositions.

This paper contributes to the literature of disaster management and FOSS. Research in disaster management information systems design has largely ignored the potential role of FOSS. Through the examination of FOSS deployment with qualitative data collected from global leaders in the field, we discuss the potential of humanitarian FOSS for leveraging public and private resources to meet the demand of disaster response. Our study contributes to FOSS literature as we identify the major issues that contribute to the successful deployment of humanitarian FOSS. The research propositions developed in this study are backed by our empirical data and can be distilled to testable hypotheses in future research. The findings in this study recognize a core set of antecedents of FOSS success and thus shed light on FOSS deployment. Our research also informs practitioners. Specifically we identify issues that are important to help disaster response authorities properly manage FOSS projects. These cover critical aspects such as

cost, adaptability, and data ownership in operating a FOSS for humanitarian purpose during large scale disasters.

This paper is organized as follows. The subsequent section introduces the background literature that leads to three focal research issues presented in the next section. Then, our research method and data collection process are described. Conclusions are drawn upon the data. We conclude the paper with discussions of our findings, limitations, and avenues to future research.

2. Background

2.1. Free Open-Source Software

Proprietary software and free open-source software (FOSS) are two popular, but very different business models in the current software marketplace. Proprietary software follows the "private investment" model, meaning that the innovation is carried out by private investment and is protected as intellectual property with a motive of achieving a return on investment as profit (Hippel and Krogh 2003) ((Demsetz 1967) and (Hippel and Krogh 2003)). Instead, FOSS follows the collective action model. The contributors share a collaborative sense of contributing their own efforts to a "common pool" as a public good and making the software freely available to all (Hippel and Krogh 2003). This implies that anyone can write, modify, or enhance the coding previously contributed by others. The process of learning, sharing, using, and modifying the codes is exercised in the process of the deployment of such systems (Hippel and Krogh 2003). GNU/Linux operating system, Apache web server, the Perl scripting language, and MySQL database management system are some of the popular open source software examples. Previously

dependent on proprietary and commercial software solutions, organizations find FOSS an important substitute for their software needs (Chengalur-Smith, Nevo et al. 2010).

In recent literature, academia has recognized the significance of FOSS. (Sharma, Sugumaran et al. 2002) developed a framework for creating a hybrid-OSS community within an organization to capture the benefits offered by FOSS. (Crowston, Annabi et al. 2005) developed a theoretical model to explain the performance and effectiveness of FOSS teams. (Currion, Chamindra et al. 2007) studied how a FOSS system named SAHANA coordinated disparate institutional and technical resources to respond to the Indian Ocean Tsunami in 2004. (Morelli, Silva et al. 2010) examined the mobilization of virtual communities through FOSS systems in an earthquake response.

Some of this previous research focused on system design from the technology perspective, while other research was with regards to the social aspects of the technology/system adoption and diffusion. Other than (Morelli, Silva et al. 2010) and (Currion, Chamindra et al. 2007), our paper is amongst the first few attempts at studying FOSS in the context of disaster management. A summary of a sample of literature is listed below with their main contributions.

Source and Title	Contribution
Currion, Chamindra et al. (2007) "Open Source Software for Disaster Management"	Discusses the significance of FOSS software for disaster management. It also discusses the component-based design in SAHANA and focuses on technological aspects.
(Morelli, Silva et al. 2010) "A Global Collaboration to Deploy Help to China"	Descriptive report about the international collaborations how IBM, SANAHA, and the government were involved in the deployment of a FOSS system to help in the recovery from the Sichuan earthquake.
(Sen, Singh et al. forthcoming 2011) "Open Source Software Success: Measures and Analysis"	Empirical study of the factors of OSS success as measured by the number of subscribers and developers. The determinants from the technical perspective were found to measure the success of an OSS project.
(Gwebu and Wang 2011) "Adoption of Open Source Software: The Role of Social Identification"	Focuses on the technological and social factors that drive a successful OSS adoption and diffusion. The integrated model was built and evaluated quantitatively.
(Peng, Zhang et al. 2011) "An Incident Information Management Framework Based on Data Integration, Data Mining, and Multi-Criteria Decision Making"	An incident information management system to deal with challenges after a disaster is architected: includes three main modules: high-level data integration module, data mining module, and a multi-criteria decision-making module.
(Lee, Bharosa et al. 2011) "Group Value and Intension to Use – A Study of Multi-Agency Disaster Management Information Systems for Public Safety"	Uses the IS success model and looks at the group value in a large-scale disaster management for public safety. The expected value of IS for collaborating organizations was a major factor studied.
(Subramaniam, Sen et al. 2009) "Determinants of Open Source Software Project Success: A Longitudinal Study"	Longitudinal data is used to investigate the success of an open source software project. The determinants include OSS license, user-interest, developer-interest from both the time-invariant and time-dependent perspectives.

Table 1. A sample of literature with main contributions

In this paper, we extend our exploration to study the issues of a successful FOSS deployment in disaster management. While (Morelli, Silva et al. 2010) focus on a similar topic as we have, their report is more descriptive in nature whereas we carry out a qualitative study, to find the major factors that drive public-private collaboration in the

context of a humanitarian OSS project. Additionally, while some authors have focused on the technical determinants (e.g. (Sen, Singh et al. forthcoming 2011) and (Peng, Zhang et al. 2011)) our paper has a strong focus on the social perspectives wherein we study the factors of the successful deployment. Additionally, the dimension of human private-public collaboration in the system is also a main focus in our paper. Our study therefore relates to but also departs from the prior studies at both theoretical and methodological level.

2.2 Technology-Organization-Environment (TOE) framework

Following (Vitharana, King et al. 2010), we first surveyed the theoretical underpinnings that we could use to explain private–public collaboration in the deployment of disaster management information systems. One analytical framework that we considered was the Technology-Organization-Environment (TOE) framework (Tornatzkey and Fleischer 1990). At its essence, TOE identifies three sources of influences: technological, organizational, and environmental factors. Technical factors include both technical instruments and processes and require a fit between the task at hand and the technological resources available to react to the situation. Technical factors include both technical instruments and processes and require a fit between the task at hand and the technological resources available to react to the situation. Organizational factors are the characteristics and resources that belong to an organization. Environmental factors refer to the social context within which an organization functions. These factors present "both constraints and opportunities for technological innovation" ((Tornatzkey and Fleischer 1990) p. 154). TOE has been used in directing system deployment within the organizational context. A few instances of empirical study regarding technology

innovation have used the TOE as a basic framework, including MRP adoption research (Cooper and Zmud 1990), e-commerce adoption research (Zhu and Kraemer 2005), the adoption of mobile commerce in the insurance industry (Lee, Cheng et al. 2007) and governmental adoption on FOSS (Guo, Yang et al. 2010). Recently (Gebauer and Ginsburg 2009) examined the black box of task-technology fit in the mobile information system domain and identified 'use context-related fit'. It is argued that a good match between the information systems and the organizational tasks and context is very important to the system's success ((Gebauer and Ginsburg 2009) and (Goodhue and Thompson 1995)). (Liu, Lee et al. 2011) investigated the framework of task-individual-technology fit, where 'individual' was added as a further dimension. It is argued that the choice of individuals can affect the performance significantly (Liu, Lee et al. 2011). In our research, we use the TOE categorization to develop factors that are important for successful humanitarian FOSS deployment and extend it to focus on potential partnerships and collaborations across firms, such as private-public partnerships that are important for disaster response and humanitarian FOSS.

In disaster management, there is potentially a great deal of uncertainty with the situation. Therefore, regarding the technological aspects, coping with urgent tasks in an uncertain environment requires the balancing of cost and adaptability of both technological artifacts as well as processes ((Conrad 1983), (Kampfner 1989), and (Williams and Mitchell 2004)). This is where the "free of cost", and "open source codes" characteristics of humanitarian FOSS would have a considerable impact. To this end, data ownership and security is an important aspect because of the various different types of

data that would need to be made available across organizations while ensuring their security. Sensitive information needs to be carefully protected against data leakages.

Regarding the organizational aspects, the strength of FOSS programming is its community-based deployment approach that invites multiple participants in system deployment. Disastrous events introduce wide impacts on a region and their responses call for joint efforts from multiple participating organizations. These organizations may have never worked together in the past and there is a lack of acquaintance and interaction experience. As a consequence, participants may not be aware of the knowledge and capability of each other, creating a barrier in inter-organizational engagements such as collaborative deployment of FOSS. To this end, clearly collaboration and sharing of knowledge resources are important within an organization (Nevo and Wand 2005) as well as across organizations. Three components "what the knowledge is about, what the individual believes they are capable of knowing and what the individual knows about others' knowledge and expertise" ((Nevo and Wand 2005, p.561), are critical in the context of humanitarian FOSS as well. Timely and effective knowledge sharing is important for disaster management. In a disaster recovery situation, people and organizations that may not ordinarily collaborate to synthesize expertise must work together quickly and effectively. A feature of disaster response is that disasters are unexpected and hence humanitarian FOSS deployment teams are formed on the fly and as such FOSS expertise is coordinated without full knowledge of member credibility and capabilities. The deployment team resembles an emerging temporary or task oriented organization with many players unknown to each other. Therefore, knowledge and experience with the system (there is no guarantee of the capabilities of a participating

organization), and awareness of skill sets of collaborators (the deployment teams may be loosely coupled and have lack of integration and transparency) are critical to successful deployment.

Finally with regard to the environmental aspect, i.e. the social context in which the organizations function, a critical stakeholder is the government, the primary first responder in emergency and disaster situations. There is a lack of prior interactions and credibility of participants are not clear, since emergency operations are expected to be a temporary exercise and the teams operate as a temporary organization. Relationships among participants with weak ties (or prior nonexistent ties) must be managed properly. In order to encourage continuity and cooperation, it is important to strengthen trust between government and the deployment teams (Poppo and Zenger 2002). This also requires strong government senior level management support.

In the aftermath of a disaster, rescue crews, government agencies, and private organizations all interact through chaotic and complicated scenarios. All information technologies and human interactions in the given social structures as well as organizational procedures and rules do matter in the collaboration of these entities. Some of the major sources of influence of humanitarian FOSS collaboration stem from information technology, the organizational and social environment, as well as partnership between private and public organizations.

While TOE offers an integrated framework to study FOSS deployment from technological, organizational, and environmental perspectives, we augment TOE with concepts from other literature so as to understand the managerial challenges that come with a typical disaster management. The fact that participating organizations do not

possess knowledge to discover expertise and that they lack strong ties to collaborate call for the aforementioned extensions.

3. Issues identified by TOE framework

3.1. Research Issue 1: Task-technology fit

The task technology fit perspective in the TOE model underscores several technical features that pertain to the disaster context. Task technology fit stresses that the matching of technology to tasks brings improvements in work effectiveness (Desanctis and Poole 1994). For proper fit to be achieved in a disaster response task, there is the need for low cost, high adaptability, and clarity of data ownership and security issues.

The low cost of FOSS makes it attractive in disaster management. Financial constraints are usually a substantial challenge to response organizations when a disaster occurs. Few countries and organizations commit sufficient resources to disaster management, regardless of past experience or future potential (Currion, Chamindra et al. 2007). The low cost feature of FOSS therefore fits this need very well. As (Currion, Chamindra et al. 2007) point out, "FOSS deployment leverages the goodwill and expertise of a global community of IT and non-IT actors at low cost"; FOSS solutions can be supported by technological organizations around the world helping their affected communities. A FOSS solution can potentially pull resources from a vast pool of programmers. All the benefits are from social goods, which are free.

Adaptability and flexibility may be another major advantage of FOSS for meeting the particular needs of disaster management. In contrast, proprietary software in general restricts system adaptation and offers limited reconfiguration options; its modifications

often require the involvement of specially trained programmers from the vendors, who may not be able to join and participate in the mitigation to disasters. In the case of humanitarian FOSS system, it can be relatively easily set up, adapted, and configured quickly by independent third-party system developers and volunteers, so that it can become responsive to rapidly changing situations (Currion, Chamindra et al. 2007). To be used in a local environment, especially one that is non-English speaking, the step of localization is essential. Without adaptability, a FOSS system could not be applied in many countries.

To work with a government leading a disaster response, another area of high concern is data security and ownership. Response to disasters often involves confidential data that describes the existing response plans, victim identities, medical information, and casualties. In the case of proprietary software, humanitarian systems go through a thorough developmental and testing process and fully comply with the applicable security standards. In addition, organizations that adopt this proprietary software own full possession of the system data. Data security and ownership is therefore not a salient problem for such proprietary systems. In contrast, government and non-government organizations rely on volunteers to develop humanitarian FOSS systems. These volunteers may not be completely verified for their credentials and background. Given the time constraint and resource limitation, the development processes may not fully comply with the highest security standards in the industry. In addition, voluntary developers may be invited to modify FOSS systems while they are actively used during disaster responses. Data security and ownership is therefore a salient issue. Government agencies will not tolerate the leakage of critical data and potential subsequent malicious

misuse of this data by others. Thus the protection of data needs to be prioritized and protective designs are expected. In a lot of the cases, the government would like to have the ownership and control of the data. The feature that FOSS can provide fits this need very well.

The above leads us to our first research issue for further exploration:

Issue 1: What are the aspects of task technology fit (low cost, high adaptability, and data ownership) that will affect the success of private-public collaborative FOSS deployment in disaster management.

3.2. Research Issue 2: Community of interest and knowledge awareness among community members

Open-source software development is collaborated through a broad community of interest (Hippel and Krogh 2003). Therefore, in addition to technological factors, organizational factors play an essential role in humanitarian FOSS deployment (Glynn, Fitzgerald et al. 2005). Programmers from all over the world voluntarily contribute to the code. As a result, it is difficult, if not impossible, to ensure that the team is creating high quality code in a collective manner. To this end, a number of imperative issues must be considered before the community as a whole can successfully pursue its objective in system deployment.

The availability of personnel with appropriate skills and knowledge is important to the successful deployment of humanitarian FOSS (Glynn, Fitzgerald et al. 2005). In particular, members' knowledge and experience with the systems that are embedded in FOSS deployment will help them to avoid the snares in system deployment and contribute to skillful use (Desanctis and Poole 1994). In the case of proprietary software, system vendors are not challenged by the availability of experts in that they may recruit

top-notch system developers. On the contrary, FOSS humanitarian systems are solely developed by volunteer developers who are equipped with mixed skills and knowledge. There is no guarantee of highly trained expert professionals who may join and contribute to the FOSS design. (Chau and Tam 1997) suggested that technical expertise of existing IT staff members is a barrier to the open system deployment. When a FOSS deployment team is assembled to assist in a disaster management operation, the team must be equipped with relevant skill sets and knowledge, or the ability to quickly acquire the missing capacity.

Awareness of the collaborative team's knowledge and support structures is important since these are the sources for planning and accomplishing the tasks. Unlike the case of proprietary software development where system developers mostly work in the same organization, FOSS humanitarian systems are made possible by volunteer developers who have no prior acquaintance with each other. They team together at the instance of a disaster and there is a lack of shared metastructure among each other. They will need the aforementioned awareness in order to develop mechanisms for collaboration and coordination. Without such cognizance, the deployment of FOSS may be delayed or halted completely. (Morelli, Silva et al. 2010) underscored the importance of deployment teams of disaster management system, and most importantly, the knowledge, experiences, and team effort that they provide to help the community. This combination of knowledge, expertise, and collaboration skills are sparse and involve a lengthy learning process, which can be nurtured or arranged by a group, organization, or the volunteer pool. For example, a deployment team may have knowledge about social structures, but if it were short of expertise in disaster systems, a sponsor organization may

need to search for the required but missing talents. In these cases, organizational knowledge of volunteer developers and their skills will play a significant role in facilitating this search process and pooling the collective efforts in building an effective FOSS through cross team and/or organizational-collaborations. In case a structure is better known, there will be consistency in the way the system is deployed. Consequently more effective use of the FOSS system may follow.

This leads to the next issue for further exploration:

Issue 2: How does deployment support from organizations and volunteers (inclusive of knowledge and experience of deployment and awareness of the skill set of collaborators) affect the success of private-public collaborative FOSS deployment in disaster management.

3.3. Research Issue 3: Support from Social Environment

Social environment support may directly affect FOSS system deployment in the context of extreme events. This dimension of influence is unique to disaster response information system development since their usage is closely supervised by government. Among others, social environment support concerns top management support. Prior studies have underlined top management support as an important factor on IT development ((Cooper and Zmud 1990); (Chau and Tam 1997); (Glynn, Fitzgerald et al. 2005)). Glynn, Fitzgerald et al. (2005) projected that upper management support could be even more important to FOSS deployment than the overall IS infrastructure. (Chengalur-Smith, Nevo et al. 2010) found that senior management plays an extremely important role in choosing the technologies of FOSS. We believe this is true for disaster response situations as well where federal governments oversee disaster relief planning and preparation (Palen, Hiltz et al. 2007). Many decisions after a disaster have to be made

quickly upon review of the immediate area. Without support from the presiding government, decisions on task critical issues, including the deployment of humanitarian FOSS, could be seriously delayed.

Moreover, social environment support may be affected by private-public trust. In the aftermath of a disaster, the government leads the overall recovery process with the participation of volunteer private sectors. Without trust between the public and private sectors, the deployment team would not have received needed support and resources from local authorities. Chengalur-Smith, Nevo et al. (2010) suggested that organizations with stronger ties to the open source community-of-practice may realize more benefits from implementing a FOSS project. For example, disaster management may encounter response data that is inaccurate, incomplete, and inconsistent. Data quality assessment is critical (Turoff and Hiltz 2008). While public and private organizations are likely to keep data repositories that are valuable to triangulate response data, they may be reluctant to share the data with one another. A presence of trust among these organizations will remove perceived uncertainty in data sharing and its subsequent use, consequently encouraging the parties to pool their data repositories in a jointed effort to certify response data. As a consequence, the following research issue is raised:

Issue 3: How does social environment support (including governmental support and trust between public-private partnership) impact FOSS deployment in disaster management

4. Methodology and Data Collection

4.1. Methodology

In this study, we examine humanitarian FOSS deployment through the example of the SAHANA system. SAHANA is a leading humanitarian FOSS system for disaster

management purposes. “SAHANA” means “relief” in Sinhala, the language of Sri Lanka. It was first built by volunteers in the Sri Lankan IT industry and deployed by the Sri Lankan government to help with disaster management after the 2004 Sri Lankan Tsunami (www.wikipedia.com). The SAHANA foundation describes the uniqueness of SAHANA as follows: “SAHANA software projects are different. They are about providing open source solutions for disaster victims and those seeking to help disaster victims. It is about the essence of humanitarianism; doing good in the world” (http://sahanafoundation.org). This free and open source disaster management information system has been growing with deployments during many massive disasters including the tsunami in Sri Lanka (2004), ‘AsianQuake’ in Pakistan (2005), ‘Southern Leyte Mudslide Disaster’ in Philippines (2006), ‘Sarvodaya’ in Sri Lanka (2006), ‘Terre des Hommes’ in Sri Lanka (2006), ‘Yogyakarta Earthquake’ in Indonesia (2006), ‘Peru Earthquake’ in Peru (2007), ‘Myanmar Cyclone’ in Myanmar (2008), ‘Sichuan Earthquake’ in China (2008), and ‘Haiti Earthquake’ in Haiti (2010) (www.wikipedia.com). Given the positive impacts that SAHANA made on collaborative disaster response and recovery, SAHANA has been well recognized in the FOSS communities, receiving the Red Hat Award (Currion, Chamindra et al. 2007).

To fulfill the needs of disaster relief organizations, SAHANA includes the following basic components:

- Organization Registry: to monitor and coordinate agencies and their geographic coverage

- Missing People/Disaster Victim Registry: to track missing, displaced, injured, and deceased individuals and allow people to find family and friends through its search engine
- Shelter Registry: to track and manage shelters and their residents
- Request Management System: to track supply and demand of aid
- Inventory Management: to track locations and qualities of response resources
- Situation Awareness: to collect updates of incident development
- Volunteer coordination: to maintain the directory of volunteers with contact and availability

Many organizations and large IT companies have shown interest in private-public collaboration for disaster management. We choose to collect qualitative data from IBM, since IBM has actively participated in disaster response over the years. IBM crisis response teams have deployed many SAHANA systems around the world and successfully aided governmental disaster responses in multiple natural disasters, including the Indian Ocean Tsunami and China Sichuan Earthquake. Their work in disaster relief has been widely acknowledged by the community. Mr. Susilo Bambang Yudhoyono, the President of Indonesia, recognized IBM for its "continued commitment to aid the people of Aceh and Nias, still suffering from the aftermath of the tsunami that hit the region in 2004." (http://www.ibm.com/ibm/ibmgives/awards/index.shtml). In response to the 2008 Sichuan massive earthquake, IBM deployed a SANAHA disaster management system, which was quickly adopted by the local authorities to help their disaster relief efforts. In a newsletter from IBM-China's communication office, the CTO

of IBM-China James Yeh gave the following speech with pride (Morelli, Silva et al. 2010):

"*All our hard work and sweat paid off when families reunited with their missing members! It was really an emotional moment of truth when we saw the happy tears… Eventually, we can say with pride that what we have done is worth remembering for our whole life. We helped people in the disaster area with our technology. We allied the best talents in IBM and contributed to the open source community.* "

(Vitharana, King et al. 2010) emphasized that it is critical to get multiple data sources in qualitative case study. Following Vitharana, King et al. (2010), we solicited information from numerous sources in addition to IBM. We contacted three governmental organizations who were heavily involved in the SAHANA deployment. We contacted officials at the SAHANA foundation. All these inputs allow us to triangulate the inputs from IBM and to develop a holistic view of FOSS systems in disaster management.

4.2. Data collection

(Seaman 1999) has stated "The principal advantage of using qualitative methods is that they force the researcher to delve into the complexity of the problem rather than abstract it away. Thus, the results are richer and more informative". Seaman (1999) especially noted the needs for qualitative methods for the study of broad issues of software deployment. Given that the topic of understanding governmental adoption of FOSS in disaster management is very complex, involving many different factors and stakeholders, we decided to adopt the qualitative case method in this research

((Bhattacherjee 2011), (Eisenhardt 1989a), and (Eisenhardt 1989b)). Our aim in the data collection phase was to gain rich and deep insights. Accordingly, we tried to gather the maximum amount of information by giving the interviewees the freedom to tell us their story, share their experiences, and express their opinions covering any topic that they felt was relevant.

A six-step data collection approach was utilized as shown below:

1. Contact the key contacts of the IBM, SAHANA team, and government agencies in various countries that have experienced disasters.
2. Discuss the potential questions with them to modify or add new questions based on the deployment of the SAHANA product in that country.
3. Discuss with the key contacts which individuals would be the appropriate and ideal interviewee to validate our propositions.
4. Identify the ideal interviewees that participated in SAHANA, refine the questions, and agree on an interview time
5. Phone interview those managers or engineers who were identified in step four
6. Phone interview senior managers and developers from the government and public sectors

First, senior engineers and project managers who participated in recent humanitarian FOSS deployment projects were interviewed. These interviewees are from multiple local subsidiaries of IBM who lent aid in most of the recent large-scale disasters. The interviewees, as the primary informants, offered their first-hand observations and lessons learned in their projects. Then, officials from a FOSS foundation and government agencies were interviewed to provide insights about the three research questions

discussed in the previous section. All five of the project managers and software engineers who we interviewed from IBM China directly participated in the SAHANA implementation project after the 2008 Sichuan massive earthquake. Some of them were sent on site in Chengdu, Sichuan, while others participated in the design, execution, and test processes in Beijing or Shanghai. The project manager who we interviewed in Taiwan is the key person of the IBM SAHANA team in Taiwan. He has a crew working for him on this project on the localization and customization of SAHANA. The interviewee in Vietnam was also the key contact and main organizer of the IBM SAHANA implementation in Vietnam. He worked with local universities on the SAHANA project. The project manager that we talked to, in IBM India was an expert in FOSS and disaster management. He had participated in numerous FOSS implementations for disaster relief in India in the past. The software engineer in IBM India who we spoke with is also an expert in SAHANA. He was the key person in the SAHANA implementation team for the tsunami and other disasters in India.

From the side of government and public sectors, our interviewees include a senior officer from SAHANA software foundation, one senior manager and a senior software developer from the government of New York City, and two senior officers from National Library of Medicine. They all had worked in the SAHANA deployment team in the corresponding organizations.

Table 2 shows the basic demographics of our interviewees below.

Interviewee	Organization	Activities Participated related to SAHANA
Project Manager	IBM Beijing - China	Full implementation of SAHANA used in the 2008 Sichuan Earthquake response
Senior Software Engineer	IBM Beijing - China	Full implementation of SAHANA used in the 2008 Sichuan Earthquake response
Project Manager	IBM Shanghai - China	Full implementation of SAHANA used in the 2008 Sichuan Earthquake response
Senior Software Engineer	IBM Shanghai - China	Full implementation of SAHANA used in the 2008 Sichuan Earthquake response
Project Manager	IBM Chengdu – China	Full implementation of SAHANA used in the 2008 Sichuan Earthquake response
Project Manager	IBM Taiwan	Implementation of SAHANA in Taiwan – Localization stage
Project Manager	IBM Vietnam	Implementation of SAHANA in Vietnam – Localization stage
Project Manager	IBM India	Various FOSS projects for disaster relief including Indian Ocean Tsunami and Gujarat Earthquake
Senior Software Engineer	IBM India	Implementation of SAHANA for various disasters happened in India
Senior Officer (CEO)	SAHANA Software Foundation	Guide the implementation of the various SAHANA projects worldwide.
Senior Officer	The government of New York City	Implementation of New York's shelter project using SAHANA platform
Senior Software Developer	The government of New York City	Implementation of New York's shelter project using SAHANA platform
Senior Officer	National Library of Medicine	Implementation of SAHANA disaster management system within National Library of Medicine
Senior Project Manager	National Library of Medicine	Implementation of SAHANA disaster management system within National Library of Medicine

Table 2: Interviewee Profile

Informing interviewees about the purpose of the interview is important ((Vitharana, King et al. 2010) and Seaman (1999)). Before we conducted all the phone interviews, we not only confirmed the time and date of the interview with the interviewees, we also introduced the purpose of the interview and attached the proposed

questionnaire. All the interviews were conducted over the phone. All of the interviews were tape recorded, with the conversations later transcribed into field notes. Such field notes can provide very detailed information (Seaman 1999); while the recording allowed the researchers time to carefully examine the interview responses. The total of nine interviews in the rounds of data collection generated approximately 100 pages of double spaced text with around 27,000 words and 150,000 characters. The authors crosschecked the validity and consistency of the translation of the transcripts afterwards.

5. Results

5.1. Task Technology Fit

The first issue we delved into was the task technology fit. In order to do so, we dissected the interviews from the perspective of cost, adaptability, and data ownership.

5.1.1 Cost

The low cost advantage of FOSS, which mainly derives from low maintenance cost, is confirmed with our interviews. The initial cost of FOSS may not necessarily be cheaper, or even in some cases more expensive than proprietary solutions, however when the system is set up, the maintenance cost is marginal. This is also noted in some previous research. For instance, (Currion, Chamindra et al. 2007) stated that besides the initial cost in setting up a humanitarian FOSS disaster management system, there is very low cost to maintain. One of our interviewees offered some insight into this:

> *Actually the initial cost of open source may be higher with that level of customized support. However once you get it set up, your cost goes down to almost nothing. However, the private product charges you annual maintenance*

fee, license fee, etc. Those are things that you really don't need, just in order for you to continue to use it. (Senior Officer of SAHANA Software Foundation).

…

The proprietary solutions always have very high maintenance cost. For the open source system that we have, we have not updated the application for five years and it is still running. The only thing that we updated was the server. In most of the cases, it is stable, it is solid, and we really don't have to do much work about that. (Senior Officer of SAHANA Software Foundation)

The above leads us to suggest our first proposition:

P1.1: The low cost of humanitarian FOSS will positively affect the success of private-public collaborative FOSS deployment in disaster management.

There is one important thing that we have noticed. Unlike proprietary software, which mostly involves tangible expenses such as purchasing cost, FOSS incurs a great amount of intangible costs. FOSS is only made available due to the valuable contributions of volunteers and generous donations from the private sector. An outpouring of support in the aftermath of a disaster can leave the response team with a large surplus of people willing and able to do what they can, to help. "*This can confer the responders the ability to pick and choose the most capable collaborators from the resource pool. This surplus of free manpower can help overcome many monetary shortages if a way can be found to utilize it*", a Project Manager of IBM Beijing stated. This condition is not limited in scope to individuals, but includes private organizations large and small. A large number of companies are willing to help after a disaster. This free resource is extremely valuable and helps compensate for monetary constraints. Such a donation from the private sector has led to a very low cost of SAHANA. A few of our interviewees talked about this as follows:

IBM donated a good deal in support of the Sahana system, which included a great amount of human resources. (Project Manager from IBM Beijing)

If we calculate the monetary value of human resources IBM put into SAHANA, it would be an enormous amount. It is far more than the goods you can provide because the human resources are much more valuable. IBM is, to my knowledge, committed to donate its human resource rather than donating money or products. (Project Manager from IBM Shanghai)

As to SAHANA, you don't have a license fee, but your cost in terms of labor and support might be equal or greater than the private product. For in the instance of IBM, it puts thousands of thousands of dollars in terms of labor in the project. (Senior Officer of SAHANA Software Foundation)

FOSS deployments have the ability to receive a large amount of support in the form of people's time and effort. The ability to accept such donations in lieu of monetary aid is of enormous benefit. A proprietary solution cannot easily realize this benefit.

Therefore we suggest:

P1.1.1: In disaster management, the availability of voluntary and highly skilled human resources is a major determinant of the cost advantage of FOSS deployment.

5.1.2 Adaptability

Another praised feature of SAHANA is that it has a great adaptability. Proprietary software is not readily adaptable due to the lack of source code visibility to external developers. Unless dedicated support teams from the software vendor are onsite during a disaster, proprietary software may not be modified in a timely manner. As a consequence, disaster management teams will have to reorganize their response activities around the existing system features. On the contrary, FOSS such as SAHANA enjoys a great level of

adaptability due to the publicity of system design details. During time critical response operations, FOSS is able to be quickly adapted when such changes are most needed and subsequently make a more effective contribution to the response teams.

> *With FOSS, you can easily adapt it to the organization's different business processes. You don't have to go in and say 'hey stop doing what you are doing now and we are going to give you a new method'. Instead, just keep doing what you are doing. What we are going to do is to get the system adapted to your process and help you do the job better, by handling the forms, the fields, and the matrix more efficiently. That is in general the biggest thing. With open source, in a couple hours, you can adapt that form into your database. (Senior officer from SAHANA Software Foundation)*

> *After a disaster happens, someone needs a solution to deal with it. They in general don't care whether it is open source or not. They want something that does the job for them. In my opinion, the adaptability and customizability are the strong points of open source projects. In our presentations, for example, we can say hey here it is already translated to your language. Or let me change the form here to match your paper form. Then they can see it fits their needs right away. (Senior officer from SAHANA Software Foundation)*

The above leads us to suggest the next proposition:

P1.2: High adaptability will positively affect the success of FOSS deployment in disaster management

Under the out-of-the-box nature, some customization is usually needed prior to its deployment, such as the language translation (Careem, Silva et al. 2007). After this localization step, it can be easily implemented under different scenarios. Most of the interviewees are in countries where English is not the primary language. So, the first task for the Chinese IBM team after the Sichuan earthquake was to translate and localize the

SAHANA system. It was handled in a timely manner; otherwise the wide deployment would not have been a possibility. Below are some highlights of some of the experiences they shared.

> *A lot of components need to be customized based on local needs. For example, a default form asks about religion. It's not that applicable here. That's just one of the difficulties we faced. We have added a lot of information which was needed here while having to ignore many other items. This customization also applied to the selection of function modules too. We customized two modules. (Project Manager from IBM Shanghai)*

> *The Chengdu police told us what interface they would like to see and what information they would like to include. So we customized SAHANA based on their requirements. For example, to input Chinese characters, we use pin-yin. One of several pin-yin methods is to input only the initial pin-yin letters and then select from a few options presented by the system. Almost all police officers in Chengdu were already familiar with this input method, so we had to implement this in the SAHANA program particularly for them. So the customization is a big issue here [where operational efficiency is linked to people's lives]. (Manager from IBM Beijing)*

Two critical aspects of adaptability are localization/ customization and the modularization of system for disaster management. Hence we suggest:

P1.2.1: Localization ability and availability of various functional modules are two major dimensions of adaptability.

5.1.3 Data Ownership and Security

When a government is considering deployment of an innovative FOSS system such as SAHANA, one of the main points of concern is data ownership and security.

With the FOSS option, the government can obtain ownership of the system and data, while this is not always the case with proprietary solutions. Governments will in general seek to avoid any risk of intrusion to their internal systems and data. This can create a barrier for adoption of FOSS technology if there are any doubts about data safety. Some insights from the public sector are offered here:

> *In a typical process, SAHANA is being adopted by the government or some organization. They have control of the system, the data security and decide who is using it.*
>
> *...*
>
> *One government, such as Pakistan, took the whole SAHANA code and integrated into their own system before being used in the governmental central call center.. ... It was never published, and none of the data was ever shared. The code was never released. It gives them the flexibility for them to accomplish it. (Senior officer from SAHANA Software Foundation)*

In the case of the Sichuan earthquake, the Chinese government used the SAHANA system deployed in collaboration with IBM. One of the major reasons was the fact that local police were assured by the IBM team regarding the safety of their internal data. Some summaries are shown below from our interviewees.

> *In terms of systems architecture, it [implemented SAHANA] has two layers. One is called the backbone which is used for the policemen to input the data. The other one is the public facing interface for them to search with. For the backbone, we have user authentication with user access controls. For example, an individual may only see the modules to which he/she has permission to access. From the construction of - the police network, the two servers, one for the public search and the other for police input, are physically separated from each other. (Manager from IBM Beijing)*

The internal and external data are physically separate. So the internal data of the police is very safe since no external user has access to them. All the data we need from the police were downloaded by the police and physically handed over to us. (Engineer from IBM Shanghai)

The analysis above leads us to suggest the proposition:

P1.3: A high level of data ownership and security will positively affect successful private-public collaborative FOSS deployment in disaster management.

5.2 Deployment Support from Organizations and Volunteers

Emergency response can be very chaotic given all of the numerous organizations and volunteers involved. Since FOSS programmers don't have well defined boundaries, the workflow is very loose and one can leave or join at any time (Sharma, Sugumaran et al. 2002). Without a well-organized and efficient team, it is very hard for a FOSS disaster system to function in a timely manner. Thus efficient deployment support from organizations and volunteers is very important to achieve a satisfactory performance of disaster response. Some insights from the manager from IBM Taiwan are shown below:

FOSS means that a lot of developers contribute to the codes, which does not necessarily mean the quality is not as good. There always needs to be someone to coordinate the whole process. (Project Manager from IBM Taiwan)

5.2.1 Knowledge and experience of the system

As IBM is a leading technology company equipped with thousands of knowledgeable engineers and experts in various fields, the team on site could always leverage the knowledge and support from other IBM groups during the Sichuan earthquake SAHANA deployment. The interviewees from IBM China crew showed the

importance of the deployment team support. Some of the relevant transcripts are shown below:

In general, a large company like IBM has a lot of experience, a lot of technology support and human resources. They were able to help us very quickly deploy SAHANA and implemented it. Their knowledge and experience will definitely help! (Senior officer from the City of New York)

The biggest disadvantage is that SAHANA has a very loose structure. If you want, you can add or delete modules. Everyone can contribute their own code to the different modules, so we don't have a standard quality across the various modules. The quality of some modules can be much higher than other modules. In our whole implementation process, we had to spend a lot of time to test it. We required a lot of people who knew about the loose structure to conduct the testing as it was of such a great scale. (Manager 1 from IBM Beijing)

Except that they had a very high requirement with regards to timing, we treated it the same as we treat our other projects. So the whole process, including the initial design, and the communication with the clients, functionality tests, system tests, were all the same. Even though they are all volunteers, they are also all highly experienced engineers. The volunteers bring with them so much intelligence and experience from their fields. (Manager 2 from IBM Beijing)

Even though SAHANA is an open source program, the program we delivered to the Chengdu police really wasn't open source because it had all the custom features added by our highly experienced engineers and project managers. They all treated it like any of their usual projects. This created a solid foundation for the success of SAHANA. (Engineer from IBM Beijing)

The above leads to proposition

P 2.1: Knowledge and experience of the system will positively affect the success of private-public collaborative FOSS deployment in disaster management

5.2.2 Awareness of skill-set of collaborators

Furthermore, through FOSS platform, the emergency response officials can exchange ideas, experiences, and learn how things are done by different organizations and volunteers (White, Plotnick et al. 2009). With this extended knowledge pool, the support could be more effective and stronger.

> *This is extremely important in disaster response. The commercially licensed software cannot be implemented to the large scale which open source software can. Everyone can access the code of the open source program. Finding the appropriate skill-set is not an issue here. The beauty is that if you would like to contribute, you will be able to. (Manager from IBM Beijing)*

> *I almost took this for granted. Like I was telling you, I actually used the global delivery center here in India which has many thousand programmers with various specialties. I was taking a very high quality team and high capability level for granted as we have access to that team, but that's not always the case everywhere. (Project Manager from IBM India)*

The above leads us to suggest the proposition:

P2.2: Awareness of the extended knowledge and support skill set will positively affect the success of private-public FOSS deployment in disaster management

5.3 Social Environment Support

5.3.1 Governmental senior level management support

Government is a major player in this content. Our interviewees all detailed the critical role the government plays in the deployment process:

I did mention that the senior government support is critical. They don't have to be involved with the technical stuff, but the signal is very important. The high level government does not need to participate that much, but you do need a senior manager type to commit into the deployment. (Senior officer from SAHANA Software Foundation)

It is really almost entirely dependent on the attitude of the government. If they are interested, they would show their requirement and ask the question how this system could integrate to their own database. It then would become a motive for us to move on to the implementation stage. This time, the Taiwan government did not show much interest to implement this system. They said they would try to use it. But I am not sure if they have actually used it. The government plays a huge role to ensure the success of the implementation. That is for sure! (Project Manager from IBM Taiwan)

The above leads to proposition

P 3.1: Governmental senior level management support will positively affect the success of private-public collaborative FOSS deployment in disaster management

5.3.2 Trust between the government and the deployment team

Trust between a government and any organization or individual can be difficult to attain. Without mutual trust, it is very difficult to promote a new technology or system to the government. Take IBM for instance. As a well-known, reputable IT firm with high social responsibility, for them to gain the government's trust can be much easier and straightforward. It is more likely for a governmental body to build a trustful relationship with large, well-known firms. Little or unknown organizations will have a hard time overcoming the trust barrier with the government. In an emergency response situation, not only do they have to gain governmental trust, but they have to do so quickly. It is a

hurdle, which can only be cleared by organizations with whom the government is already familiar. In the case of 2008 Sichuan earthquake, Chinese governmental authorities trusted IBM and involved IBM in the joint recovery operations (Morelli, Silva et al. 2010). In an instance where the government could not identify the collaborators that quickly, it is more likely for the government to hire its own agencies to do it.

> *... the Chengdu police are not willing to share their internal database with the external volunteer teams. However, when IBM volunteered for the development task, they decided to share a portion of their data. This would not be possible in a pure grass-root open-source project. The police trust us more compared to other random volunteers as we have the reputation of the firm to uphold. When the earthquake happened, you could find some people there with good intentions, but some may have malevolent purposes in mind. Without trust, it is very difficult to implement the project in an efficient way. It's not just a technical issue. (Engineer from Shanghai IBM)*

> *Because you had IBM there, it may be much easier for the government to agree. It may get the government feel more comfortable when they cooperate with a big technology firm. They don't need to participate, since they only need to know the system is working. In this case, IBM is successful in the public-private collaboration for reason. If you don't trust IBM, whom else will you trust? (Senior officer from the Government of New York City)*

In the case where a government chooses to utilize a proprietary software solution, there are a limited number of providers able to supply the needed service. These providers require, and are obligated to support and service the software package. A FOSS solution however allows the government to work with a wide variety of people and companies. These resources have no legal obligation to support and service the disaster management solution. As a result, a high level of trust is essential between the

government and those who support a FOSS deployment. Additional aspects of a disaster management deployment emphasize the advantages using FOSS with regards to trust. As mentioned by the IBM Shanghai Engineer, there can be data sensitivities where a high level of trust is a prerequisite. With the limited number of proprietary solutions available, it is unlikely there is a preexisting relationship between the involved government and any of the potential proprietary software providers. A FOSS solution allows the customer to instead choose from any number of capable organizations where a preexisting relationship is already present.

The above leads to proposition:

P 3.2: Trust will positively affect the success of private-public collaborative FOSS deployment in disaster management

Based on the above we propose the exploratory model in Figure 1 below.

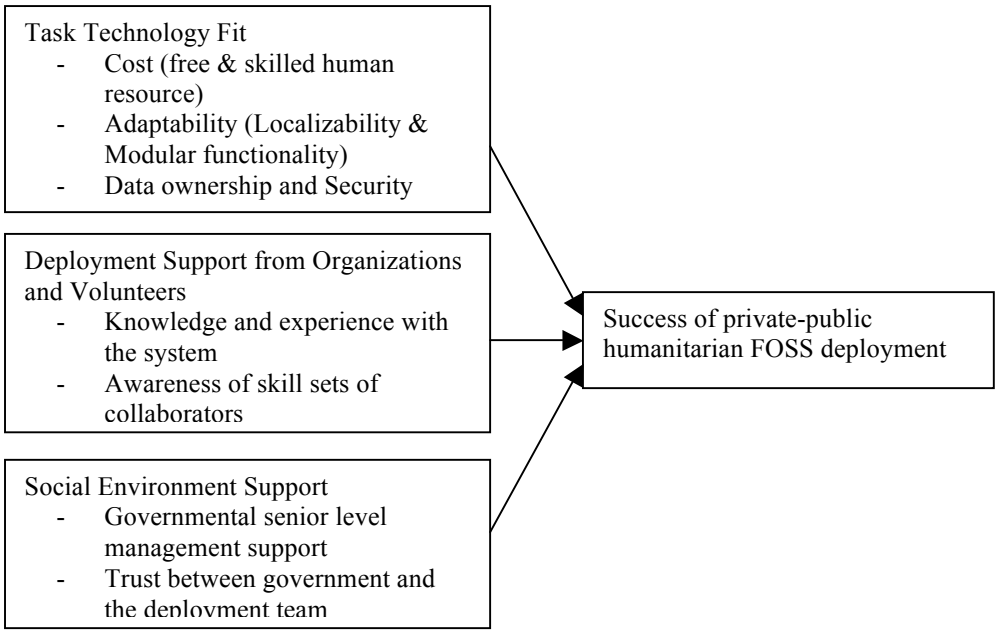

Figure 1. Proposed Model

6. Discussion and Conclusion

Disaster management faces numerous challenges in mounting a rescue effort, such as the lack of qualified rescue staff, limitations of relief budget and resources, and a constant struggle against time. For response organizations, which often suffer from insufficient resources under a disaster situation, humanitarian FOSS presents an attractive alternative with its unique characteristics, including an open and transparent technical architecture, low cost, and high adaptability. It is especially the case when there are not many private solutions available in the market. We have examined the major determinants of successful FOSS deployment in emergency management. The task-technology fit, deployment support from organizations and volunteers, governmental support, and the trust between the public and private parties all have positive relationships with the success of this private-public collaborative deployment.

In addition to these relationships we measured, many of our interviewees also indicated the great importance and value of the human resources donated by people and companies. FOSS offers individuals and companies alike to make a far greater contribution to disaster aid in a non-monetary manner. With a successful deployment requiring a great deal of human resources, much of a highly skilled variety, being able to accept contribution of people's time and effort instead of currency is of enormous benefit. This is something which would be severely limited, if not impossible with an effort utilizing a proprietary solution.

We feel our research will be of interest to both practitioners and researchers. FOSS can potentially offer technological benefits, yet successful collaboration for disaster management FOSS requires organizational and social level supports as well.

Regarding the implications to the practitioners, our findings can inform them of the key factors that affect the potentials for response organizations to explore this novel and economically preferable approach for disaster management. This could also help them better understand how the partnership between government and a private organization may be initiated in this area, how to encourage government to better support their deployment, and how to coordinate with different organizations and leverage the humanitarian FOSS advantages to the maximum extent. From a collaborative system deployment perspective, Table 3 highlights the key findings of the current study and the implications to the disaster management as well:

Factors	Impact on Humanitarian FOSS	Implications for Management
Cost	- Financial constraints are frequently a substantial challenge faced by government when a disaster occurs	- Adopt the FOSS approach despite the likelihood of higher initial cost - The cost of labor, in terms of availability of high skill sets in the FOSS deployment community is very critical - Leverage the goodwill and expertise of a global community of IT and non-IT actors at little cost to cover the intangible costs
Adaptability	- In order to fit to a specific situation, the system needs to be set up, adapted to the situation at hand, and localized quickly	- Keep high modularity of FOSS systems - In countries where English is not the primary language, translation is the first necessary step for system deployment - If translation and other localization steps could be performed ahead of time, a great deal of time would be saved
Data Ownership and Security	- Governments and private organizations are protective of sensitive and confidential data - Government prefers to have the ownership of data and system if possible	- Government obtains the ownership of the data - Guarantee the collaborators of the safety of any sensitive data - Separation between the government server, the FOSS system, and the public access method - Install security measures (e.g., firewall and access control list) wherever appropriate

Knowledge and experience of the system	- The staff's knowledge of and experience with the system can be an enabler to the fast deployment of the relief system	- Equip the team with relevant skill sets and knowledge through training programs and exercises - Equip the team with staff who has experience with the system and who can quickly assist with any missing capacity to respond to the current situation
Awareness of extended knowledge and support pool	- It is difficult for a group to obtain all the necessary knowledge and experience while simultaneously struggling against the clock - Support from external groups can be in great surplus	- Leverage knowledge from inside and outside the organization - Maximize collective efforts by increasing the boundaries of the working group and volunteers globally - Receive consultation and support from the FOSS organization
Government management support	- Without the government's support, it is very different to obtain the resources needed or deploy the system in a timely manner	- Create strategic relationship with government officials - Facilitate the government's perception of the merits of the system
Private-public trust	- Without the trust, it is hard for the deployment to get any support or resources from the local authorities - Trust can be a hurdle for collaboration and deployment- After a disaster, multiple groups and organizations need to collaborate under the lead of the government	- Build mutual trust foundation from long term relationships and from institutional trust - Get the parties familiar with each other - Establish a long term public-private relationship - Try to work with the government as closely and transparently as possible

Table 3. Interaction Effects and Management Implications

One limitation of the current study is that only a qualitative case study was used to develop the research propositions. A further validation from a formal quantitative empirical study can also be conducted. This would not only tell us the relationship between the model constructs, but also measure the degree and extent of the

relationships. This could serve as a direction for future research. Some other measures may also be considered. For example, the Disaster Preparedness Index can be used for measuring 'the success of the deployment' and scalability for measuring the 'Task-Technology Fit'. In addition, this study looks at FOSS volunteers who are from IBM. All employed by the same organization, these volunteers exhibit fewer problems in volunteer structuring and organization. Additionally, IBM volunteers are paid by IBM and they are more committed to SAHANA deployment, whereas other volunteers may be restrained by their own jobs and family issues and cannot continue their services for a prolonged period of time. Future study may examine other types of volunteers (e.g., emerging, ad hoc groups) and understand the differences in humanitarian FOSS deployment.

Essay 3 Risk Communication through the Twitter Service: An Exploration of Retweeting During the 2011 Japan Nuclear Radiation Incident

1. Introduction

1.1 Social media in disaster response

Prompt information sharing and communication is very important in emergency response. New technologies are being used to facilitate communication and collaboration, minimizing time and geographic constraints (Teigland and Wasko 2000) These new forms of virtual communities have created original venues for communication and social exchanges (Silva, Goel et al. 2009). For example, online social networking sites (SNS) (such as Facebook, MySpace, Twitter, etc) present a novel platform for effective message dissemination. In many instances social media has been faster in distributing breaking news than the legacy mainstream (Li and Rao (2010), Oh, Kwon et al. (2010), and Oh, Agrawal et al. (2011)). After the massive 2011 Japan earthquake and Tsunami, Twitter also served as an invaluable tool for distributing information to millions of people around the world. Even in situations where the voice calling service of cellular phones did not work, Facebook and Twitter often continued to function well. The Japanese government used Twitter to publish emergency information, relief organizations used Twitter to publish shelter information, and the general population also used this service to post news on the severity of their local situation and upload mobile videos which everyone around the world could view (Wallop Mar. 13, 2011).

1.2 Research issue

After the Japanese earthquake and tsunami, radiation fears and concerns were of utmost importance in the minds of the Japanese people. However the Japanese government and the owners of the crippled nuclear plants, TEPCO, had a difficult time communicating with the population regarding the risks related to the nuclear power plants. Available information was full of controversial and contradictory statements. For example, Greenpeace stated, "its scientists' findings largely correlated with the official Japanese data" (Japan Probe Mar 30, 2011). Meanwhile, it was also said "The Japanese government withheld the release of data showing that levels of radiation more than 18 miles (30 kilometers) from the crippled Fukushima nuclear plant exceeded safe levels" (Newyork Post April, 4, 2011). The general population started asking itself whether the government was telling the full truth or perhaps covering up some potential risks, leading to further panic. Poor risk communication may even be more dangerous than any risk from the radiation itself.

Simultaneously, the risk perception of the public could be biased, either overestimating or underestimating the danger. The overestimation is often caused by fear, emotion, and stress, while the underestimation can be caused by apathy, fatalism, and optimism (Chartier and Gabler 2000). Adequate information is needed before one can make the best possible decision to cope with the risk and crisis. Emerging information technologies have dramatically increased the speed of information exchange flow, the scopes of the participants, and the boundaries of all audiences. Social media networks, such as twitter, provide the general public a platform to perceive and involve themselves in risk communication after a disaster. More involvement leads to a more complete perception of the risk from the general public, thus the more effective the overall risk

communication would be. Chartier and Gabler (2000) suggest that to ensure more complete information, inputs from sources including the government, news media, and public ends of the spectrum are needed. The two-way information exchange framework is desirable. Social media, the most accessible of platforms, copes with this need and aggregates the views from different stakeholders.

One popular behavior in Twitter is called 'Retweeting', through which people can pass on or share the tweets they find of interest or importance to their own followers and contacts. Amongst the millions of messages being disseminated on a daily basis, retweets reflect the information that had the greatest impact on the readers. At least one reader thought the information important enough to echo, and by their nature as repeated information, a retweet is seen by more people. Information can quickly spread through the use of retweets, thus making it a powerful method of information propagation. These very characteristics make retweets more influential on the population as they are exposed to a greater number of observers than a typical lone, unrepeated twitter message. As the content of these messages that have been amplified is important, we decided to focus on this behavior in our research.

In this paper, we aim to examine the reassurance coverage of a 'hot crisis' in the micro-blogging environment. We expand the findings of the prior literature focused on traditional media coverage and see how it compares with this new social networking environment. Simultaneously we will also look at what the pattern of communicating reassurance by the government on twitter was, and how the public treats this information.

The remainder of this paper is organized as follows. The literature background is presented in the following section. Data collection and quantitative analysis are illustrated next. The paper finally concludes with some main findings.

2. Prior Literature

2.1. Risk Communication

Certain disaster situations result in a prolonged period of danger and instability. In such a case, organizations and governments must make a choice in striking a balance between the level of information provided, concerns of causing panic, and in some instances, their own reputation and 'saving face'. The nuclear radiation danger in Japan after the 2011 earthquake was one of these instances. (Perrow 1984) has described nuclear risks as "involuntary, delayed, unknown, uncontrollable, unfamiliar, catastrophic, dreaded, and fatal" (p. 325), it is a typical example of a crisis which could cause a scare among the populace (Ungar 1998). Under this type of hazard situation, what, when, and how to communicate to the public encapsulates the concept of 'risk communication'. "Risk communication has been defined as an interactive process of an exchange of information, involving multiple messages about the nature of risk" (Chartier and Gabler 2000). The media plays an important role in risk communication. It not only provides information, but also brings the public's attention to urgent issues. Slovic (1999) examined risk assessment and the relationship to public perceptions and stated "risk is the socially constructed sum of hazards and public perceptions". In other words, there can be discrepancies between the "real" and "perceived" risk from society. Often the public tends to think the risk related information published by the government could be biased, incomplete, or incorrect (Chartier and Gabler 2000), therefore an individual could ask the

question “Is the government covering up any portion of the story? Where do we get all the facts?” Even though the most perfect risk communication strategy may not solve all problems or conflicts, a poor one could lead to an overall failure of risk perception and risk management.

2.2. Reassurance

As shown earlier, many major international news channels reported that the Japanese government withheld the release of the radiation data (for instance Newscore (April 4, 2011)). This reflects a serious issue in risk communication: reassurance. ‘Reassurance’ means to restore to assurance or confidence (www.dictionary.com). Many previous literatures have studied reassurance. For instance, Iizuka, Ogawa et al. (2007) examined the factors affecting user reassurance when confidential information is handled in a public environment. Barnett, Timotijevic et al. (2007) examined the public perception to precautionary advice originating from the government. In particular, they looked at the public’s perception towards the government’s advice communicating the health risks of mobile phone use. They suggested that information must be unambiguous when it is communicated to the public, and that this is especially true in an uncertain environment. It is also suggested that information that could help people psychologically cope with the magnitude of a crisis situation should be provided (Sturges 1994; Reynolds 2002). The general population needs to understand the true magnitude of the risk in order to take all necessary precautionary steps. If the risk is pronounced to be less serious than it actually is, people can feel very anxious, panicked, and angry when the real situation is later revealed. As Reynolds (2002) argued “If you have to amend the estimate of damage

or victims, it's better to amend it down, not up." It is better to let people feel "It turned out to be less dangerous than we thought" rather than to let them feel "It is actually more serious than we were told". Other times it can be important to get people concerned. An important matter to understand is how the twitter environment fosters a balance between alarming and reassurance and how the public receives the messages coming from the government under different circumstances.

Some prior research studied this issue in the disaster scenario. For instance, Ungar (1998) looked at the media reassurance under the conditions of 'hot crises'. In particular, they tried to identify under which situations reassuring coverage was more likely than alarming coverage. They found that reassurance is much more prevalent in the immediate aftermath of a disaster, when the panic was spreading quickly. Stephens and Edison (1982) looked at the news media coverage during a nuclear energy accident. Their research was partially in answer to a perception that media coverage of crisis situations tends to be over sensationalized. While they found this not to be the case, exploring the new micro-blogging platform in a similar context is important. We examine the echoed retweets on twitter in order to determine whether the information making an impression on this new platform is reassuring. We do the same to see if the retweeted messages are instead alarming. Seeing how twitter fosters a balance between reassurance and alarm-ism will improve how this medium is understood. By focusing on the retweets, in making comparisons to the previous research with the traditional media, we see not the tone of the information being made available, but instead what information the public is choosing to hear. In exploring this question, we also look at how the governmental role is communicated on twitter and how this information is received.

3. Analysis

3.1. Data Collection

As discussed in the earlier sections of this paper, we are particularly interested in how Twitter propagates information, with our focus on "retweets".

By utilizing the twitter search API with the service 'twapperkeeper', we collected tweets containing 'Japan radiation' in the month after the earthquake. "RT @" and "via username" are the two most common ways to distinguish retweets. By searching all tweets which includes "RT @" or "via username", we then narrowed the dataset to include a dataset of 38,300 retweets regarding radiation during the month after the earthquake. There are some other alternative conventions for retweets, which are not included in our current analysis. We identified the top retweeted messages, for our analysis.

3.2. Descriptive Analysis

3.2.1. Prompt responses

American Public Health Association Executive Director Georges Benjamin commented about social media as follows: "It speeds up communication, and, for all practical purposes, it speeds up awareness" (Currie 2009). Based on that, Currie (2009) argued that "social media should be employed to transmit critically important information immediately to as many people as possible". (Rogers and Seidel 2002) determined that interpersonal networks were one of the three major channels that people first heard about the September 11 terrorist attacks. News was quickly passed on through word-of-mouth. Ten years later, social media has evolved as a major channel through which people pass

on information. In the aftermath of the Japan earthquake and Tsunami, the Twitter communication channel was extremely active. Wallop (Mar. 13, 2011) mentioned "Within an hour, more than 1,200 tweets a minute were coming from Tokyo. By the end of Friday, American time, a total of 246,075 Twitter posts using the term "earthquake" had been posted." Our retweet records regarding radiation showed a similar pattern. Figure 2 describes the distribution of the retweets for this time frame.

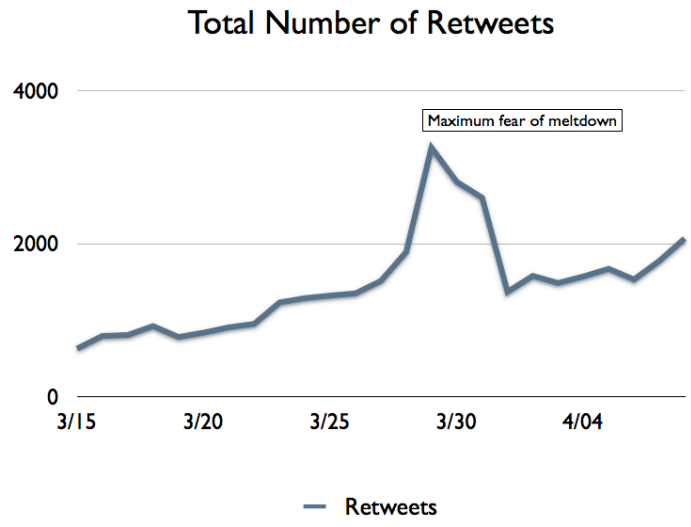

Figure 1. The distribution of the retweets

We observed how the retweets and their origin changed over time as worries about the nuclear situation unfolded. Interest in the nuclear aspect of the situation started relatively low, but shifted as time moved forward. People were more concerned and focused on the dead, the missing, and the raw devastation of the tsunami in the days immediately following the disaster. Meanwhile, the possibility of nuclear meltdown was just under way. Indeed, there were still expectations that cooling would resume at the

nuclear plant on March 12th, and therefore be a trivial issue in the bigger picture of the earthquake and the tsunami (Reuters Mar 16, 2011). However, fears surrounding the safety of the nuclear plant continued to grow as the situation continued without being brought under control. A similar trend is shown in the figure above. The numbers of retweets with keyword of "Japan radiation" steadily increased as the situation remained. Twitter retweet activity peaked in the final days of March as the possibility of a meltdown continued and radiation fears dramatically increased. As numerous news channels mentioned, radiation levels rose again and Japan set the maximum nuclear alert with worries of a full meltdown (Newscore Mar 31 2011; Yamazaki and Maruta Mar. 31, 2011). Our data shows that twitter, as a real-time and active platform, conveys and disseminates information to facilitate risk communication in the aftermath of the crisis.

3.2.2. Valuable information provided by most retweeted messages

In order to capture the most public interest we first focused on the messages most frequently retweeted. Table 1 lists the top 25 most commonly retweeted messages, and their frequency in the time frame. Messages discerned to have a governmental origin are highlighted in green while the remainder is in blue.

Rank	Main message of the retweet	# of Retweets	Date of first tweet	Main Source
1	Low levels of radiation found in US milk	389	31-Mar	BreakingNews/AP
2	Japan's chief cabinet secretary says it could be several months before radiation stops leaking from Fukushima nuclear plant. - Sky News	234	3-Apr	BreakingNews/AP
3	Radiation in water rushing into sea tests millions of times over limit.	181	21-Mar	CNN
4	Despite everything you've heard, the health risk of radiation in Japan remains pretty low	151	7-Apr	TIME
5	At this time, #Japan #radioactive particles detected around the world have no #health risk to humans #globalhealth #radiation	145	25-Mar	WhoNEWS
6	#radiation levels keep rising why doesnt #japan bury the reactors NOW?!	130	31-Mar	EricGrill
7	Level of radiation in ocean off #Japan's damaged nuclear plant rises to 4,385 times the standard	129	31-Mar	CNNBrk
8	Three Mile Island was 32 years ago. I was 10 miles away. So here's facts on radiation, beyond the XKCD graphic	123	29-Mar	Anildash
9	Iodized #salt doesn't have enough #iodine to protect you from #radiation. Too much #iodizedsalt can cause poisoning.	111	17-Mar	WhoNEWS
10	#Radiation counters sell out amid US fears over #Japan's nuclear reactor - sbsnews.com	108	29-Mar	BreakingNews/WWBNews
11	EPA boosts radiation monitoring after low levels found in milk.	87	31-Mar	CNNBrk
12	"The Fukushima situation has exposed a grave danger to our world. But the danger isn't radiation, it's the poor state of science education."	89	21-Mar	DamnedFacts
13	Japan eases restrictions on milk, spinach after radiation levels fall below legal limits for three straight weeks.	87	8-Apr	CNNBrk
14	For the first time, Japan sets a standard for the amount of radiation allowed in fish	86	5-Apr	BreakingNews
15	Governor says radiation levels in Tokyo 20 times normal, The Japan Times reports	83	16-Mar	CNNBrk
16	#Hiroshima Organizes Scientific Teams & Medical Treatment to Aid Victims of #Radiation Poisoning.	61	17-Mar	DemoCracyNow
17	Japan race to find radiation leak path	57	4-Apr	BBCWorld
18	Radiation scare sparks run on bottled water in Tokyo	57	24-Mar	Reuters
19	IAEA says radiation levels at #Iitate, 40km from #Japan's #Fukushima plant, exceed one of its 'operational criteria for evacuation'	56	30-Mar	BBCBreaking
20	Seawater radiation measured at 7.5 million times legal limit - latimes.com	53	5-Apr	@ ... Japan earthquake, tsunami
21	'Fukushima radiation' found in UK	52	29-Mar	BBCWorld
22	Japan's chief cabinet secretary Yukio Edano says it could be several months before radiation stops leaking from Fukushima nuclear plant.	51	3-Apr	SkyNewsBreak
23	112,000 Americans die from obesity every year. No one has died from radiation in Japan. #prayforobesepeople	51	29-Mar	@InvisibleGaijin
24	#Radiation levels "10,000x higher than normal" prompt fears of #nuclear #reactor breach at #Fukushima. #AlJazeera	50	25-Mar	AJELive
25	Japan seeks Russia's help over nuclear leak	50	5-Apr	AJEnglish

Table 1. Top 25 most retweeted messages

Of the twenty-five messages most often retweeted, nine of them conveyed information from or of a government regarding the situation. These messages account for thirty percent of the most frequently retweeted content. The remaining content was of a more independent nature coming from a variety of sources.

From the twenty-five most retweeted messages, we can see that with the exception of two that are from users of the social forum, the remaining twenty-three are all passed on from the authenticated major media. This finding is in line with what Starbird and Palen (2010) identified - that it is more likely for the tweets originally distributed by main media (especially the local ones) and other traditional media service organizations to be retweeted. In addition to their messages being viewed by those specifically seeking out information about radiation in Japan, they have the built-in advantage of their information being 'pushed' to an even larger number of users as a result of being

followed in great numbers. By having their messages viewed by a greater number of eyes initially, tweets from these organizations have a far greater likelihood of being retweeted. The ability to utilize Twitter in this situation was of utmost importance to the public. At a time when risk communication from government sources was arguably on the verge of failing, media such as Twitter allowed those seeking more information to access a large amount of it quickly. While information from governmental sources was not in high supply, other places of origin were very successful in getting their view expressed to the public.

3.2.3. Reassurance in the context of the Japanese nuclear hazard

As established in the previous section, there was some withholding in the release of the radiation data by the present authorities. This is a reverse case of the peril in risk communication. Out of the top twenty-five most frequently cited retweets only a few messages are of a reassuring nature. Most of the messages are instead of an alarming and cautioning tone. Each of the three messages most frequently retweeted helped in avoiding to 'over-assure: "Low levels of radiation found in US milk", "Japan's chief cabinet secretary says it could be several months before radiation stops leaking from Fukushima nuclear plant.", and "Radiation in water rushing into sea tests millions of times over limit." All of these lead to a more cautious public. Looking further down the list of the top twenty-five retweets, at least 12 of them are alarming in nature while five of them are assuring in nature.

Given the valuable information regarding radiation levels and concerns provided in the top retweeted messages, the general population has the means to become sufficiently alerted and apply all necessary precautions.

3.3. Quantitative Analysis

3.3.1 Coding Schema

In order to answer the questions we raised above, quantitative analysis was conducted. Our first step was to determine how to determine the best way to measure alarming, reassuring, and assuring characteristics.

We examined the previous literature. First, Stephens and Edison (1982) used a simple classification of "measuring the number of reassuring or positive statements versus alarming or negative statements". Later, Speckens, Spinhoven et al. (2000) developed the questionnaires for measuring reassurance in the context of whether the patient feels reassured by their physicians. For instance, they used 'worrying' to measure the alarming dimension. For instance, some of their questions are:

-'Do you keep worrying as long as it is not possible to rule out a serious illness?'

-'Do you keep worrying as long as you do not know the origin of your symptoms?'

In their analysis, reassuring is simply taken to be the negative of alarming. We've adopted some of the questionnaires applicable to our context as our coding schema. In an attempt to improve on this, the authors of this paper had various discussions regarding more refined ways to look at these dimensions. Reassuring and alarming are not the only two traits a statement can have. Something that is not alarming is not by default reassuring and vice versa. After careful consideration of the dictionary definitions of the words, we assembled our questionnaire.

Coding categories and associated questions are as follows below:

Alarming:

1. Does the message communicate worry?
2. Does the message indicate the situation is dangerous?

Reassuring:

1. Does the message not communicate fear of the situation?
2. Does the message communicate calm?

Assuring:

1. Does the message indicate the situation is stable?

Additionally, we also measured an extra dimension of 'doubt'.

Doubt:

1. Does the message not communicate doubts about the situation?

Finally, we are also interested whether a message is from the government. So we coded two additional questions.

1. Is the message from government?
2. If "Yes" for the previous question, is it a direct quote or a secondary quote?

Inter-Coder Reliability

We hired two experienced coders, one a masters student majoring in Industrial Engineering, the other a Ph.D. student in Management Information Systems, to conduct the coding process. These two students both have prior experience on other projects with

coding tweets making them very familiar with the coding process. Before the formal coding process starts, a pilot coding with a randomly chosen 50 tweets was conducted. The Kappa value of .988 was extremely high, and so the reliability of the coding was confirmed. The two students then proceeded to code the full data set of 1520 retweets. The Kappa value of the full dataset is .977. Any Kappa value higher than .70 is considered as acceptable.

3.3.2 Results of Quantitative Analysis

As described in the previous chapter, the number of tweets on nuclear radiation started relatively low, but shifted as the timeline progressed. Retweet activity climaxed during the period at the end of March when fears of a nuclear meltdown were rampant. After this spike in interest and micro-blogging activity, interest proceeded to gradually decrease through early April. For our analysis we chose the top 1520 distinct, most frequently retweeted messages of this time period. The distribution in the number of distinct retweets in our 1520 most frequently retweeted messages shows a similar pattern as our full universe (figure 1).

As indicated in the prior section, our questions are coded independently. A positive response to one question does not necessarily require a negative answer to another. For instance, one message can communicate worry, but also communicate the situation is stable. As a result, we needed to ensure we are measuring truly different things. Between each of the three combinations of the dimensions, we conducted the non-parametric T test. The results below indicate that there is a statistically significant

difference between the mean values for alarming and reassuring retweets, alarming and assuring retweets, and reassuring and assuring retweets.

Difference	T Value	Probability
Alarming and Reassuring	6.78	<0.0001
Alarming and Assuring	33.23	<0.0001
Reassuring and Assuring	30.52	<0.0001

Table 2. T test between the measures

As described in the previous chapter, the number of tweets on nuclear radiation started relatively low, but shifted as the timeline progressed. Retweet activity climaxed during the period at the end of March when fears of a nuclear meltdown were rampant. After this spike in interest and micro-blogging activity, interest proceeded to gradually decrease through early April. Accordingly, we separated the data sample into three periods demonstrating these differing patterns. We separated the data sample into three periods. The first segment consists of retweets from before March 29 (579 retweets in total). The second segment contains the messages originating between March 30 and April 3 (493 retweets in total). Finally the third period is made up of retweets from between April 4 to April 8 (450 retweets in total). These three time periods, while having a similar number of retweets, also represent three distinct periods of time; both with regards to the disaster, and in the micro-blogging community. In the days following the earthquake, little was changing, and the public was not focused on the nuclear situation. Activity on twitter surged in late March with regards to radiation as the possibility of a nuclear meltdown became distinct. This surge in activity is our second time period. Finally, the timeline is completed with a third period of time following this surge in interest and activity. The communication patterns are discussed below.

Alarming

Two measures were used to examine the different dimensions of 'Alarming'.

- Does this message communicate worry
- Does this message indicate the situation is dangerous

While the three time periods will certainly have different averages through chance, we need to determine if these communication patterns differ in a statistically significant way. If so, then we can legitimately claim the periods have a different communication pattern. Our first step in comparing the three sub sample sets is to determine whether the patterns on communicating 'Alarming' are different over time. Nonparametric analysis was performed to help answer this question. Friedman's nonparametric test in SAS was conducted, and the result shows: Chi-Square = 28.9036, with the $p<0.0001$. This means the three sub-datasets show significant differences in the communication patterns of conveying 'Alarming' messages.

In the following chart, we see the communication patterns in the three time periods with regard to the messages communicating worry, and ones communicating the situation being dangerous. In this diagram and elsewhere in the paper, we refer to distinct and total tweets. The majority of messages in our sample were just retweeted once or a few times, but others were retweeted hundreds and hundreds of times. There were 1520 different messages in our sample which were retweeted a total of 9545 times. References to 'distinct retweets' refer to this total pool of 1520 messages, weighing every message

equally. References to total retweets instead look at the number of times each message was retweeted, referring to the 9545 times all of the distinct message were retweeted in total.

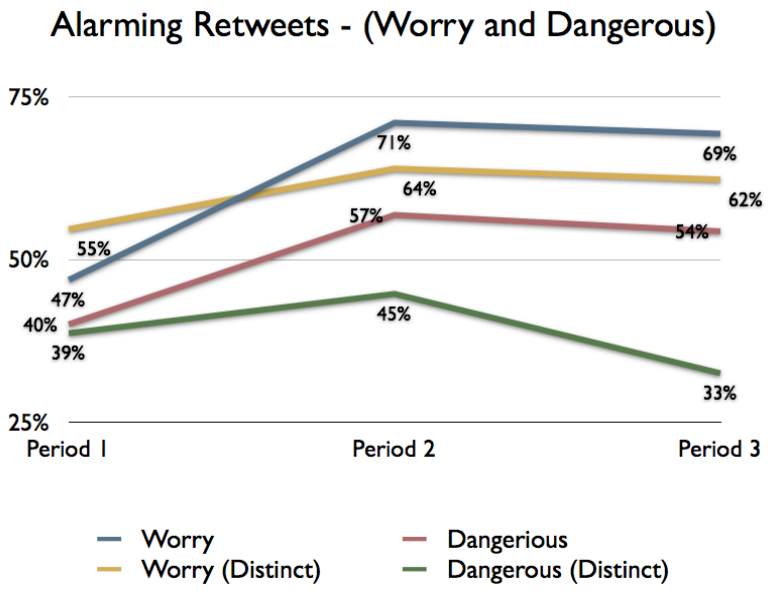

Figure 2. Alarming Retweets

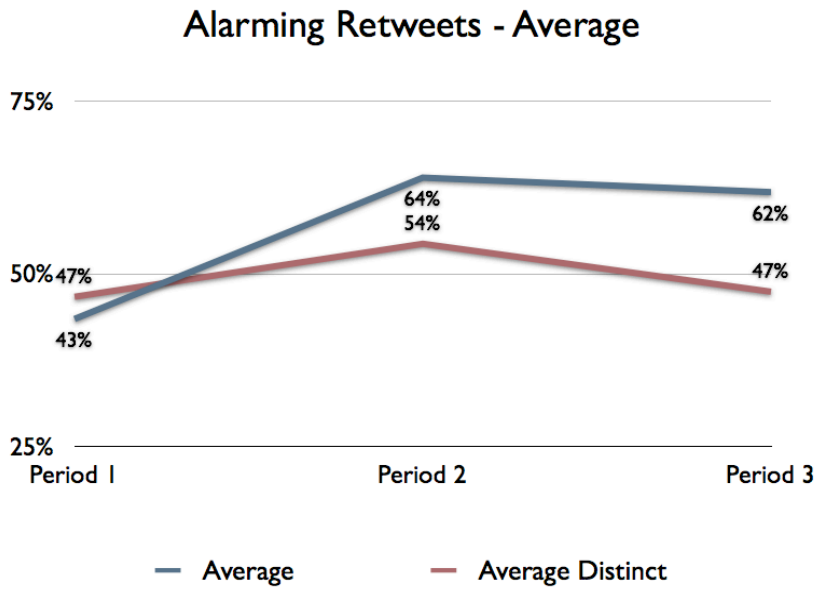

Figure 3. Alarming Retweets - Average

These results are reflective of the circumstances at Fukushima as the situation unfolded. We can see the great surge in twitter activity coincided with a large increase in alarmism. Distinct retweets indicating worry increased over 50% while retweets indicating a dangerous situation increased over 40%. These percentages started to decrease as twitter activity subsided later on, but their levels remained well above their initial state. Regardless of whether this increase of concern was warranted or not, the population was clearly feeling more alarmed, and reflected this via their behavior and retweets on twitter.

At the same time, we can see that while number of distinct retweets indicating worry increased, it did not increase nearly as much as the total volume of these retweets. While the first period showed 55% of distinct retweets indicated worry, this increased only 16% to 64% in the second period. Initially, these alarming messages making up 55% of the distinct retweets were being muffled in the twitter ecosystem, only accounting for 47% of the total volume of retweets. The same is true for the average in the first period where we see a higher percentage of overall alarming distinct tweets than we see as a percentage of the total number of retweets. As the situation progressed and alarm increased, the twitter community started retweeting worrisome messages more frequently than non-worrisome ones, amplifying the content exhibiting worry. The average total number of retweets started 4% lower than the distinct number of retweets in period one (43% vs. 47%). This shifts to where it becomes 10% greater in period two (64% vs. 54%), and finally 15% greater in period three (62% vs. 47%).

A similar phenomenon can be seen in our data regarding retweets where 'the message indicates the situation is dangerous'. The distinct number of retweets coded showing the situation was dangerous saw a minor, but definite increase in period two from 39% to 45%. However the raw number of times these messages were retweeted saw a much larger increase from 40% to 57%.

We can see that as the situation worsened in Japan, the amplification of this information was greatly increased. As time passed and the amount of alarming information decreased, the public remained in a more alarmed state, their total proportion of retweets remaining elevated at nearly the same levels. While there were fewer

alarming messages for them to retweet, the public continued to seek out this information and echo it.

Reassuring

Two measures were used to examine the different dimensions of 'Reassuring'.

- The message does not communicate fear of the situation
- The message communicates calm

As mentioned above when discussing alarming retweets, we need to determine if the communication patterns of the three periods differ in a statistically significant way. Now we must do the same with respect to 'reassuring' attributes over time. Nonparametric analysis was again performed, and the result shows the difference is significant with Friedman's Chi-square=14.8925 and p=0.0019. This shows the communication patterns of 'reassuring' are different over the three periods.

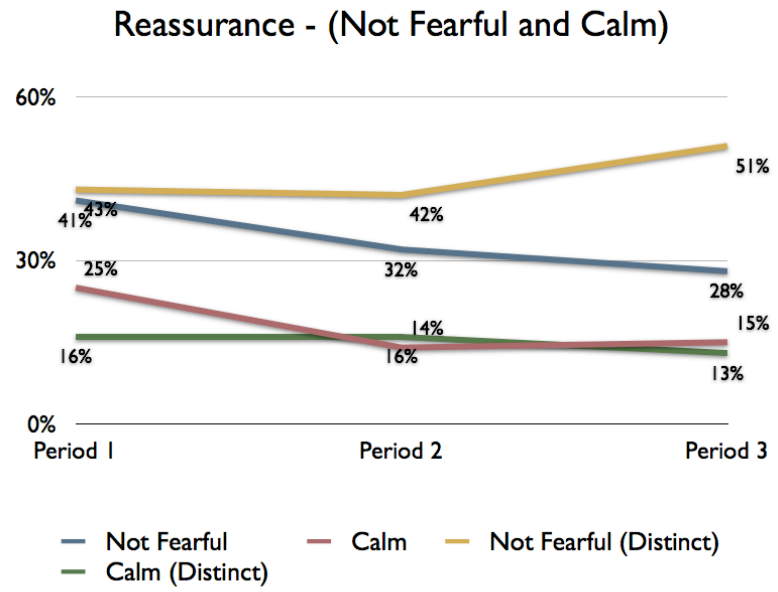

Figure 4. Reassurance Retweets

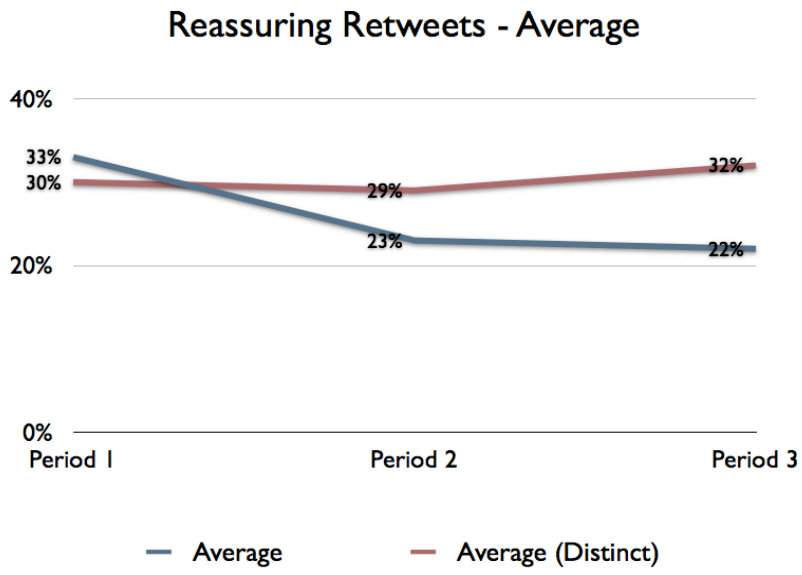

Figure 5. Reassuring Retweets - Average

We first note that as the situation worsens, people are retweeting reassuring content less frequently. During period 2 at the end of March as fear of the meltdown reached its climax, the messages communicating reassurance decreased a great deal. A similar level of low reassurance remained throughout period 3. This reflects the grassroots community was on edge as the possibility of meltdown continued, regardless of information coming from the government or media.

The distinct content of the retweets shows a similar level of reassurance. However the total volume of people retweeting this content drops significantly in periods 2 and 3. This shows the non-amplification of this information. Compared to the two dimensions, the most frequently retweeted messages were of an alarming nature while the content of a reassuring nature was retweeted less frequently. People were not echoing the reassuring information. This is the exact opposite of what we saw in the alarming dimension where the community was quick to frequently echo the content that was alarming.

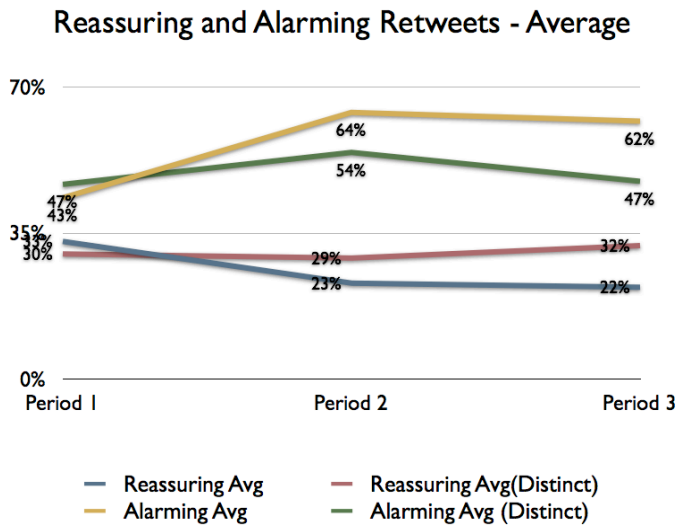

Figure 6. Reassuring and Alarming Retweets - Average

Figure 6 is the simple combination of Figure 3 and Figure 5. This allows us to see two things quite clearly. First, we see there is a significantly higher proportion of retweets of an alarming nature in all three periods. This is true for both the number of distinct retweets, and the total number of retweets. Second, we see there is an inverse relationship between the proportion of alarming, and reassuring retweets.

Assuring

One measure was used to examine the different dimensions of 'Assuring'.

- The message indicates the situation is stable

Again our first step is to determine whether the patterns of communicating 'assuring' attributes are statistically different over time. Nonparametric analysis was performed, with the result again showing the difference is significant with Friedman's Chi-square=11.4972 and p=0.0007. The communication patterns with respect to 'assuring' are different over the three periods.

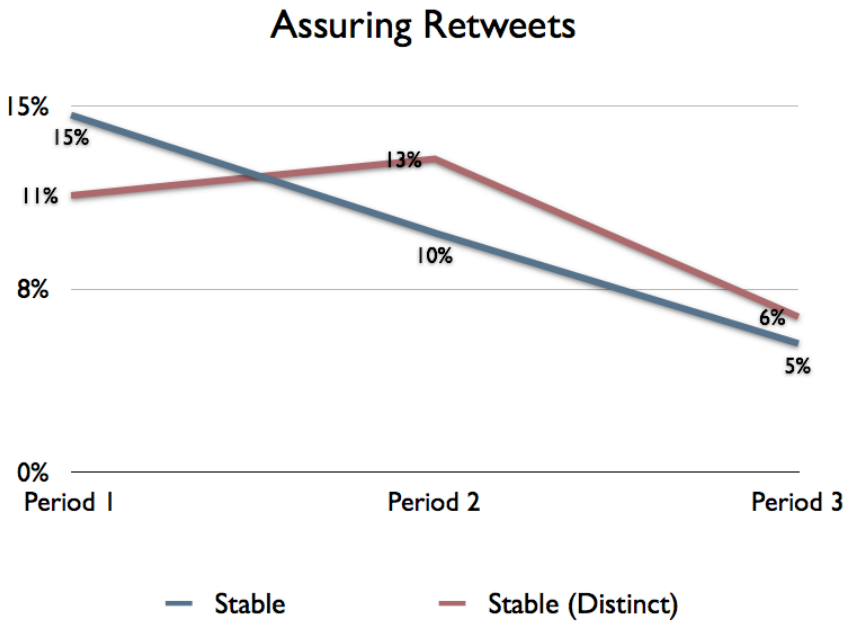

Figure 7. Assuring Retweets

During the late March surge in twitter activity, there was a slightly larger proportion of distinct messages indicating a stable situation. These messages were retweeted less frequently however and were thus less noticeable as a smaller percentage of the total sample of retweets. This is in agreement with what we saw previously where the more alarming messages were more likely to be retweeted.

Sandman (1994) states "Alarming content about risk is more common than reassuring content or intermediate content – except, perhaps, in crisis situations, when the impulse to prevent panic seems to moderate the coverage". Similarly when studying the coverage of Three-Mile Island, certainly qualifying as a crisis situation, Stephens and Edison found coverage by television and newspaper media, while alleged to be

sensationalized, actually turned out to tend more towards a reassuring posture. Studying the data from twitter however, we find the opposite to be true for the retweet activity. When it comes to information being communicated and echoed by the population themselves on twitter, coverage tends toward a more sensationalized, alarming state rather than a reassuring condition.

Messages from the government

Besides measuring the three dimensions above, we are also interested in the governmental presence within the micro-blogging environment. We would like to see how much the government was involved and participatory in the conversation (directly, or indirectly) and how often the public quotes these messages from the government via retweet. The questions that we asked were:

- The message is from government
- If "Yes" for the previous question, it is a direct quote

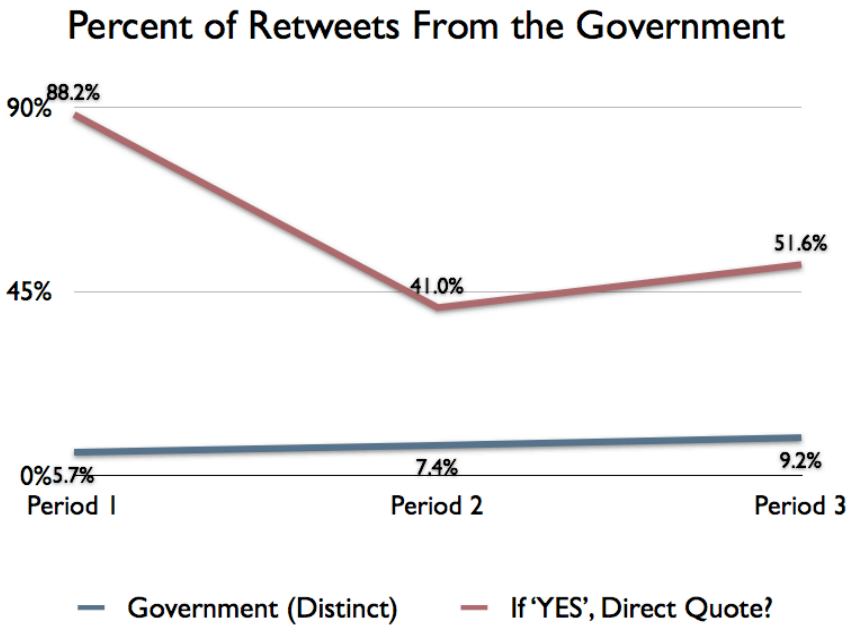

Figure 8. Percentage of Retweets from the Government

We repeated the same analysis, focusing solely on the messages with a governmental origin (either directly or secondarily quoted from the government).

We can quickly see that messages attributed to a government organization make up a small proportion of the sample of distinct retweets. There is a gradual increase in the contribution rate of messages with an apparent governmental origin as time progresses, however this increase is not particularly large.

Of this sample of messages attributed to the government, there is a dramatic drop in how many appear to be direct quotes as the situation accelerates.

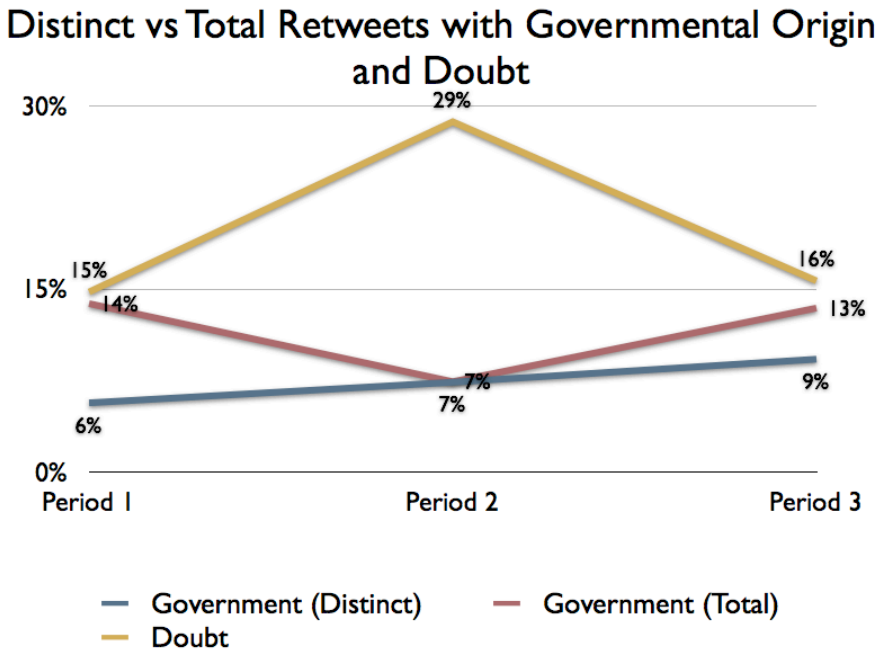

Figure 9. Distinct vs. Total Retreets with Governmental Origin

In period 1, prior to the surge in twitter activity, the governmental messages did enjoy significant amplification from the twitter community. Despite accounting for only 5.7% of the distinct messages retweeted, the total number of times these messages were retweeted accounted for over 14% of the total retweets in sample. It is important to note that during the surge in interest, this amplification vanished completely. The percentage of distinct retweets, and the percentage of the total volume of retweets from the government are identical in period 2 at 7.4%. The voice of the government was either being drowned out or ignored by the twitter community. Their voice on twitter had certainly become less influential. Messages with a governmental origin actually make up a slightly growing percent of the sample of distinct messages retweeted as time

progresses, however they are retweeted proportionally less frequently as interest intensifies. The government is attempting to get more information out to the public, but this is not translating into the information being more widely distributed. The additional information from the government is failing to be echoed by the public. The amplification of governmental information partially returns during the third period where the government is the source of 9.2% of the distinct retweets, and 13.4% of the total volume of retweets. This 46% amplification is far short of the 145% amplification governmental tweets experienced in period 1.

Another question we had coded asked whether the message communicated doubt. We observed a very large increase in doubt in the second period which then decreased again in the third period. The drop in the amplification of governmental information directly corresponds to this increase in doubt. From this we can theorize that as people had more doubts about the situation, they were less apt amplify the government's information by repeating it. We can draw a similar conclusion regarding the direct quotation of government sources dropping significantly as doubt spikes.

Composition of governmental tweets:

Where the government has no control over how frequently their words are retweeted, they are able to control the amount of information they provide, and the content of this information. For this reason, we will concentrate on the distinct number of retweets with governmental origins instead of the total number of times these message are retweeted.

First we will look at messages indicating calm.

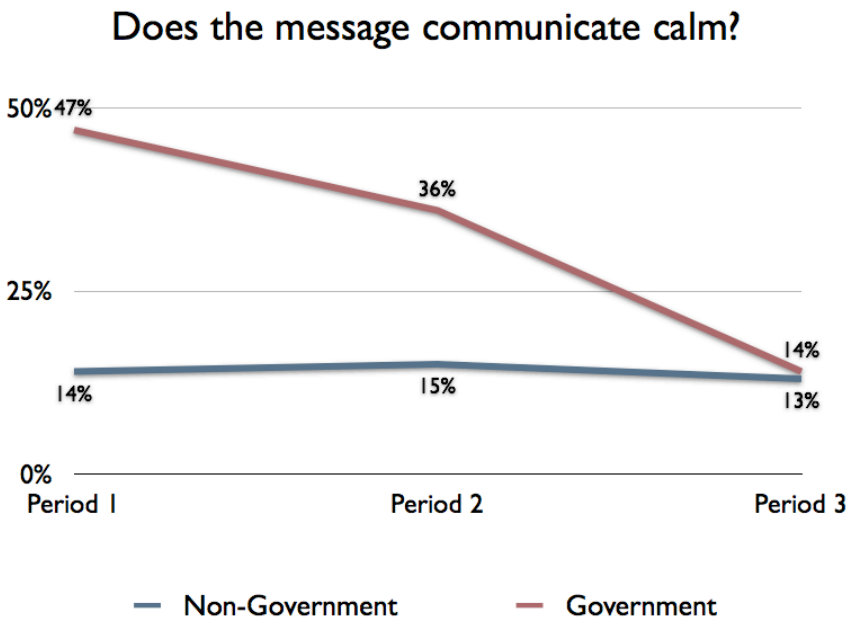

Figure 10. Percentage of Retweets Communicating Calm

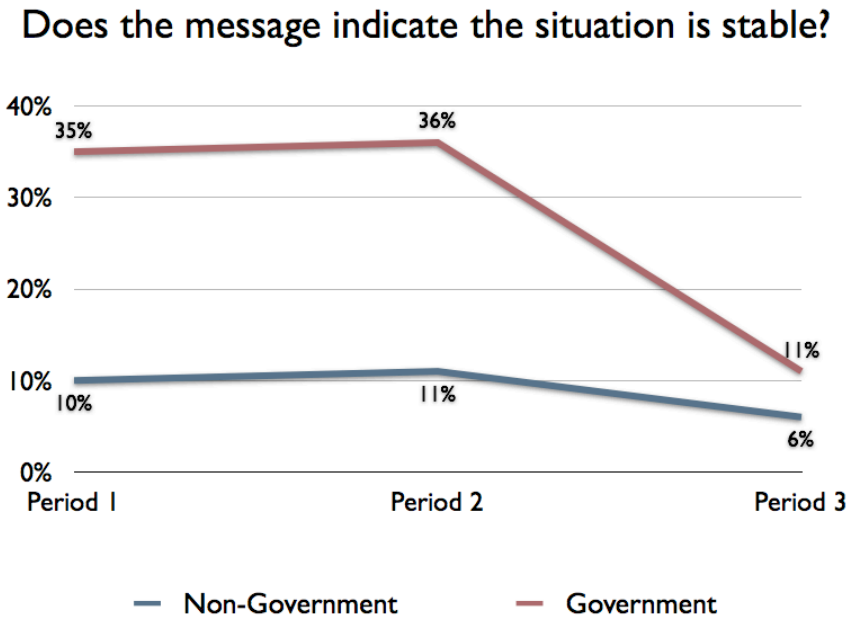

Figure 11. Percentage of Retweets Indicating the Situation is Stable

We can see from Figure 10, during period 1, 47% of the governmental messages communicated calm, while only 14% of the non-government messages communicated calm. In period 2, 36% of the government messages communicated calm, while it is only 15% in the non-government universe. We are seeing a similar pattern for the 'stable' messages.

We can see the governmental messages were much more reassuring than those coming from non-government sources. In all three periods, governmental messages were 10-250% more likely to be reassuring.

Relationship between the volume of retweets and content

We also wanted to look at the relationship between the volume of retweets and the content to see what relationships may be present. To do this, we examined the coded content of the retweets by day, and drew a relationship to the number of retweets that were on those particular days in our sample. Days with an extremely small number of retweets in our sample (<20) were excluded. The following correlations were drawn.

Pattern	Relationship	Correlation
Alarming	Worry	Positive
	Dangerous	Positive
Reassuring	Not Fearful	Negative
	Calm	Negative

Table 3. The relationship between the volume of retweets and the content

The each individual relationship is shown below.

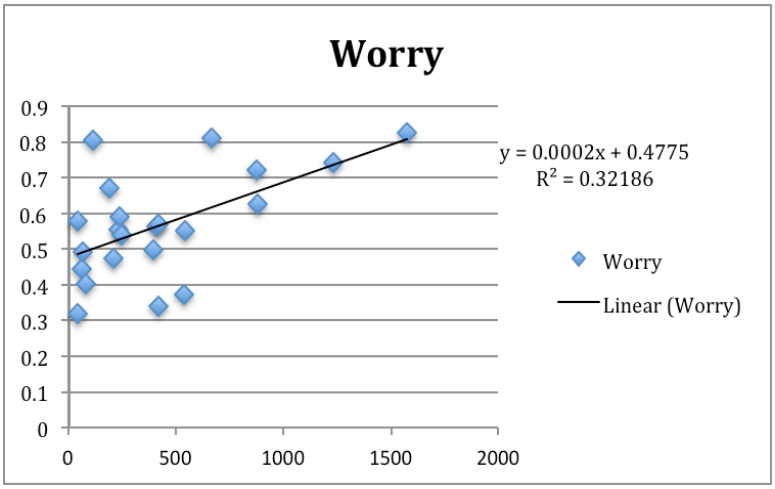

Figure 12. Relationship between message of "Worry" and number of Retweets

We immediately see a strong positive correlation between retweets communicating worry, and the volume of retweet activity on that day. Amongst the characteristics we examine, this is one of the stonger fits with an R-squared of 0.32.

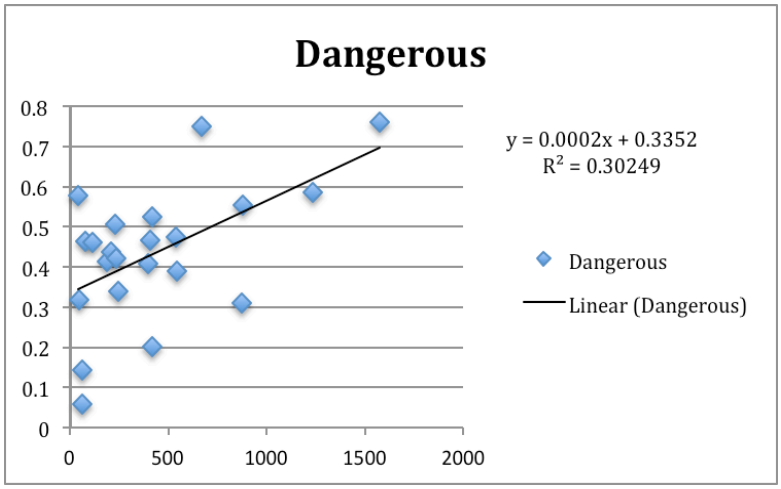

Figure 13. Relationship between message of "Dangerous" and number of Retweets

We again see a strong positive correlation between retweets communicating the situation is dangerous, and the volume of retweet activity on that day. Amongst the characteristics we examine, this is one of the stonger fits with an R-squared of 0.3.

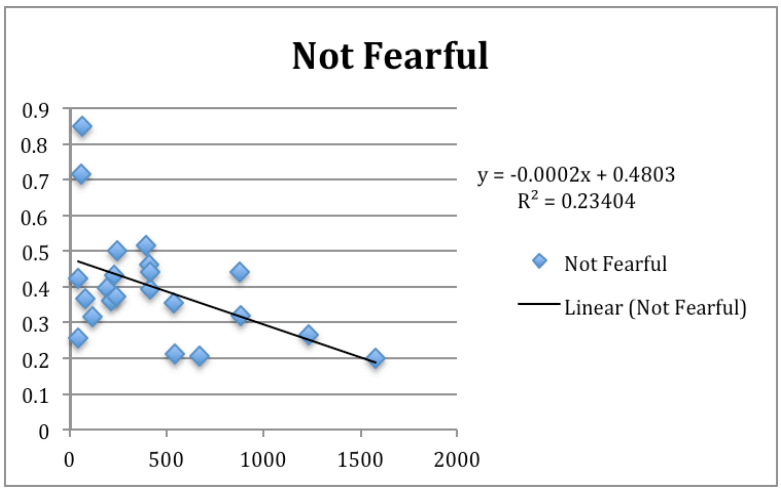

Figure 14. Relationship between message of "Not Fearful" and number of Retweets

We again see a strong negative correlation between retweets not communicating fear, and the volume of retweet activity on that day. Amongst the characteristics we examine, this is one of the stonger fits with an R-squared of 0.23.

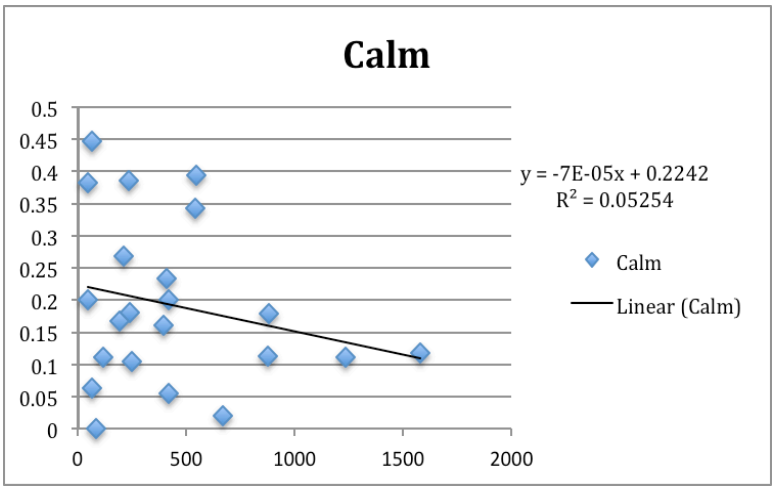

Figure 15. Relationship between message of "Calm" and number of Retweets

We see a negative correlation between retweets communicating calm, and the volume of retweet activity on that day. Amongst the characteristics we examine, this is one of the weakerer fits with an R-squared of 0.05.

4. Conclusion

The analysis provides strong evidence that the alarming and reassuring content of the micro-blogging environment changes greatly as the situation and the mindset of the public evolves. Additionally, we find the information communicated via retweet on twitter is quite different than that found in previous research of television and newspaper media coverage. While traditional media coverage was found to be of a more reassuring nature, the societally driven micro-blogging universe tends towards a more alarming stance.

In looking at the retweets coming from a governmental source, we find this information is of a much more reassuring nature than that not coming from the government. This is especially the case in the immediate aftermath of the earthquake and during the grass-roots fear of a possible meltdown. In order to gain a measure of control over the possibility of panic from the general population, the affected government and organization may sometimes need to withhold or postpone publishing some negative hazard data. This is especially the case when their own reputation and the issue of 'saving face' are involved. As time progresses, the government feels less of a need to be reassuring and shifts towards a more alarming posture. While initially they wish to avert

a panic, in the later stages of the situation the government desires to keep the public alert and focused on possible danger.

Framing was widely used to understand the media effects in the prior research (e.g. Semetko and Valkenburg 2000). The media determines the frame and coverage in distributing information to the public. They have discretion of what news to choose, and how this material is presented. Our paper aimed to expand on this and see how public is seeking and digesting the information in great part passed on by the media. We found that the public tends to seek and share information more driven by the interest of self-preservation. It is especially true when uncertainty, fear, and panic are common at the immediate aftermath of a disaster. Amongst those seeking alarming information, if any is found, this is what they are most likely to echo. As a consequence, the messages with an alarming and cautionary nature usually get the most attention. Thus it is not surprising to see a clear and consistent trend that shows the more active the micro-blogging community is, the coverage tends to become even more alarming and less reassuring.

DISSERTATION CONSLUSIONS

The first essay explored micro-blogging as a rapid response news service in the first major natural disaster where Twitter was used in a very significant way. We found that micro-blogging can serve as an excellent supplement to traditional information channels, and when required, could also serve as a short-term replacement in the immediate aftermath of a disaster. Some factors compared more favorably while others were less favorable than traditional media channels. We provided a complete picture of how micro-blogging distributes information based on the well-defined dimensions of information quality.

Furthering our examination of disaster relief, our case study regarding the use of FOSS provides great insight into numerous factors affecting a disaster relief deployment. The interaction effects and management implications of cost, adaptability, data ownership, system knowledge and experience, awareness of extended knowledge and support pool, government management support, and private-public trust in a FOSS disaster relief deployment are all examined in depth. This information will be of great use to practitioners in better understanding how the partnership between government and the private sector may be better initiated, supported, and coordinated.

As we return in the third essay to micro-blogging in the disaster relief context, we find great differences in the communication patterns of alarming and reassuring content. These patterns are different, and also tend to be more alarming than that which has been previously found in the traditional media outlets. We additionally find the governmental voice to be of a more reassuring nature, especially in the time period immediately following the disaster. Finally, we also see a consistent trend that shows the more active

the micro-blogging community, the more alarming and less reassuring the coverage tends to be.

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