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Utilization of Crowdsourced Maps in Catastrophic Disasters

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UTILIZATION OF CROWDSOURCED MAPS IN CATASTROPHIC DISASTERS

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UTILIZATION OF CROWDSOURCED MAPS IN CATASTROPHIC DISASTERS

by

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ABSTRACT

UTILIZATION OF CROWDSOURCED MAPS IN CATASTROPHIC DISASTERS

By Makiko Naoe Hong

Crowdsourced data, the collective messages from citizens through social media like Twitter® or Facebook®, have been increasingly recognized as a vital information source in a catastrophic disaster. Because there is often insufficient emergency personnel to gather situational information during a big disaster, the crowdsourced data can offer a supplemental means for data collection or dissemination immediately after the disaster. In addition, crowdsourced maps can empower citizens with their involvement.

In the Haiti earthquake of 2010, crowdsourced data was first used to create a web map application to aid the humanitarian effort. With some success in Haiti, these crowdsourced maps have since been created for other disasters in many countries. However, although the crowdsourced map showed great potential, it also revealed a major shortcoming: most first responders did not use the crowdsourced map.

This thesis addresses the issues associated with using crowdsourced maps in the responder community and seeks a possible solution for increasing utilization by first responders during catastrophic disasters. Citizen messages from the Japan earthquake of 2011 were analyzed and filtered by categories best suited for responders. Then, considering the technological difficulties experienced immediately following the disaster, the best communication means were explored to complete two-way communication between responders and citizens.

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I would like to thank Dr. Richard Taketa for introducing me to a different world of technology and teaching me the value of problem solving skills, which I will use my whole life. I would like to thank Dr. Kathryn Davis for making me aware of social problems in the world, and making me believe that I can be a part of the solution. I would like to thank Laurie Brown for providing insight into the responder community. I would like to thank my son, Seth, for his role in pursuing my goal. He is the reason I could not and cannot give up. I would like to thank Steven for believing, encouraging, and supporting me the entire time. While our journey continues, I would like to be a person he is proud of.

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Introduction

Citizen participation in emergency response has been active through social media in recent years. The *National Journal* reported that more people turn to social media like Twitter or Facebook as a communication tool during an emergency (Hatch, 2011). Twitter, in particular, has already proven its communication speed in past emergency events like the Southern California wildfire in 2007 and the Mumbai terrorist attack in 2008 (Hughes & Palen, 2009). The USGS experimented with earthquake detection on Twitter and found that it was faster relaying the event than a scientific alert (Earle, Bowden, & Guy, 2012). Social media's speed advantage empowers humanitarian efforts, too. Using social media, some citizens in disaster affected areas started to communicate with people in the outside world almost immediately by sending out help requests for supplies or immediate rescue. Those messages were collected and mapped out over the web by spontaneously organized volunteer groups for humanitarian deeds. From these efforts, crowdsourced maps emerged, opening the new prospect of the citizen's role in emergency response. Any person directly affected by disaster, or living some distance away from a disaster stricken area, can contribute to improve the situation (Heinzelman & Waters, 2010).

The first recognized crowdsourced map focusing on emergency support is the Ushahidi crisis map service. Launched during the 2010 Haiti earthquake for emergency relief, the crisis map service demonstrated its potential benefits in aid efforts. The U.S. Coast Guard disseminated the timely reports from Ushahidi to search-and-rescue operations on the ground. Rescue requests tagged with spatial information enabled rescue workers to quickly reach survivors in the rubble of collapsed buildings. The U.S. Marines also used the map service to deliver clean drinking water (Heinzelman & Waters, 2010).

The emergence of crowdsourced maps can help facilitate gaps in data collection, which often creates a problem for disaster management. Collecting reports from affected citizens in real time via mobile text message and social media fill the gap of data availability immediately after the disaster. This insightful information, where and what help is needed, cannot be conveyed through satellite photos to mobilize responders with the specific resources required.

Crowdsourced maps, in general, have received positive reviews in emergency response. Zook, Graham, Shelton, and Gorman (2010) analyzed information technologies (ITs) used for relief effort in Haiti including Crisis Camp Haiti, OpenStreetMap, Ushahidi, and GeoCommons. Their findings demonstrated that "ITs were a key means through which individuals could make a tangible difference in the work of relief and aid agencies without actually being physically present in Haiti" (Zook et al., 2010, p. 7). The World Bank (2012) reported that "Open source portals, such as the Ushahidi-based sinsai.info, are important tools that allow requests for help from local people to be logged and acted upon" (p. 13).

Although crowdsourced maps have proven to have potential in emergency response, they have not been widely embraced. The citizens have been given a voice, but the communication has been largely one way. The research conducted in Haiti's case revealed that Haitians were disappointed that they did not receive sufficient response although their messages, often requests for help, were out there. Nelson, Sigal, and Zambrano (2011) emphasize the importance of response to the citizen's request. "The 'feedback loop' of communication is only complete when the appropriate action has been taken" (Nelson et al., 2011, p. 9). As found in the Haiti case, the biggest disappointment has been that most first responder agencies were not even aware of the crisis map service. This fact alone threatens the potential of utilizing crowdsourced maps in emergency response.

This thesis will explore how to encourage responders to utilize a crowdsourced map. The main objectives of this study are (a) identifying why the responders do not use the crowdsourced map, and (b) finding a possible solution. Towards this goal, the relative strengths and weaknesses of crowdsourcing will be evaluated from the viewpoint of the responders. Understanding responder needs will lead to a better understanding as to what can be improved. Providing insight towards utilizing crowdsourced maps to close the 'feedback loop' between citizen and responder has the potential for more efficient responses and a visual means to provide aid transparency.

Evaluation of Crowdsourcing

Ushahidi and Crowdsourced Maps

Ushahidi is a non-profit organization, which develops a free and open-source software platform for taking messages from texting or social media and plotting them on an interactive web map. The visualization of these messages on a map empowers citizens by calling attention to their voice. On its website, Ushahidi (n.d.) explained the role of Ushahidi as “We build tools for democratizing information and increasing transparency– we're lowering the barriers for individuals to share their stories” (What We Do section, para. 2). The goal of the original Ushahidi project was broadcasting the oppression of the Kenyan government to the world during the aftermath of Kenya’s election in 2008. Indeed, the web map helped raise awareness of human rights violations. The collection of citizen testimonies through email, mobile phone, or web reports was visualized and organized by geographic content, and later used as evidence for bringing officials to criminal trial in international court for charges against humanity.

Soon the role of the Ushahidi map platform was expanded to aid other humanitarian efforts. Ushahidi organizers launched the Crisis Map of Haiti when a catastrophic earthquake struck Haiti in 2010. It was the first among crowdsourced maps with a goal towards supporting the aid effort. The fact that the U.S. Coast Guards and Marines utilized the crisis map for their operation validated the potential of crowdsourced maps during emergencies. Ushahidi’s software was adopted for other disasters after the Haiti earthquake in countries such as Chile, New Zealand, and Japan. Each country developed its own version of a crisis map with the help of volunteers.

Benefits of Crowdsourced Maps

Real-time data. A great benefit of crowdsourcing is the availability of timely data as the situation can dramatically change from second to second during the response period. GIS has been utilized for emergency management for decades. Past experience indicates the lack of data immediately following a disaster has caused serious problems in aid efforts. Cova (1999) stated that “[t]he primary benefits of GIS in this phase lie in spatial information integration and dissemination. Emergency personnel need to know where an event is occurring in order to minimize further loss and effectively deploy relief” (p. 850). The capacity to handle real-time data is limited by the number of GIS specialists available for data collection and dissemination. The number of people affected by a disaster easily overwhelms the capacity of these professionals. Collecting data in a timely manner becomes almost an impossible task, especially during large disasters.

This failure of GIS during an emergency situation was reported in Miyagi prefecture, one of the hardest hit prefectures of the Japan earthquake of 2011. The Miyagi Integrated Disaster prevention Online system for Rapid and accurate Information (MIDORI) collected some real-time reports from various resources to help coordinate the aid effort, but the lack of personnel (Sakamoto & Yamori, 2012) prevented the data collection necessary for comprehensive situation reports. As a result, MIDORI’s analysis concerning damage assessment, search and rescue, and logistics was often hampered by gaps in information. Crowdsourced maps with the citizens filling the information gap represent a major shift from traditional GIS data collection by specialists (Budhathoki, Bruce, & Nedovic-Budic, 2008)

Information accessibility. Another advantage of crowdsourced maps is information accessibility. Because aid efforts include multiple levels of government and private organizations, communication between the agencies becomes a big challenge. Russo (2011), who worked in fire and public safety for over 25 years in the U.S., expressed concern over the inability of first responders to communicate with each other during the aftermath of the 9/11 terrorist attack when he said, "Interoperability between public safety agencies was inadequate, and in many cases non-existent. The first responders on the scene at Ground Zero arrived from many different agencies and geographical jurisdictions. We were severely hampered by not being able to communicate with each other, as radio systems did not allow for inter-agency communications" (p. 1). Communication systems involved with emergency response in Miyagi prefecture (n.d.) clearly support Russo's claim (Figure 1). The hierarchical communication structure prevented interaction between fire fighter, police, and the self-defense force on the ground.

Difficulty in centralizing operations is evident in many disasters. A report from the Japanese government clearly stated that field workers in the disaster area are the decision makers and operators during the early response period (Government of Japan, Cabinet Office, 2011). The crowdsourced map provides a common data set for responders to collaboratively use by leveraging text and social media from citizens in a format that all can view.

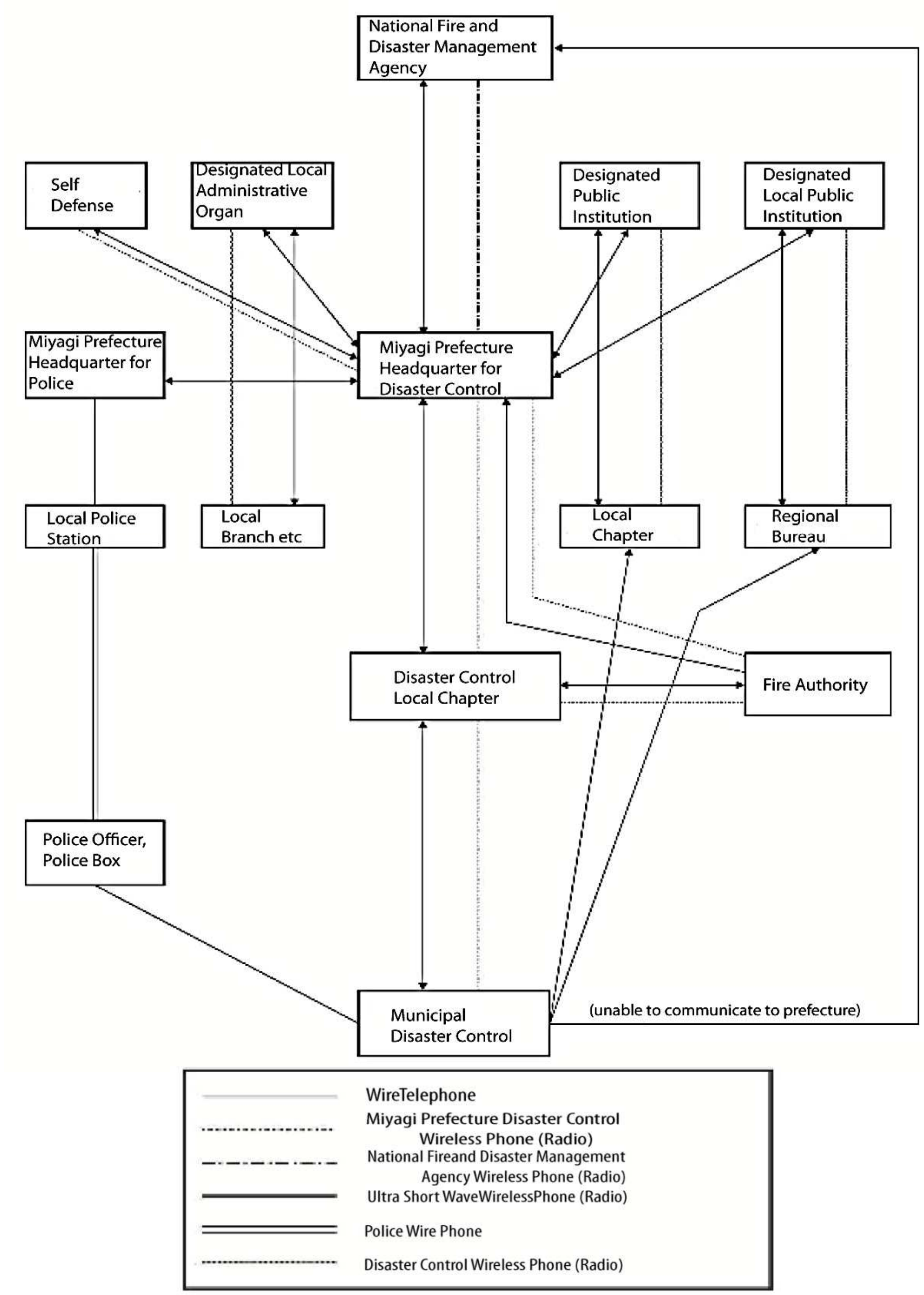


Figure 1: Communication system in emergency situation.
***Note:* From Miyagi Prefecture.**

Drawbacks of Crowdsourcing in Emergency Response

Utilization of crowdsourced data has great potential to change the audience and participants during emergency response. More involvement of regular citizens means increasing the knowledge of a situation in a timely manner. Unfortunately, this notion of allowing anyone to contribute also is a major reason why few first responders use crowdsourced maps. Information coming from anyone and in any format raises questions of reliability as well as data management challenges. Concerns for the accuracy and heterogeneous nature of crowdsourced data are frequently discussed among GIS professionals.

Accuracy of data. Accuracy is always a prime concern in GIS. Inaccurate data can lead to flawed decision making and a disastrous outcome. However, an emphasis on accuracy requires time and labor. Official reports during emergency situations tend to be slow because of the necessity of verifying data by trained professionals. On the other hand, crowdsourced data are nearly real time, but their sources are from untrained citizens and often unverifiable. The question is whether crowdsourced data suffer from inaccuracy. Giles (2005) found these claims to be without merit with his research of Wikipedia that reflected an accuracy level on par with expertly written encyclopedias. This high degree of accuracy is attributed to the self-correcting mechanism from the majority of the readers’ own expertise. Thus, accuracy increases with the number of interested readers. Goodchild and Glennon (2010) recognized that similar accuracy benefits apply to data in a geographic context during non-real-time emergency circumstances. However, their study of the Santa Barbara wildfires shows the correction mechanism would not work in a real-time emergency situation as “asserted information is more prone to error, and there were many instances during the fires of false rumors being spread through Web sites” (Goodchild & Glennon, 2010, p. 239). Critical mass for self-correction is often not reached because of the time and geographic constraints. Yet, their conclusion still supports citizen’s participation; responding to a false alarm is better than failing to be aware of a real danger. Zook et al. (2010) even dismissed the need for high accuracy in emergency situations. They believe “In disaster situations, however, geographic information need only be good enough to assist recovery workers using the maps, meaning that crowdsourced information is likely to be just as helpful as that produced by more centralized means” (p. 13). Since the situation rapidly changes in an emergency period, the availability of data outweighs the desire for high accuracy.

Heterogeneous nature of data. The free form of expressing oneself on the Internet also creates challenges when trying to normalize and aggregate data. Dunn (2007) pointed out this challenge when stating that crowdsourced GIS “is characterized by its inclusion of some of the ‘messiness’ and fuzziness of much geographical information and of human-environment relations” (p. 619). Elwood (2010) further described the difficulties caused by this ‘messiness’ as “grappling with the representation, analysis, and administration of large volumes of heterogeneous data, particularly spatial data expressed in qualitative or natural language terms” (p. 349). Ushahidi’s crisis map shares the same problems. The need for organizing the data becomes a crucial task that requires trained personnel.

Operating a crowdsourced map like the Ushahidi crisis map requires volunteers. The volunteers filter, classify, and geocode the incoming reports received over the Internet (Nelson et al., 2011). However, organizing and directing the volunteers become another challenge right after the disaster. Furuhashi, contributor of startup sinsai.info for the Ushahidi crisis map in Japan, explained this difficulty as: "For the first month, more and more active volunteers were coming, but they were getting over our capacity and we could not direct them efficiently, especially for foreign volunteers" (as cited in Miyazaki, 2011, p. 9). The first month is the critical time for emergency response; the volume of reports is at its largest, and the demand for real-time reports is also great. Volunteers need to be trained quickly to keep up with real-time information, while being mindful of the quality of work. Each message from texting or social media needs to be sorted into categories for charting. Out of 50 reports randomly sampled from the 3584 listed during the Haiti disaster, 36% of them were deemed to have been misclassified (Morrow, Mock, Papendieck, & Kocmich, 2011). A good plan to train volunteers needs to be developed to deter such a high percentage of misclassification. The effort to establish a global guidance as part of preparedness might be necessary in crowdsourced data as well as exploring more integrated technology, including automated filtering, classification using key words, and utilization of cellular phone GPS.

The Issues with the Crowdsourced Map in Haiti

Some of the general problems of crowdsourcing data discussed in the previous section along with some new insights can be found in the responder issues attributed in the Haiti case. Ushahidi assessment reports of Haiti revealed responders did not use the crisis map for three main reasons: (a) information overload, (b) responder community's unawareness of the map service, and (c) technological difficulty.

Information overload. "All the people involved in actual response activities and those that have had operational experience spoke of the issue of information overload in recent emergencies including Haiti" (Morrow et al., 2011, p. 17). In emergency response, responders want to obtain related information as quickly as possible. However, too much information on the Ushahidi crisis map makes interpretation difficult. For example, Sarcevid et al. (2012) recognized the potential use of the Ushahidi map as the information exchange destination to connect needs on the ground and suppliers for the medical field, but they dismissed its use because the web map required too much sorting effort for a medical response.

Responder community's lack of awareness of the map service. As the role of the crisis map as an emergency response tool only began during the Haiti disaster in 2010, spreading the service among users and building a reputation will take time. For the Haiti disaster, extensive studies revealed traditional humanitarian communities including United Nations cluster leads and United States government officials were unfamiliar with the Ushahidi service. "Even after initial media reports that included high level endorsement, many traditional humanitarian actors on the ground or in headquarters offices were not aware of the UHP [Ushahidi Haiti Project] or were only vaguely aware of its existence" (Morrow et al., 2011, p. 16).

The responder community tends to be slow in seeking out new tools. "Large traditional emergency responders rely on response plans and long-standing protocols"

(Morrow et al., 2011, p. 16). These rigid plans were established over time by political and security restrictions that pose difficulty for new tool adoption.

Technological difficulties. "It is clear that most emergency responders have some technical difficulty with access whether it is policy, hardware, software, or connectivity" (Morrow et al., 2011, p. 17). Certain system requirements including sufficient Internet speed and an acceptable browser version must be met to allow for viewing the map service. The U.S. government staff testified that the computers available during the crisis were only equipped with an early version of Internet Explorer (2.0), which was incapable of viewing the Ushahidi map site. Even worse, some field workers had difficulty in connecting to the Internet. These technical issues revealed the need for alternative communication tools to deliver citizen requests collected on the website.

Motivation for the Current Study

These Ushahidi issues uncovered during the Haiti crisis should be addressed in order to motivate the responding community to utilize the crowdsourced map service. Understanding the difficulties in Haiti reveals the crisis map was not well suited for responders. To address information overload, responders need to quickly understand the citizen requests from the map. Consequently, understanding the citizen requests will also bring focus to whom needs to be notified, thereby addressing the issue of responder's lack of awareness by making it possible to customize and promote the crisis map to specific responders. To address technological difficulties, an evaluation of communication technology of what needs to be conveyed and system availability after a disaster was conducted. To this end, the Japan crisis map was used as the primary research subject. The disaster unfolded during the writing of this thesis, so near real-time data were available. Unlike Haiti, Japan is a highly industrialized country with very active social media and heavy cell phone use that will reflect a wider coverage of citizen needs. In addition, the thesis author’s familiarity with the country and native language fluency enabled firsthand access to the Ushahidi map postings unlike the many secondhand English reports during the Haitian crisis.

Method

Procedure

To understand the citizen requests, the daily postings from the Japan Ushaihidi Crisis Map were downloaded and analyzed over the period of a week to identify the categories under which citizens had made requests. The end result was filtered categories suited for responders. The methodology involved having the actual messages collected and analyzed immediately after the disaster. The data used for analysis was from sinsai.info (Figure 2), Ushahidi's crisis map for the Japan disaster in 2011.

レポートする方法

1. 次のアドレスにメールで投稿 report@sinsai.info
2. Twitterから投稿。次のハッシュタグをつけてツイート **jishin** or **j_j_helpme** or **hinan** or **anpi** or **311care**
3. こちらのフォームから投稿

Figure 2: A screenshot of sinsai.info web map.
***Note*: From sinsai.info website. Retrieved Apr 4, 2012, from www.sinsai.info. Copyright by sinsai.info. Reprinted with permission.**

Background of sinsai.info. On March 11, 2011, a powerful 9.0 earthquake occurred off the coast of northern Japan and created a destructive tsunami. The damage assessment as of April 13, 2013 included a total of 13,392 fatalities, 15,133 missing, widespread building damage, and a nuclear threat from the malfunctioned Fukushima Daiichi nuclear plant (Norio, Ye, Kajitani, Shi & Tatano, 2011). Although the Japanese government has emphasized emergency management planning due to being an earthquake prone country, the disaster reveals the shortcomings of their efforts. The Ushahidi crisis map of Japan, called sinsai.info (www.sinsai.info) was launched about 4 hours after the disaster struck while the government struggled to gather information, (N. Takahashi, 2011; Seki, 2011). Sinsai.info is run by volunteers through Open Street Map Foundation Japan, and they received support from large corporations such as Amazon, Yahoo Japan, Glee, Heart Beats, NTT, and E5Gamers. The web service was also recognized by the Japanese government, and the crisis map was embedded in the official website of the Japanese cabinet during the response period.

The operational flow of sinsai.info is identical to other Ushahidi crisis maps: (1) messages, referred to as reports, are submitted through email, Twitter, web form, and other websites and (2) moderators filter and classify reports into different categories with location tags so that the reports appear on the map (Figure 3). The data on sinsai.info is freely available to the public, and independent development of applications connect to the crisis map for the relief efforts is encouraged.

Figure 3: Process of sinsai.info.
***Note*: From sinsai.info website. Retrieved Apr 4, 2012, from http://www.sinsai.info/page/index/4. Copyright by sinsai.info. Reprinted with permission.**

Data collection. The reports used for the analysis were downloaded from the sinsai.info website over a span of one week from the disaster date (March 11 to March 18), which is the most critical time for rescue efforts. The number of reports published on the web map for Japan during this short period was 6302 which was more than all the 3584 mapped reports for the entire duration of the Ushihidi Haiti Project (Morrow et al., 2011).

The reports were first filtered into those needing feedback from responders by two important criteria: (1) reports are asking for feedback, in short, a citizen request form, and (2) spatial reference of the reports is relevant. An example of a request is: "There were about 100 people in a facility, who were not recognized by any emergency responders. Please inform the rescuers." On the other hand, an example of a non-request (mainly informative) is: "The residence of X completed evacuation. All of them are safe." Although the possibility exists that informative reports could be a response to a request report, the relationship between the reports was unclear. In addition, because the study intends to understand citizen request reports, informative reports are excluded. After the classification, the number of requests from the postings was reduced to 3820 from the original 6302.

Then, the 3820 reports were determined to be location critical or not. For instance, reports asking about the safety of a loved one might require an address for identification, but mapping out their addresses on the web map is not very useful. In fact, Google's "Person Finder" service, the most popular website for inquiring about the safety of family members and loved ones, uses a registry rather than a map. The registry grew to more than 670,000 people by the middle of May 2011, which was a huge increase from previous disasters where the registry numbers of the Christchurch and Haiti earthquakes were 11500 and 55000 respectively (M. Takahashi, 2011). As demonstrated from its success without maps, these types of reports were excluded because they were not location critical. This filtered out 90% of the requests, leaving a total of 453 reports requiring feedback on a map. The 453 reports were then studied to understand the nature of the citizen requests.

Categorization. The 453 reports were further filtered for the appropriate responders by categorizing into 8 groups: rescue, medical, supply, information, lifeline, transportation, manpower and other. These eight categories are noted by the Japanese government's areas of emphasis during an emergency response (Government of Japan, Cabinet Office, 2011) and the ones used in sinsai.info during the period. As explained in the previous section, categorization of heterogeneous reports poses many challenges. One challenge found in this analysis is that many reports overlap multiple categories. For instance, the report “47 people are isolated in X building. They need to be rescued quickly. If rescue is not possible, deliver food supply at minimum” belongs to both rescue and supplies. Overlapped reports were counted as separate posts in each category as responding actors will vary depending on the categories.

Results

The results reveal that major demands are in the categories of supplies, rescue, medical, and information (Figure 4). This confirmed that citizens do use text message/Twitter to reach out to first responders.

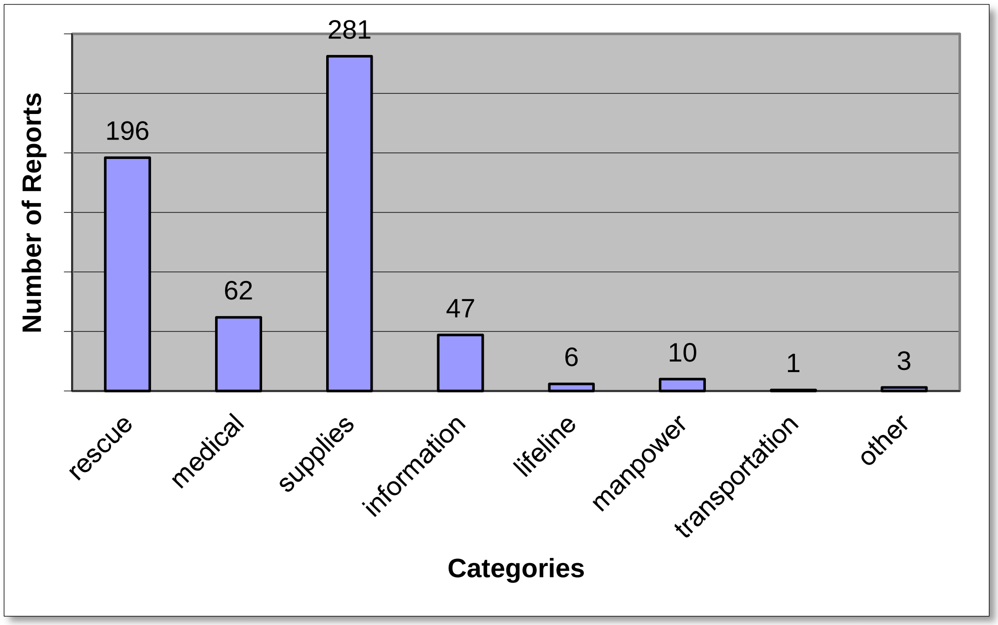


Figure 4: Categories of requests.

Some of the Twitter messages indicated that citizens tweeted publicly about their problems after realizing emergency call lines were unavailable. Emergency call lines during a disaster are often disrupted for various reasons such as blacked out phone service or no emergency personnel available to answer the call. Most citizens do not know where to call for help other than 110 (equivalent to 911 in US). Therefore, the text messages may serve as the last hope for citizens to get help.

Figure 5 illustrates how the requests changed over the course of the seven day period after the earthquake. Not surprisingly, rescue requests were highest during the first three days, which coincides with the 72 hours rule for search and rescue. However, rescue requests continued after the 4th day. Requests for supplies show a growing trend in spite of a dip on the 6th day.

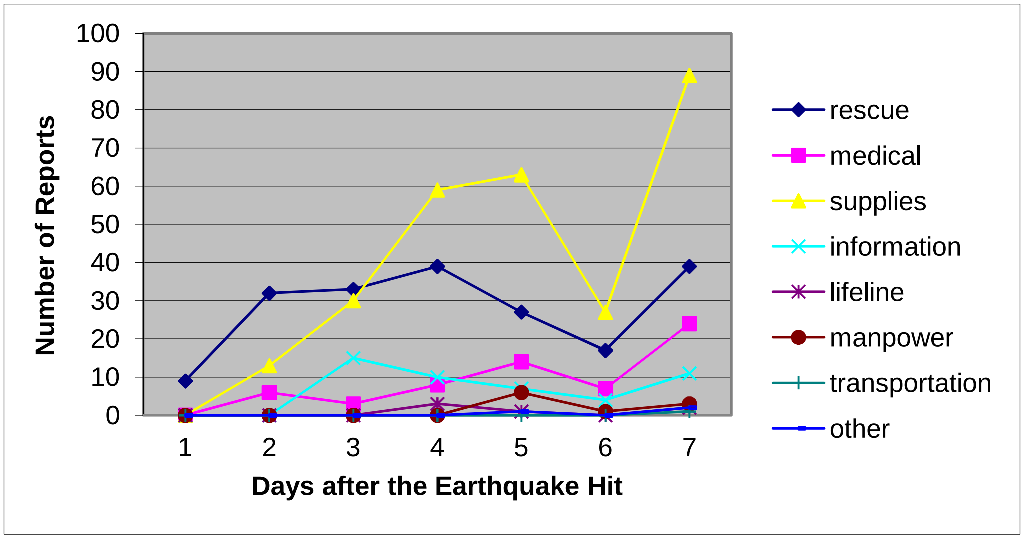


Figure 5: Trend of requests.

Discussion

This effort to understand the citizen requests can serve as guidance for future crowdsourced maps during an emergency crisis. The responder now becomes the targeted user. Without a targeted user, the crowdsourced maps of the past have suffered from information overload. Not surprisingly, information overload is a common occurrence in today's digital maps. "[G]etting lost in the flood of data still occurs frequently as the consequence of unavailable navigation guide, a service that must be offered by cartographers" (Meng, 2003, p. 1891). Development of GIS software has enabled more people to make maps without cartographic training. As a result, many maps lose their focus. Maps become ineffective when not easily conveying relevant information to their intended users. A map should be a communication tool linking location and human perception. Guelke wrote that "success in map communication depends on how well the cartographic designer has been able to interpret the requirements of the user" (as cited in Dent, 1999, p. 15). This notion is at the core of cartography, and should be applied to any map including crowdsourced maps.

Focusing on the resulting four major categories of supplies, rescue, medical, and information will also reduce information overload on the map when compared to the more than 10 categories used in sinsai.info: rescue, supplies, medical, news, lifeline, volunteer services for foreign language, transportation, safety of loved one, shelter, and others. One important note is that citizen requests change over time. Further study is necessary to identify the selection of categories in later phases of emergency response.

Furthermore, the major categories (supplies, rescue, medical, and information) will help address the second issue identified in the Haiti crisis of the responders' lack of awareness of the crisis map. In the case of Japan, the possible responders who may have made use of the crisis map are listed on the disaster response protocol from Miyagi prefecture (Table 1). Meng (2003) emphasized the importance of usability studies for digital map designs by explaining the "modelling of user tasks is considered as a feasible approach that helps to reduce the great diversity of user characteristics influencing the usability of maps" (p. 1892). Thus, with a targeted promotion of a better map that fits their needs, responders may be more inclined to utilize the crowdsourced map in return.

Table 1: Possible responders from Miyagi prefecture protocol.

	Supplies	Rescue	Medical	Information
Responders	- Prefecture General Affairs Department - Living Unit Environment Department - Health and Welfare Department - Industrial Economy Department - Enterprise Bureau - Municipals - Tohoku Agricultural Bureau - Japan Post Tohoku Branch - Japan Red Cross Miyagi Branch	- Prefecture General Affairs Department - Municipals - Prefectural Police headquarters - Second Regional Coast Guard Headquarters - The Defense Army	- Prefecture General Affairs Department - Health and Welfare Department - Hospital Authority - Municipals - Tohoku Regional Bureau Health and Welfare - Japan Post Tohoku Branch - The Defense Army - Japan Red Cross Miyagi Branch - Miyagi Prefecture Medical Association - Miyagi Prefecture Pharmacist Association	- Prefecture General Affairs Department - Prefectural Police Headquarters - Municipals -Tohoku Regional Bureau of Telecommunications - Sendai Region Meteorological Observatory - Japan Post Tohoku Branch - NTT Miyagi Branch - NHK Sendai Branch - Japan Red Cross Miyagi Branch - Tohoku Broadcasting Corporation

			- Miyagi Prefecture Union Drug Wholesalers - Tohoku Association of High-Pressure Gas	- Sendai Broadcasting Corporation - Miyagi TV Broadcasting Corporation - Eastern Japan Broadcasting Corporation - FM Sendai Corporation

Designing an effective map requires careful planning, which can be accomplished by working with users. However, the spontaneous nature of crowdsourced maps complicates this process. Therefore, developing a crowdsourced map template could become a viable preparedness tool. A starter kit with sufficient guidelines and a sample map template will help to create a quick and effective crowdsourced map when time is critical.

Communication Technology

Field responders often encounter technical difficulties when accessing citizen requests on a crowdsourced map. An alternative plan to forward the information to field responders becomes important as crowdsourced maps are not available in areas where Internet service is disrupted. The Ministry of Internal Affairs and Communication (2012) released their findings regarding the availability of communication tools in the severely affected area following the disaster. These findings were the result of interviews conducted with 306 people, who were either victims or volunteers in thirteen cities: Miyako, Oduchi, Kamaishi, Osento, Rikuzenntakata, Sendai, Kisennuma, Ishinohemaki, Natori, and Minamisouma, and Iwaki (Figure 6).

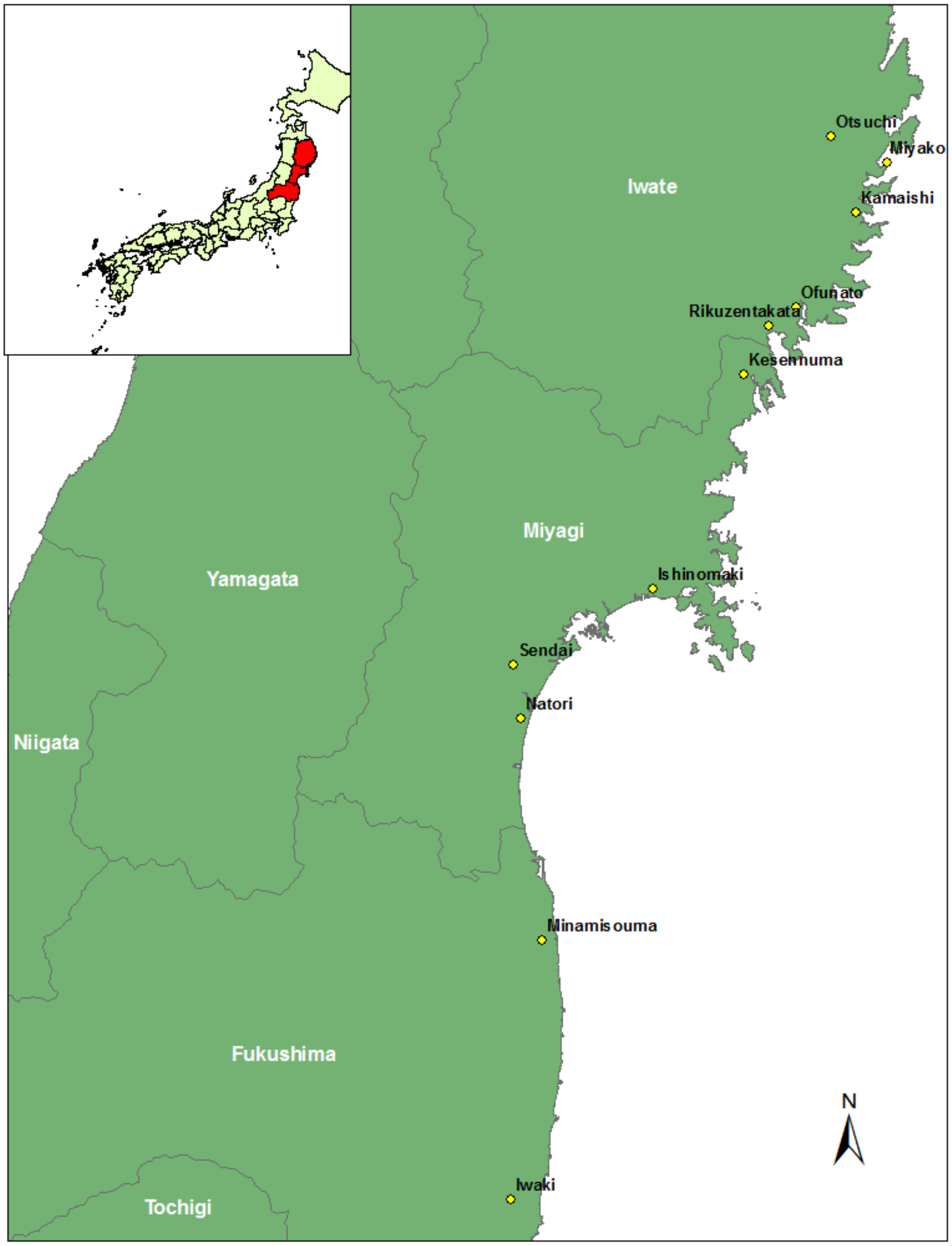


Figure 6: The areas of the research conducted.

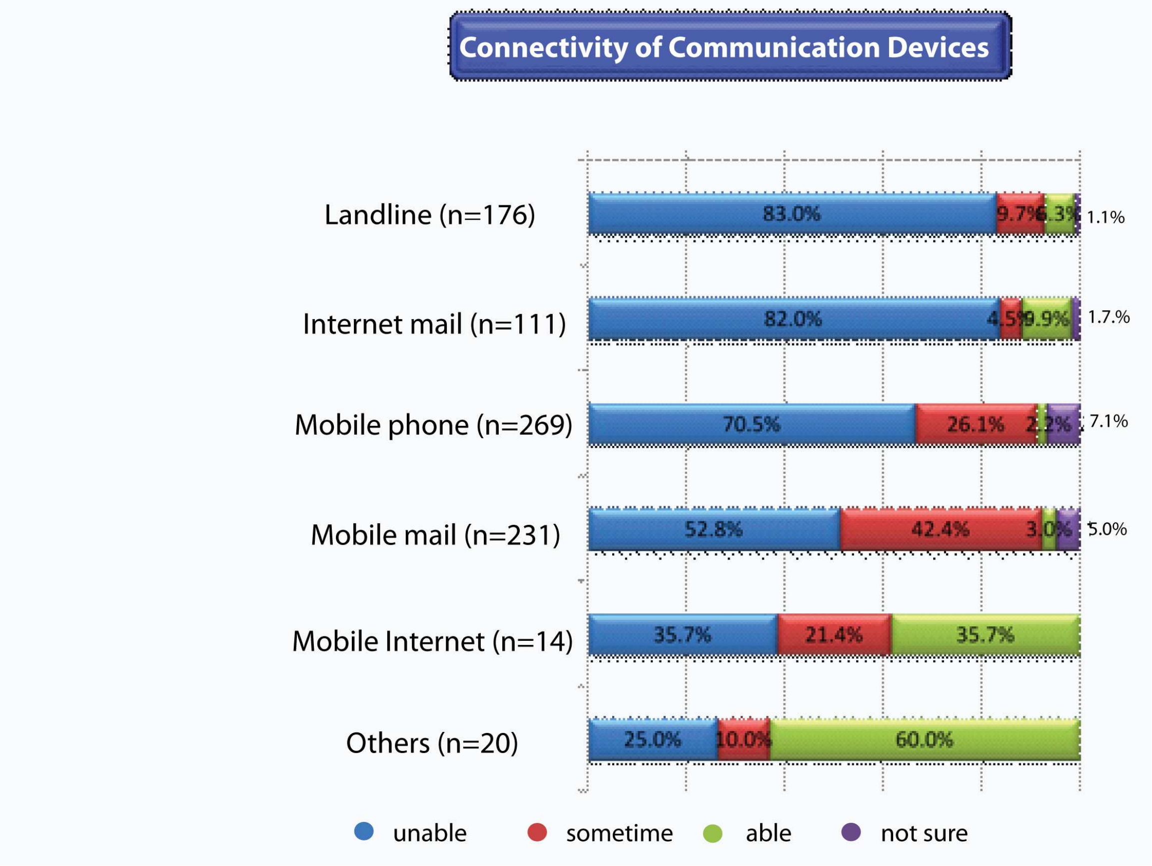


Figure 7: Availability of communication tools in severely affected areas.
***Note:* From Ministry of Internal Affairs and Communication.**

The communication tools in the research were landline (phone), Internet mail (computer), mobile phone (voice), mobile mail (text), mobile Internet, and others. Figure 7 revealed that landline and Internet email were the most vulnerable with 83% and 82% of users respectively whose communication attempts failed. On the other hand, mobile Internet proved to be the most optimal tool having the greatest availability at 35.7% and "sometime" available at 21.4%. If mobile Internet is available, users can directly access the crowdsourced map. However, the small user size of mobile Internet (n=14) indicates a lack of popularity. The second ranked optimal device was mobile mail. It showed

45.4% of users were able to connect including 42.4% of “sometime” possible. In addition, the high number of mobile mail users (n=231) reflect its popularity among the public.

The resilience of text messages in mobile is also supported by other studies. “Text, not talk” in emergency periods is recommended because text uses less capacity, and therefore is more likely to be delivered (Coyle, 2005). The Study Group on Maintaining Communications Capabilities during Major Natural Disasters and other Emergency Situations (2011) also proved this that “it was significantly easier to make contact via text messaging than via phone calls” (p. 3).

The research suggests that mobile Internet is the most optimal communication tool in heavily damaged areas; however, text messaging is a possible alternative tool considering its broader audience and performance in past studies.

Dealing with spatial information in text messages. A question surrounding text messages is how to deal with spatial information. A benefit of the Ushahidi crisis map is that citizen reports are tagged with a spatial value so that users could find information based on their geographical area of interest. The spatial value needs to be embedded in the text message. At present, the most promising way to include a spatial value with a text message is by applying Location Based Service (LBS), which sinsai.info and the Haiti project also utilized.

LBS is an information service based on the location of mobile devices, and has already been deployed in emergency situations. For example, the E911 service returns the approximate location of mobile 911 callers for police, firefighters, and ambulances.

LBS can help eliminate inaccurate verbal descriptions of a person's location. Another example is a warning system as in the case where tsunami warning messages are sent to people in the possible affected areas (Dao, Rizos, & Wang, 2002; Steiniger, Neun & Edwardes, 2006).

The five basic components for implementing LBS technology are the following:

1. Mobile devices and application
2. Communication Network
3. Positioning Component (GPS or Telecommunication Network)
4. Service and Application Provider
5. Data and Content Provider

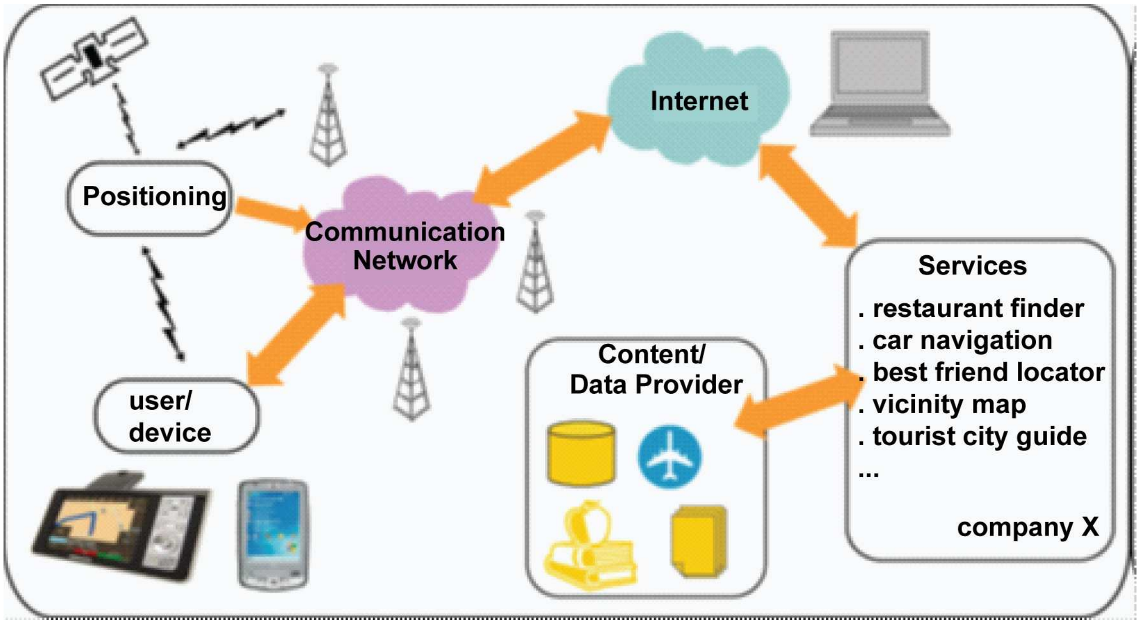


Figure 8: LBS components and workflow

***Note*: Adapted from "Foundations of Location Based Service," by S. Steiniger, M. Neun, and A. Edwardes, 2006 by *Lecture Notes on LBS, 1*, p.16. Reprinted with permission from CartouCHe http://www.e-cartouche.ch/content_reg/cartouche/LBSbasics/en/text/LBSbasics.pdf**

The LBS workflow (Figure 8) can be illustrated with the following example of a person looking for the nearest restaurant.

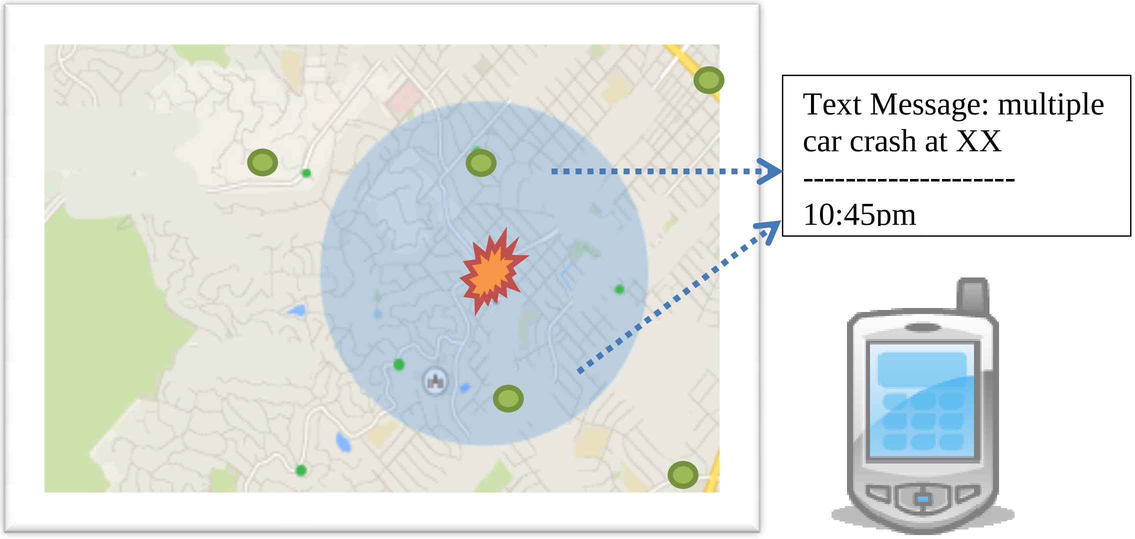
- User makes a service request (e.g. finding the nearest restaurant) with his/her mobile device.
- The mobile device’s position is obtained from either the device’s own GPS or through the use of the wireless telecommunications system.
- The request moves from the communication network to the Internet through the gateway. The gateway not only exchanges messages between the communication network and the Internet, but also routes the request to the specific server, which responds to the request.
- The application server is activated. The requested information is gathered including the device’s position, road network, and restaurant locations by proximity.
- The result from the application server is sent back to the user via SMS.

(Steiniger et al., 2006)

LBS is generally categorized into two types: push and pull services. The main difference is whether a mobile user is active in initiating a service or not. The above example of a user looking for a nearby restaurant is a pull service. On the other hand, a user that passively receives a service is a push service. A tsunami warning message is an example of a push service because users do not initiate the service.

A sample of LBS in emergency response is illustrated in Figure 9 based on the application developed by Esri’s Situational Awareness Bundle and the Loma Linda

University Medical Center Advanced Emergency GIS. The application uses a push service; the locations of field workers are visible to the command center. When an incident is reported, its location is loaded into the GIS. Then, the commander draws a defined area around the incident point in order to send text messages to field workers in that area.



Text Message: multiple car crash at XX

10:45pm

Figure 9: An example of LBS application for emergency response.

Utilization of LBS in crowdsourced maps will increase the possibility that field responders can receive timely information. Knowledge of mobile device and application types will be helpful in developing mobile applications with LBS.

Mobile devices and applications. Mobile devices are any portable devices used as a communication tool via a communication network. Today these devices have a wide range of choices between physical size, memory size and operating systems. Although functionality greatly varies from low end cell phones to high end tablets, almost all mobile devices support text message service (SMS). The three main approaches to develop mobile GIS applications are identified as native application based, mobile browser based, and message based (Fu & Sun, 2011). Identifying the strength and weakness in each case will be helpful in choosing devices and developing LBS applications (Table 2).

Table 2: Application types and criteria to develop mobile GIS.

	Native based application	**Mobile browser based application**	**Message base application**
SMS	Yes	Yes	Yes
Digital map (online)	Yes	Yes	No
Digital map (offline)	Yes	No	No
Access to peripheral device	Yes	Limited	No
Skill level	High	Medium	Low

Native application based. Development of native applications requires installation on mainly 3rd Generation or above smartphones or tablets. Although the possibility exists to build native applications in 2G or 2.5G capable cell phones (non-smartphone), the absence of a CPU and the small memory size is very challenging as compared to smartphones, which have become the current norm (Fu & Sun, 2011).

One advantage of native applications in an emergency situation is the capability of operating in an offline environment. For example, a digital map application can reside in the device and be available anywhere regardless of Internet connection. In addition, the accessibility of peripheral devices such as GPS, local files, and databases enables development of applications that can incorporate them. For example, if a device has GPS capability, the position of the device can be retrieved and incorporated into the application. Once the location of the user is identified, navigating to a destination is possible with a digital map. Companies such as MapsWithMe (http://mapswith.me/en/home), Google (https://support.google.com/gmm/answer/2650218?hl=en), and Navfree (http://www.navmii.com/gpsnavigation) developed offline maps available in the market today. When citizen requests are sent through SMS, a possible crowdsourcing application during an emergency could have the request location displayed on an offline map for a responder to find quickly.

The downside of this approach is the development costs. The developers are required to possess advanced programming skills to create applications, and applications developed for one operating system may not be interchangeable with others. For example, the applications developed for iOS only work with the iPad or iPhone, but not with devices using the Android operating system (Charland & Leroux, 2011) (see Table 3).

Table 3: Programming language to develop native applications for popular OSs.

Mobile OS	Programming language
Android	Java, C, C++
iOS	Objective C
Black berry	Java
Symbian	C++
Palm OS	C, C++, Pascal
Windows Mobile	C, C++
Windows phone	C#, Visual Basic, C, C++

***Note:* Adapted from Mobile application development in Wikipedia. Reproduced with permission. Retrieved Mar 21, 2014, from http://en.wikipedia.org/wiki/Mobile_application_development**

Native applications are the most promising approach for working environments with no Internet connection. These applications are especially appropriate for responders who are unfamiliar with the local geography since responders from outside the region are often sent due to a lack of local personnel in the affected area. This may also be useful for responders who are from the disaster area. Understanding where he/she is in relation to where he/she is going could be challenging with the chaotic conditions immediately after a disaster (Figure 10).

Figure 10: Unrecognizable housing.
***Note:* From Cabinet Office, Government of Japan. Retrieved March 17, 2013, from http://www.bousai.go.jp/kohou/kouhoubousai/h24/70/special_01.html**

Mobile browser based. Mobile browser based applications reside on the server and not on the device. This makes the target of mobile devices very broad; any devices having Internet capability are able to receive a web-based location based service. The advantage of this application is that it works on any platform (i.e. works on both iOS and Android). Not needing to develop applications for each platform means less work and cost. However, because these applications cannot access all of the hardware or local files (Fu & Sun, 2011), the versatility is limited compared to native applications. The crowdsourced map is a web browser based application (full website), but it can be separately developed for a mobile site by modifying the design for a smaller screen size and different user experience.

Another option for a web browser based application catering to a crowdsourced map is the use of GeoRSS feeds. GeoRSS adds a spatial attribute onto a Rich Site Summary (RSS) feed, which is often used for publishing frequently updated information.

An example of a GeoRSS feed is the USGS earthquake monitoring site (Figure 11). Subscribers receive the latest earthquake activity information tagged with location.

M 5.0, eastern New Guinea region, Papua New Guinea
Date: September 19, 2010 15:03:28 GMT

M 5.4, Volcano Islands, Japan region
Date: September 19, 2010 11:51:54 GMT

M 5.0, State of Yap, Federated States of Micronesia
Date: September 19, 2010 09:43:16 GMT

M 5.0, Fiji region
Date: September 18, 2010 14:29:14 GMT

M 5.0, eastern New Guinea region, Papua New Guinea
Date: September 19, 2010 15:03:28 GMT
http://earthquake.usgs.gov/earthqu...

Figure 11: A screenshot of GeoRSS in USGS earthquake monitoring website.
***Note*: From Latest Earthquake in USGS website. Retrieved Feb 10, 2014, from http://earthquake.usgs.gov/earthquakes/map/**

While the USGS GeoRSS feed does not take into consideration the location of the subscriber, Filjar, Bušić, and Vidović (2008) proposed an enhanced GeoRSS which does. They developed a conceptual utilization of GeoRSS with LBS. The concept is that after receiving the LBS request, the application server searches for relevant information in the GeoRSS. The GeoRSS feed is further filtered out according to the requester’s location, and mapped out. The feed attached with a spatial feature is sent back to the users. Applying these technologies, responders are able to receive the latest citizen request tagged with spatial information on a digital map. However, the disadvantage with this application along with any mobile browser based approach is that the application does not work when the Internet is not available.

Message based. At present, most mobile devices using 2.5 Generation technology or above are capable of sending/receiving text messages. Aloudat, Michael, and Abbas (2011) suggest two message services: short message services (SMS) and cell broadcasting services (CBS). Some differences between SMS and CBS are shown in Table 4. A major difference is that CBS is capable of sending one message to many devices. Any device within the cell range can receive the text message (Figure 12). Many countries use CBS to send warning messages because of this capability. However, unlike SMS, the target devices to receive messages are not specified. Therefore, forwarding information to only responders is not possible in CBS. Another limitation of message-based applications in general is the absence of a map in the device. Thus, these approaches work best for field workers that have local geographic knowledge or are carrying a paper map of the area.

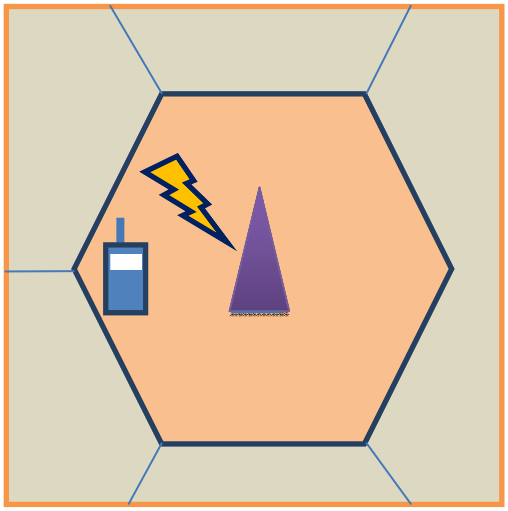


Figure 12: Concept of CBS.

Table 4: SMS vs CBS.

Characteristic	**SMS**	**CBS**
Transmission type	Message sent point to point.	Messages sent point to area.
Mobile Number dependency	Required. Requires specific phone numbers to be known.	Independent. Does not require phone numbers to be known.
Location based Targeting	No. Only pre-registered. numbers will be notified; message will be received regardless of actual location.	Yes. All phones within a targeted geographical area (cells) will be notified.
Message type	Static messages can be sent to pre-registered number.	Location specific. Tailored messages can be sent to different areas.
Bi-directionality	Direct. Users can receive messages and respond directly to the sender via SMS.	Indirect. The message should contain a URL or number to reply.
Congestion and Delay	Subject to network congestion. Delivery is queued. Congestion can occur.	Cell broadcast is always available.
Message length	140-160 characters.. Longer 'concatenated.'	93 characters. Longer 'multiple page.’

***Note*: Adapted from Mobile Network Public Warning System and the Rise of Cell-Broadcast, 2013. Reprinted with permission from © GSM Association 1999 – 2009. Retrieved Feb 10, 2012, from http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2013/01/Mobile-Network-Public-Warning-Systems-and-the-Rise-of-Cell-Broadcast.pdf**

Privacy Concerns

Some consideration must be given to the longer lasting social implications that accompany these technological advances in communication during an emergency. Privacy and security of the individual becomes a concern because citizen requests are publicly available on the crowdsourced map. The Ministry of Internal Affairs and

Communication released a survey report conducted among 240 residents in the affected areas regarding their opinions of public disclosure of their individual information during the emergency (Figure 13). The survey showed 86.7% did not have any problem and 8.2% had a problem only because their request was not answered. Meanwhile, the survey showed 5.1% had a problem with what they felt was unnecessary disclosure. The research institute concluded that most of the affected people were not hesitant in providing individual information to save someone's life. This was summarized by one interviewer stating "saving life is the most priority. Protection of privacy should be a concern after that." However, long lasting exposure of individual information in public was not acceptable. One complaint was that individual information used for shelters was still available after the emergency period had ended. The lesson learned is that individual information should be removed when the crisis had passed.

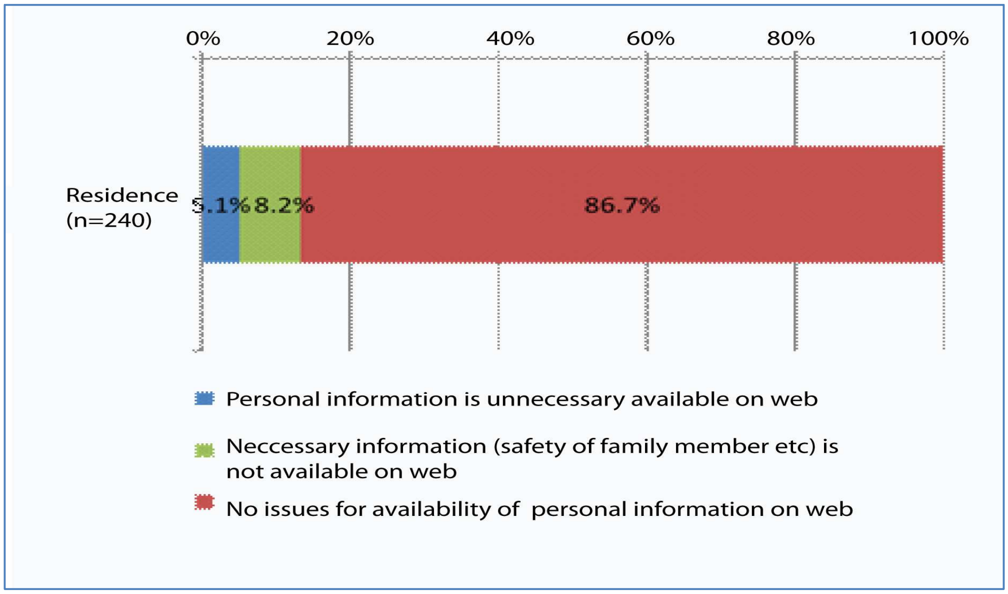


Figure 13: Citizens' concern of releasing personal information on the Web.
***Note*: From Ministry of Internal Affairs and Communication.**

Conclusion

This study explored closing the two-way communication loop with special attention paid to finding a way to make a crowdsourced map more usable to responders. The important finding of this study is that crowdsourcing should be utilized by first responders especially immediately after the disaster. The evaluation of actual data in sinsai.info verified that citizens tried to contact first responders via tweets and text messages. The crisis map can be adapted for first responders through simplifying citizen requests into a few main categories and employing technology that would most likely work under disaster conditions. These improvements increase the potential for crowdsourced maps to gain awareness and acceptance from the responder community.

Citizens now have increasing capability to ask for help or report their status in emergency situations with the advancement in technology. The future vision of Next Generation 911 (NG911) aims to collect more situational information from citizens providing text, photos, and videos. However, even with NG911, no clear plan for filtering and responding to citizen requests has been developed. The aid efforts during a widespread disaster can be even more chaotic, not only with the scale but with the difficulty in sharing information among aid agencies and the public. The lack of transparency will detract from the overall effort and cast public suspicion over the aid agency activities.

The Ushahidi crisis map is successful in reaching their original goal; citizens are now able to broadcast their own status to the world. Moreover, this new tool can increase transparency of aid efforts, and help collaboration among responding agencies.

Crowdsourced data is important and resourceful, but it is still the starting point for aid efforts. Ushahidi co-finder Ory Okolloh acknowledged that “Ushahidi is only 10 percent of the solution” (cited in Heinzelman & Waters, 2010, p. 11). Since aid efforts are complex and cover a wide range of stakeholders including fire, police, National Guards, NGOs, state, municipalities and private companies, aid efforts need to be more open to the public. By making the crowdsourced data more usable to responders, the focus can then be switched to using the same technology to make the response more transparent to the citizen. For responders, a two-way communication map creates the opportunity for aid agencies to work together and establish their creditability. If crowdsourced maps can build a bridge across many stakeholders including citizens using web GIS technology, aid efforts will dramatically improve.

References

Aloudat, A., Michael, K., & Abbas, R. (2011). Toward the regulation of ubiquitous mobile government: A case study on location-based emergency services in Australia. *Electronic Commerce Research*, *11*(1), 31-74.

Budhathoki, N. R., Bruce, B., & Nedovic-Budic, Z. (2008). Reconceptualizing the role of the user of spatial data infrastructure. *GeoJournal, 72*(3-4), 149-160.

Charland, A., & Leroux, B. (2011). Mobile application development: Web vs. native. *Communications of the ACM*, *54*(5), 49-53.

Cova, T.J. (1999). GIS in emergency management. *Geographical information systems*, *2*, 845-858.

Coyle, D. (2005). The role of mobiles in disasters and emergencies. GSM Association. Retrieved March 1, 2013, from http://www.enlightenmenteconomics.com/about-diane/assets/disasterreport.pdf

Dao, D., Rizos, C., & Wang, J. (2002). Location-based services: Technical and business issues. *GIS Solutions*, *6*(3), 169-178. Retrieved February 14, 2014, from http://link.springer.com/article/10.1007%2Fs10291-002-0031-5

Dent, B.D. (1999). *Cartography: Thematic map design*. Boston, MA: WCB McGraw Hill

Dunn, C.E. (2007). Participatory GIS – a people's GIS? *Progress in Human Geography, 31*, 616-637

Earle, P., Bowden, D., & Guy, M. (2012). Twitter earthquake detection: earthquake monitoring in a social world. *Annals of Geophysics*, *54*(6). Retrieved January 10, 2013, from http://phg.sagepub.com

Elwood, S. (2010). Geographic information science: emerging research on the societal implications of the geospatial web. *Progress in Human Geography, 34*, 349-357.

Filjar, R., Bušić, L., & Vidović, K. (2008). Role of Geospatial Content Syndication in Location - Based Services Development. *The Navigation Conference and Exhibition 2008.* London: Royal Institute of Navigation.

Fu, P. & Sun, J. (2011). *Web GIS: Principles and applications*. California: Esri Press.

Government of Japan, Cabinet Office. (2011). 東日本大震災における災害応急対策に関する検討会 [Panel discussion about the disaster management in the East Japan great earthquake disaster]. Retrieve March 17, 2013, from http://www.bousai.go.jp/oukyu/higashinihon/index.html

Giles, J. (2005). Internet encyclopaedias go head to head. *Nature*, 900-901.

Goodchild, M. F., & Glennon, A. (2010). Crowdsourcing geographic information for disaster response: a research frontier. *International Journal of Digital Earth*, *3*, 231-241.

Hatch, D. (2011, May 5). Social media: emergency response's next frontier. *National Journal*. Retrieved May 14, 2013, from http://www.nationaljournal.com/tech/social-media-emergency-response-s-next-frontier-20110505

Heinzelman, J., & Waters, C. (2010). Crowdsourcing crisis information in disaster-affected Haiti. *Special Report*. Washington, DC. United States Institute of Peace.

Hughes, A. L., & Palen, L. (2009). Twitter adoption and use in mass convergence emergency events. *International Journal of Emergency Management, 6*, 248-260.

Meng, L. (2003). Missing theories and methods in digital cartography. *Proceeding of International Cartographic Conference 2003*, Durban.

Ministry of Internal Affairs and Communications (2012, March 7). 災害時における情報通信の在り方に関する調査結果 [Survey results on the role of information and communication in disaster]. Retrieved March 10, 2013, from http://www.soumu.go.jp/menu_news/s-news/01tsushin02_02000036.html

Miyazaki, H. (2011, July). Great contributions to the aid against East Japan Great Earthquake interview with Mr. Taichi Furuhashi. *ISPRS SC Newsletter, 5*(2), 8-9. Retrieved March 10, 2013, from http://www.isprs-sc.org/material/isprs_sc_vol5_no2.pdf

Miyagi prefecture (n.d.). *Disaster Response Operations*. Retrieved December 1, 2012 from http://www.pref.miyagi.jp/uploaded/attachment/203868.pdf

Morrow, N., Mock, N., Papendieck, A., & Kocmich, N. (2011). *Independent Evaluation of the Ushahidi Haiti Project.* Development Information Systems International Ushahidi Haiti Project. Retrieved March 10, 2013, from http://www.alnap.org/resource/6000.aspx

Nelson, A., Sigal, I., & Zambrano, D. (2011). Media, Information Systems and Communities: Lessons from Haiti. *John S. and James L. Knight Foundation* retrieved Mar 11, 2011, from http://www.knightfoundation.org/media/uploads/publication_pdfs/KF_Haiti_Report_English.pdf

Norio, O., Ye, T., Kajitani, Y., Shi, P., & Tatano, H. (2011). The 2011 eastern Japan great earthquake disaster: Overview and comments. *Int. J. Disaster Risk Sci*, *2*(1), 34-42.

Russo, C. (2011, September 9). Emergency communication remains a challenge ten years after 9/11. *Homeland Security News Wire* . Retrieved January 30, 2013, from http://www.homelandsecuritynewswire.com/emergency-communication-remains-challenge-ten-years-after-911?page=0,0

Sakamoto, M., & Yamori, K. (2012). Understanding mutual assistance coordination among prefectures and municipalities in a multi-location disaster through the experience of the Great East Japan Earthquake. *Institute of Social Safety Science, 18*, 391-400. Retrieved from www.dri.ne.jp/research/profile/pdf/sakamoto/2012.pdf

Sarcevid, A., Palen, L., White, J., Starbird, K., Bagdouri, M., & Anderson, K. (2012). "Beacons of hope" in decentralized coordination: learning from on-the-ground medical twitterers during the 2010 Haiti earthquake. *CSCW '12,* 47-56.

Seki, H. (2011, April 12). Sinsai.info を一ヶ月やってきて思うこと [One month after sinsai.info started]. Techweb. Retrieved March 10, 2013, from http://techwave.jp/archives/51650191.html

Steiniger, S., Neun, M., & Edwardes, A. (2006). Foundations of location based services. *Lecture Notes on LBS, 1*. Department of Geography, University of Zürich. Retrieved March 10, 2013, from http://www.e-cartouche.ch/content_reg/cartouche/LBSbasics/en/text/LBSbasics.pdf

Study Group on Maintaining Communications Capabilities during Major Natural Disasters and other Emergency Situations (2011, December 27). *Maintaining communications capabilities during major natural disasters and other emergency situations*. Tokyo: Ministry of Internal Affairs and Communications. Retrieved March 10, 2013, from http://www.soumu.go.jp/main_content/000146938.pdf

Takahashi, M (2011, June 6). Google 「命令などはなく、全員ができることを一切にはじめた」:安否サイト「パーソンファインダー」などの取り組み [Google “all of us started anything we could do”: the process of “Person finder”]. Internet Watch. Retrieved March 10, 2013, from http://Internet.watch.impress.co.jp/docs/column/20110311/20110606_450533.html

Takahashi, N. (2011, June 20). 震災に立ち上がった技術者たちは何をしたか [What engineers did for the disaster]. Nikkei press. Retrieved March 10, 2013, from http://www.nikkei.com/article/DGXNASFK1703B_X10C11A6000000/

Ushahidi. (n.d.). Press Kit. Retrieved March 23, 2014, from http://ushahidi.com/about-us/press-kit

World Bank. (2012). *Hazard and Risk Information and Decision Making. Risk and Damage Information Management, Note-5-2*. Washington, DC. Retrieved March 10, 2013, from http://wbi.worldbank.org/wbi/document/risk-and-damage-information-management

Zook, M., Graham, M., Shelton, T., & Gorman, S. (2010). Volunteered geographic information and crowdsourcing disaster relief: A case study of the Haitian earthquake. *World Medical & Health Policy*, *2*, 7–33.