Geospatial Information Improves the Decision-Making Process during the Disaster Response: The Experience of the Emergency Mapping Team in the 2011 off the Pacific Coast of Tohoku Earthquake

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SUMMARY:
The Great East Japan Earthquake that occurred in 2011 caused a tremendous amount of damage spanning over multiple prefectures due to severe vibrations and tsunami. In order to provide quick and appropriate disaster responses, prefectures must establish a common operational picture regarding damage situations and disaster response statuses among cities, "cho" districts, and villages. This is especially important along the coast to supplement basic functions of those municipalities. The needs of the front line disaster response workers were extracted, and the Emergency Mapping Team (EMT) clarified the characteristics and challenges related to the visualization of those needs. The EMT was put in place at the Iwate Prefecture Hall to investigate how maps should be utilized. Herein, we propose effective information sharing of disaster response activities using maps.

Keywords: 2011 off the Pacific Coast of Tohoku Earthquake, Emergency Mapping Team (EMT), Geospatial Information Systems (GIS)

1. INTRODUCTION

The Great East Japan Earthquake that occurred on March 11, 2011, caused a tremendous amount of damage over a wide area spanning over multiple prefectures due to severe vibrations and tsunami. Based on the proximity to the victims, disaster relief is normally provided by public organization in the cities, "cho" districts, and villages. In this disaster, however, those municipality organizations also suffered major damages to their facilities, employees, and equipment. In fact, city halls were washed away and employees were killed, which hampered the ability to maintain municipal functions. This forced prefectures to lead the disaster relief activities.

Geospatial information systems (GIS) were used in past earthquake relief activities. In the case of the Chuetsu Offshore Earthquake in 2007, for example, the Chuetsu Offshore Earthquake Disaster Response Support GIS Team was formed at the Niigata Prefectural Hall on the day after the earthquake. The Emergency Mapping Team (EMT) operated for 23 days to generate 139 maps (Urakawa). Additionally, the Emergency Mapping Center - Kashiwazaki (EMC-K) was formed on September 11 in Kashiwazaki City, Niigata Prefecture, during the recovery period. EMC-K generated 81 types of maps (EMC-K report). Recently, during the emergency response period for the Great East Japan Earthquake of 2011, the Emergency Mapping Team (EMT) was formed on the day after the earthquake. The EMT generated 500 maps in 45 days from its headquarters at Building No. 5 of the Chuo government office complex located in Kasumigaseki, Tokyo.

While practical initiatives of emergency mapping teams have been carried out on front lines of disaster responses, no activity has been conducted at the prefectural level during the recovery period of expansive, complex disasters. Our research team, which was headquartered at the Prefectural Hall of

Iwate, who suffered damages, enabled us to collect and organize information regarding the needs and utilization of the maps from disaster response workers including prefecture employees. Based on the information gathered from the front lines during the recovery period, we were able to determine the challenges that were faced at the prefecture level. Herein, we discuss effective information sharing using maps during the disaster response.

2. OVERVIEW OF THE IWATE EMERGENCY MAPPING TEAM

In June 2011, about three months after the disaster occurred, the EMT started its operation at the Iwate Prefectural Hall. At the core of the EMT was our research team. Our objective was to organize and present information from prefectural departments, cities, "cho" districts, villages, and associated organizations, on the same maps to aid in the decision making process. This chapter provides an overview of the Iwate Emergency Mapping Team.

2.1. Organizational Structure of the Iwate Emergency Mapping Team

In May 2011, members of the EMT and the Cabinet Office of the national government (Inoguchi) visited municipalities that had incurred damages, and conducted a briefing on mapping and a survey on the needs of municipalities. Based on these findings, the decision was made to support to the Iwate Prefecture June 1, 2011. The headquarters for this activity was a special meeting room on the fourth floor of the Iwate Prefectural Hall, where the Iwate Disaster Response Center was located. We initially tried to model the Iwate EMT after the EMT at the Cabinet Office in terms of role distribution and personnel. However, it was difficult to secure voluntary workers from private corporations on an on-going basis because Iwate is far from Tokyo. As a result, several people from the university research teams stayed there, mainly during weekdays, to shoulder multiple roles.

2.2. Overview of the Activities of the Iwate Emergency Mapping Team

The Disaster Response Centers of the Prefecture and municipalities displayed published information regarding the damages and disaster response activities. This information was displayed as text, numbers, and tables on map that were superimposed with multiple pieces of information in response to requests from different departments (users) of the prefecture. Types of generated maps include: blank maps, maps of evacuation centers, maps about temporary emergency housing, maps of hospitals and clinics, welfare facilities, and others. Table 1 shows a breakdown of the number of maps per category.

Table 1. Categories and Numbers of Developed Maps as of early December 2011

Major category	Number of maps where only one subject layer was used	Number of maps that were mashed up with temporary houses	Total
Medical service	32	124	156
Landslide forecast	0	90	90
Welfare and elderly nursing care service	1	64	65
Social statistics	34	0	34
Human and property damage	13	0	13
Temporary emergency house	11	0	11
Evacuation center	11	0	11
Background figure	1	0	1
Total	103	278	381

2.3. Details of Maps

The maps were categorized based on the goals of the map how the maps were generated.

2.3.1. Blank *Maps*

In Iwate Prefecture, there are regional municipalities that encompass multiple cities, "cho" and

villages, and wider regional municipalities that encompass multiple regional municipalities. The regional disaster action plan of the prefecture also requires that the Disaster Response Center of the prefecture coordinate with those regional municipalities and wider regional municipalities. This means that each subject map to geospatial dataset for each geographical space that these activities are based. Therefore, we generated GIS data using a pdf version of maps that indicate boundaries of these regional municipalities at the start of our activities combined with a pre-existing boundary dataset of cities, "cho", and villages to generate GIS data (Figure 1)

2.3.2. Maps of Evacuation Centers

To indicate positional relationships among evacuation centers (Kimura), the Cabinet Office EMT generated a large-area map that encompassed afflicted areas along the Pacific coast from Chiba to Aomori prefectures; it was useful for providing a whole picture. Moreover, in addition to a map of the entire Iwate Prefecture, zoom-in maps were generated for the regional municipalities to provide details of the situation (Figure 2).

2.3.3. Maps of Emergency Temporary Houses

Multiple prefectural departments requested maps of temporary emergency houses, which was one of the major disaster response and relief activities during the recovery period. The Iwate Prefecture Comprehensive Disaster Prevention Office wanted to grasp the positional relationships with landslide areas. The Iwate Prefecture Medial Services Department and Aging Society Department wanted to grasp the positional relationships between medical and welfare facilities and emergency temporary houses. There was also a request for maps for visitors from outside the prefecture with required precision so that people not familiar with Iwate Prefecture can make their way with landmarks and indexes on maps (Figure 3). The latitude and longitude data for representative temporary emergency houses was obtained from the KML files generated by the Building Department of Iwate Prefecture. We generated GIS data by table-connecting data of the number of buildings and address data that were obtained separately.

2.3.4. Maps of Hospitals and Clinics

The Iwate Medial Services Department wanted to plot the operation status of hospitals and clinics and setup status of temporary hospitals and clinics on a map to grasp their positional relationships with temporary emergency houses, in order to provide clinics support services, rebuild medical system, and apply for national government aid. Update data became available on a regular basis so that the maps were updated regularly. Initially, the dataset was input and processed manually from paper data by the Iwate EMT. When regular updates became available, we requested to the requester of the maps, which is the Medial Services Department, to provide a primary processing of table data that was provided by the medical association into a format that was easy to use in GIS for on-going updating. In addition to a map for the entire prefecture, we generated a map for each medical jurisdiction (Figure 4). It was required that we make provisions to display all labels of facilities with such means as adding an insert of zoom-in map of an area with a high facility density.

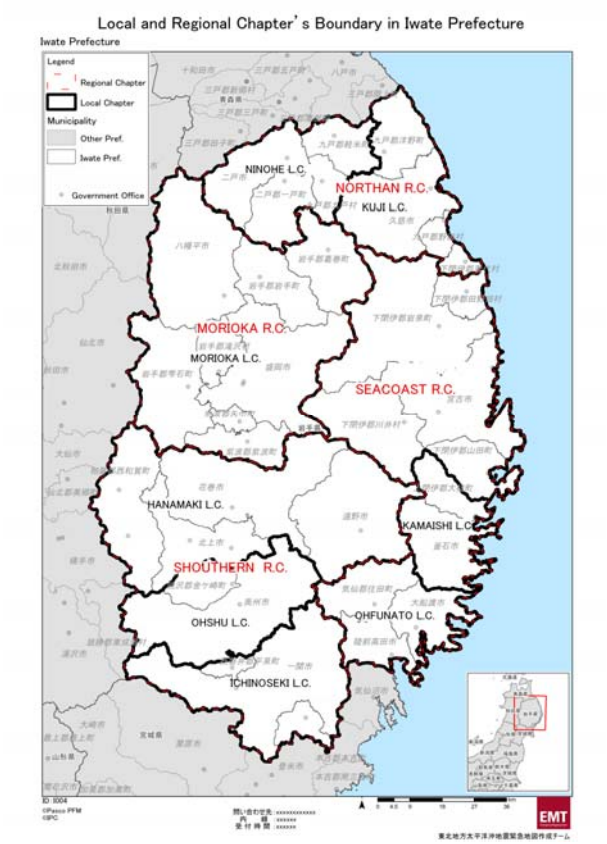

Figure 1. Blank map of Iwate Regional Municipalities and Wider Regional Municipalities

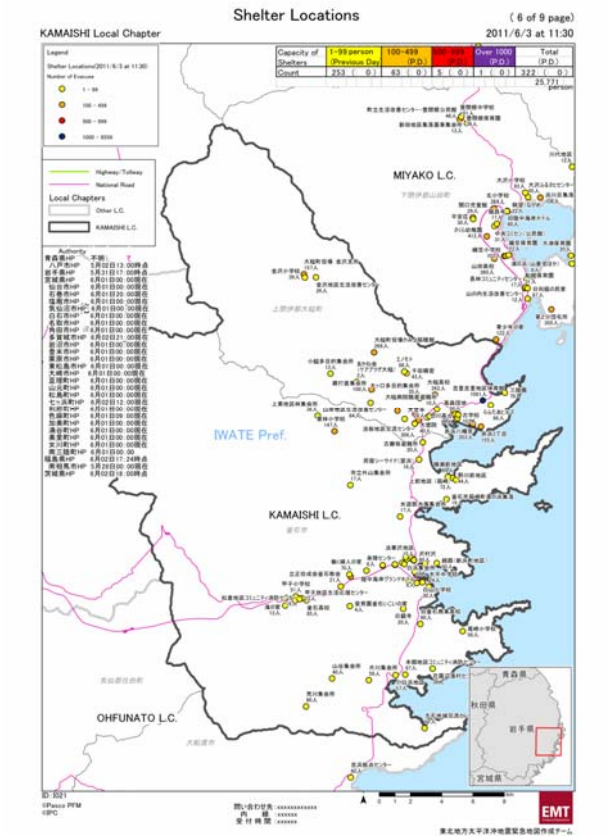

Figure 2. Positional relationships among evacuation centers (Kamaishi Regional Municipality) as of June 3

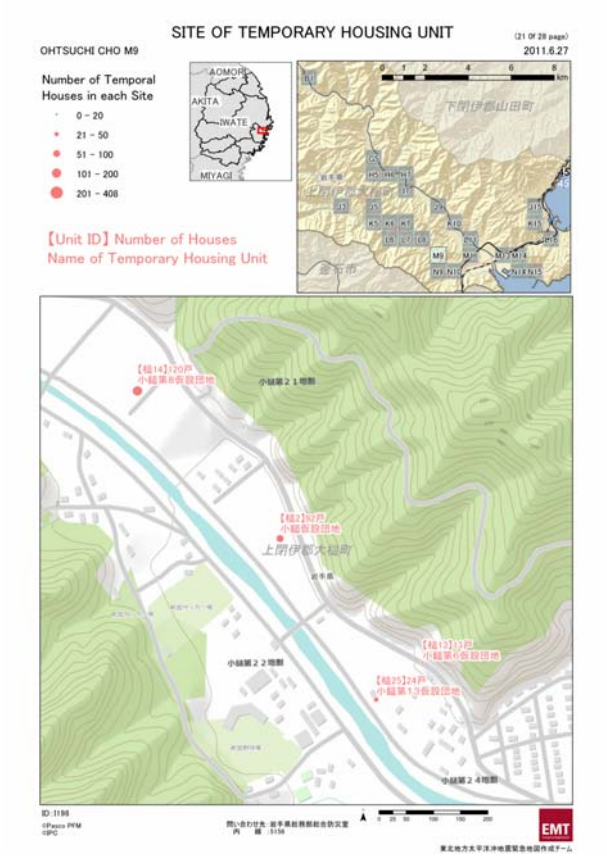

Figure 3. Positional relationships among temporary emergency houses for supporters from outside the prefecture

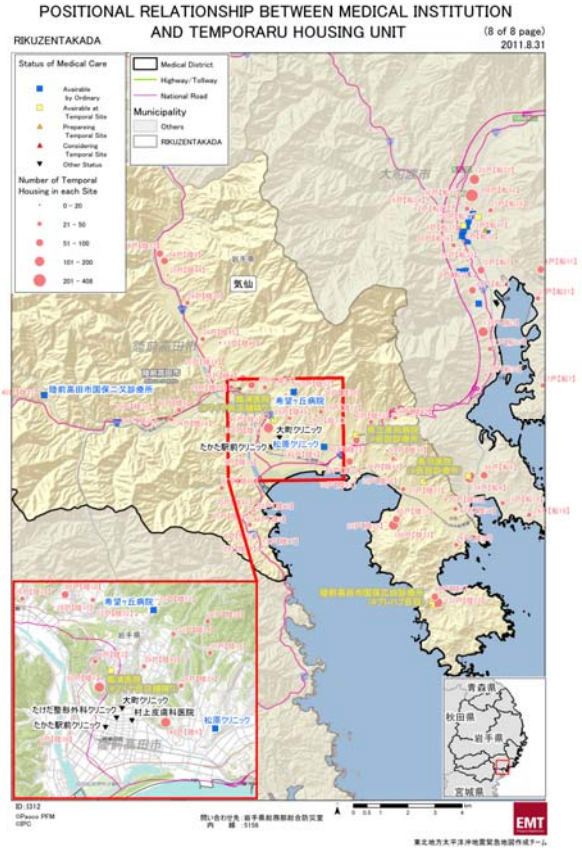

Figure 4. Operational status of hospitals and clinics, and their positional relationships to temporary houses

2.3.5. Maps of Welfare Facilitiess

The Iwate Aging Society Department wanted to use maps to plan care-taking visits and new facility construction based on the spatial relationship between elderly care facilities and temporary emergency housing. The facilities were classified into five categories: consultation, care, visitation, day use, and others. As we generate maps with five categories for each of twelve municipalities, a balance between the quality and speed was found to be a bottleneck. We also found that prefectural employees themselves wanted to share the information with afflicted municipalities along the coast. For these reasons, we decided to introduce dynamic maps using the Internet where users can select ranges of information to be superimposed, instead of using static maps on paper. We provided user guidance sessions. As a result, employees were actively able to utilize the system to display the layers in any region, which could then be shared over the Internet (Figure 5).

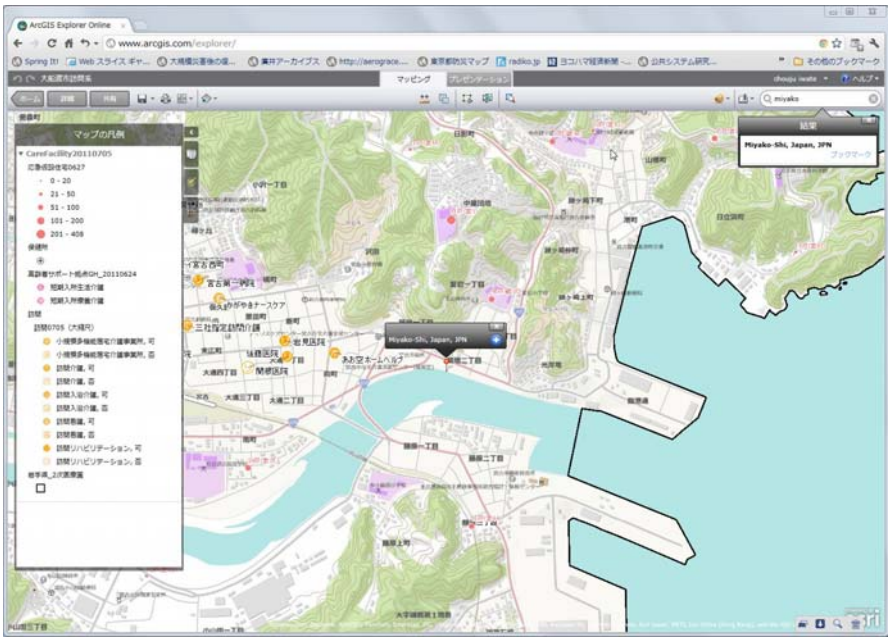

Figure 5. Positional relationships between elderly nursing care facilities and temporary houses using Web-GIS

3. CHARACTERISTICS OF MAP UTILIZATION BY MUNICIPALITIES DUREING RECOVERY AND REBUILDING PERIOD

Here we summarize characteristics of map generation processes for each category from the viewpoint of needs for maps and their utilization. We then compare them against our findings about the EMT activities at the national level to consider the differences.

3.1. Characteristics of Needs for Maps

Maps that captured information from the front line level of each department were predominantly used, rather than maps that provided a common operational picture for the entire prefecture. Additionally, there were some requests from other departments to visualize data and disaster response results by superimposing them on maps.

3.2. Methods to Use Maps

In order to ensure that the maps were publicly available, we published them on the EMT website, posted them on walls, and prepared booklets using clear folders. These methods were the same as we did for the Cabinet Office EMT. However, at that time, we only uploaded maps to a shared folder for

the entire ministry through employees responsible for disaster prevention. In combination with the chaotic situation during the emergency response period, we only gave maps as requested, and there were no means to obtain evaluation and feedback from people who requested those maps. The Iwate EMT, however, took a different approach by providing maps directly to people using e-mails or USB flash drives. We also visited employees in relevant departments within the prefecture hall to brief them about maps that the Iwate EMT and other departments generated. Maps generated by the EMT were used for various purposes, including at meetings within the prefectural government, at national government meetings for budget requests, during information sessions to residents, and when planning visits to afflicted municipalities.

3.3. Effectiveness of Dynamic Maps

Static maps were useful for the national level disaster response because at that level the purpose is to share a common operational picture. Fish that was show that grasping the overall picture through maps that show the entire disaster area. In contrast, maps for the prefectural level disaster response had to cover information not only in one city, cho, or village, but also wider areas under Regional Development Bureaus that function as comprehensive satellite offices of the prefectural government as well as variety of spatial ranges that span across cities, cho, and villages to secure medical system concerning hospitalization in a secondary medical jurisdiction. Furthermore, spatial positional relationships of temporary individual houses and medical and welfare facilities in these spatial ranges had to be grasped. These needs to visualize the whole picture as well as detailed situations on maps necessitated dynamic maps. Unlike static maps, dynamic maps allow users to flexibly change display areas and scale, and freely combine a variety of spatial dataset according to roles and challenges of each disaster response worker.

The Aging Society Department used these dynamic maps prior to visiting afflicted municipalities for investigation to understand the range of needs with appropriate scale as needed to conduct more appropriate survey and planning.

Dynamic maps were introduced at the national level for the Great East Japan Earthquake, and they featured a mashup of geospatial information from different information sources. At the prefecture level, the number of spatial datasets was greater. However, a high degree of freedom to set the range to be displayed satisfied the requirements of disaster response workers.

4. SUMMARY

This research determined the needs and utilization methods for maps that were designed at the prefecture level during a disaster recovery period. By closely observing users' needs and obtaining evaluation/feedback from requesters and front line workers, as well as regularly visiting prefectural departments about generated maps, we found that new requests for maps were generated during these processes. It was necessary to place the EMT headquarters in close proximity to the departments that use the maps in order to brief the users and to identify new needs. Furthermore, it became clear that utilization of dynamic maps made it easy to fill in the gaps between a big picture and individual understanding, which was not possible on static maps.

It has been almost one year since the earthquake (as of the writing of this manuscript on February 27, 2012). It is necessary to provide support on a longer time scale until the recovery of the afflicted area is complete. As relief activities shift from recovery phase to reconstruction phase in the future, it is expected that targets of disaster response and countermeasures will also shift to households and individuals that are segmented. When these needs become a reality, then it will be essential to continually examine the utilization of geospatial information to support decision-making processes in closer collaboration with municipalities under a prefecture.

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REFERENCES

URAKAWA, G., HAYASHI, H., FUJIHARU, K., TAMURA, K. and SAKAI, H.(2008). Constructing Common Operational Picture of Emergency Operation Center, Niigata Prefecture at Niigata-ken Chuetsuoki Earthquake, 2007, *Journal of Institute of Social Safety Science.* **10**, 127-134.

Disaster Prevention Research Institute Kyoto University, Research Institute for Natural Hazards & Disaster Recovery Niigata University, GK Kyoto(2009). Emergency Mapping Center REPORT -2007 Niigata-ken Chuetsu-oki Earthquake -.

INOGUCHI, M., TAMURA, K., FURUYA, T., KIMURA, R.and HAYASHI, H. (2011). Proposal of Effective On-Demand MashUp among Spatial Information from the activity of Emergency Mapping Team - A Case Study of the 2011 off the Pacific Coast of Tohoku Earthquake -, *Journal of Institute of Social Safety Science.* **15,** 219-229.

Iwate Prefecture Disaster Prevention Council (2010). Iwate Prefecture Regional Disaster Prevention Plan. http://www.pref.iwate.jp/~hp010801/kentiikibousaikeikaku/keikaku.pdf (Accessed 2011.2.27)

KIMURA, R., FURUYA, T., INOGUCHI, M., TAMURA, K.and HAYASHI, H. (2011). Clarifying the Characteristics of Data Set and Data Sharing about Damage and Disaster Responses in Government in Widespread Gigantic Disaster －A Case Study of the Data of Evacuees in Evacuation Shelters in the 2011 off the Pacific Coast of Tohoku Earthquake－, *Journal of Institute of Social Safety Science.* **15,** 333-342.