A Methodology for the Standardization of Information Processing following the Great East Japan Earthquake of 2011

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SUMMARY:
The Great East Japan Earthquake of 2011 caused a widespread tsunami and building damage. In order to facilitate rapid and efficient deployment of disaster responses, we developed an initial response system to share essential operational information. Our group worked as part of the Cabinet Office Mapping Team, beginning on the day after the earthquake, to provide a common operational picture by providing spatial visualization services using maps. Through this experience we determined that it was necessary to establish an initial response system. This system could be used to determine disaster response policies based on damage estimation calculated from hazard observation information. In addition, this system would also be beneficial in the event that the disaster spreads over a wide area and complex factors hinder the ability to collect damage information. Furthermore, we also proposed a methodology for the processing of necessary information to obtain a common operational picture.

Keywords: Processing information in disaster responders; Common operational picture; Standard data format

1. INTRODUCTION

The Great East Japan Earthquake that occurred on March 11, 2011, caused tsunami and liquefaction. In addition, there was a tremendous amount of human and property damages. This disaster triggered a call for immediate life saving activities, restoration of utilities, and the dispersal of support for victims across many prefectures throughout Japan.

The effective and efficient implementation of disaster response measures necessitates a shared common operational picture. Sharing a common operational picture involves the dissemination of information regarding the state of damages and disaster response activities among disaster responders, thus enabling a common understanding of the situation. In Japan, there have been initiatives to realize a common operational picture through effective and efficient information collection at disaster response fields. A recent example of this is the Emergency Mapping Center that was established by the Niigata Disaster Management Headquarters after the Chuetsu Offshore Earthquake of 2007. In this case, a common operational picture enabled effective and efficient disaster response activities. In this case, a common operational picture enabled effective and efficient disaster response activity via the mapping.

Based on these experiences, we sought to develop a system to share a common operational picture to aid in a decision making process at the national level by visualizing information on maps. These maps provided a common operational picture for the large-scale disaster due to the Great East Japan

Earthquake of 2011. In particular, we extracted information about needs, in order to elucidate the challenges for realization of sharing a common operational picture on the national level through our collaboration with the Cabinet Office. We believe that our system is effective for information processing and can be used to support the deployment of disaster resources in the future.

2. Overview of Mapped Information Generated by the Emergency Mapping Team to Provide a Common Operational Picture

The Cabinet Office Mapping Team operated from the day after the earthquake on March 12, 2011 until April 26 at a meeting room within the Cabinet Office. Initially we started our day at 10:00 a.m., and often continued until well past midnight when we just started the activities. As time progressed, we managed to end each day at around the end of a normal working day by clearly specifying the working time; however, we worked seven days a week until the situation stabilized. After April 2 when the system was well established and things were stabilized, we did not work on Saturday afternoons and Sundays. The Emergency Mapping Team was comprised of the maximum number of people per day during this period at the special meeting room (n=17). For the duration of the activities, the number of man-day was 278 in total (as counted by a half day). In reality, there were more people involved; we mobilized more people than 278 man-days due to the back-up system (Figure 1).

EMT headquarters (special meeting room, Cabinet Office) — Discussing mapping needs while considering requirements from the Cabinet Office — EMT soon after its launch — EMT near the end of the term

Figure 1. EMT meetings

Procedures used for the mapping work were: (1) Organize a list of general affairs and needs; (2) Generate data, figures, and tables; (3) Data processing and spatial processing; (4) Mapping and layout; and (5) Regular updating and mapping. The primary author of this paper was responsible for the generation of data, figures and tables, and created a database for mapping and sharing the status recognition data. The co-authors were responsible for other procedures. Together, we generated maps in response to requests (Figure 2).

The Emergency Mapping Team (EMT) generated a total of 500 maps during its operational period (March 21 through April 26). The maps were classified into 30 categories that were further subdivided into the following seven major categories: (1) Hazard observation information (63 maps); (2) Hazard scenario information [Areas under the nuclear plant evacuation advisory and directive (8 maps), Planned power outage by Tokyo Electric Power (5 maps)]; (3) Estimated damage compensation [Seismic intensity distribution for each building (1 map), Building distribution within areas under evacuation advisory and directive (5 maps), Building distribution in low-altitude areas (33 maps)]; (4) Actual damage [Isolated people (31 maps), Missing people (38 maps), Injured people (40 maps), Building damage (23 maps), Fires (13 maps)]; (5) Social infrastructure [Population and number of households in each municipality (2 maps), Distribution of population age 65 and over (8 maps), Facilities that can accept people who require assistance (7 maps), Satellite images of disaster areas (2 maps)]; (6) Response policy [Relationship between transportation centers and transportation capability (54 maps), Resources to consider for long-term evacuation designation (1 map), Resources to consider for specific disaster-afflicted area designation (1 map), Resources to consider for specific disaster-afflicted local public organizations (5 maps)]; and (7) Disaster response results [Evacuation center provisions (8 maps), Personal safety confirmation (1 map), Application of rescue methods (9 maps), Application of rescue methods and assistance methods (3 maps), Goods procurement (1 map), Temporary assistance staff dispatch (25 maps), Utility damage recovery (88 maps), Empty maps to record disaster response results (18 maps), Visualization of the recognition of disasters to the society by trend leaders (7 maps)].

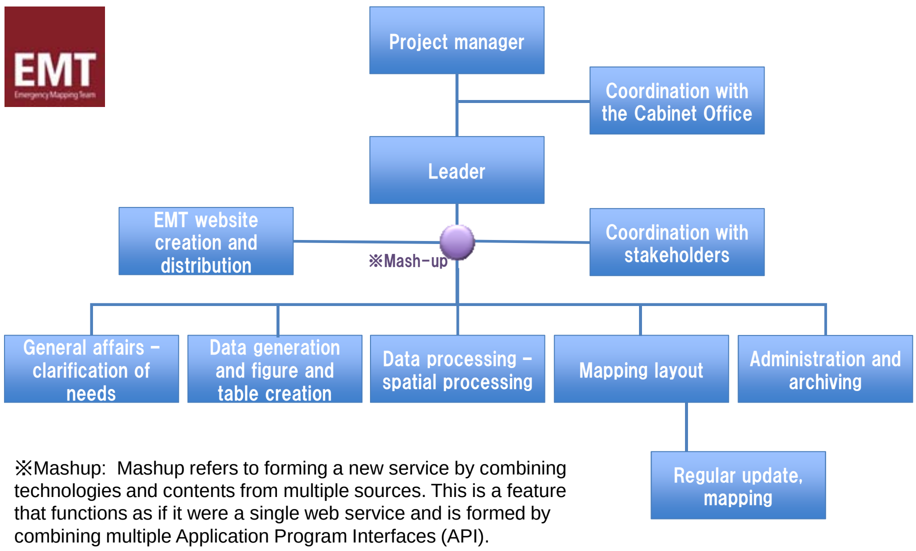


Figure 2. EMT structure (as of March 17, 2011)
(One week after the earthquake, six days after EMT launch)

3. Examples of Maps Generated by the Emergency Mapping Team to Provide a Common Operational Picture

The 500 maps that were generated by the Emergency Mapping Team resulted from a series of spatial analyses using information that was superimposed onto maps. This process is commonly called "mashup." Mashup refers to the formation of a new service by combining technologies and contents from multiple sources. This allows the child to function in a single web service that was formed by combining multiple Application Program Interfaces (API). Information that was subjected to mashup by the EMT is schematically presented in Figure 3. There were also issues with the data collected from the governments as shown in Table 1: (1) Issues with raw data (data was exchanged as hard copies); (2) Issues with the database (many of the Excel files generates could not be incorporated into the database); and (3) Issues with making data publicly available (collected data items were not uniform across different municipalities because they had different intentions and policies in making data publicly available). Two of representative maps made with mashup are shown.

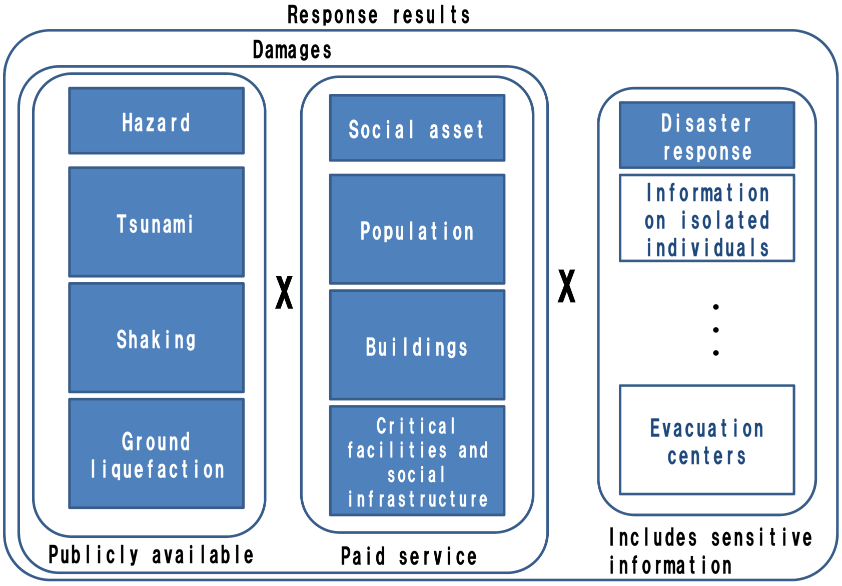


Figure 3. Information mashed up by EMT

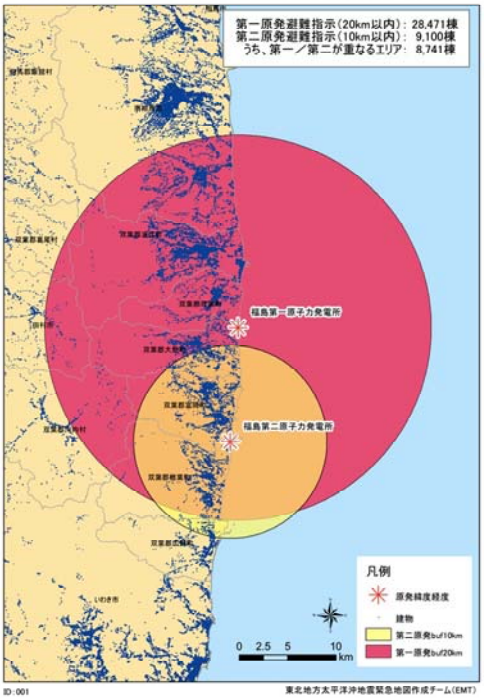
Table 1. Characteristics of data from the government in Japan

1. Issues with raw data: Hard copy data is exchanged as a raw data
   - Communication through FAX
     - FAX is used even when e-mail is available
     - Issues with security (copying, altering and leaking) and personal information
     - Large amount of forwarded FAXes (Faxing is repeated)
   - Even if the original is in Excel or Word, data have to be input from a hard copy
2. Issues with database: Many Excel files cannot be used directly as database
   - Many municipality staff uses Excel to generate documents
     - Cells are connected, a number and its unit are entered in the same cell, and character strings such as "ditto" are entered along with numbers
     - Meaning is conveyed by slashes and colors, and figures are inserted
     - Various issues emerge at the data analysis stage
3. Issues with making data publicly available: Each municipality has different policies and intensions in making data publicly available
   - Different meaning in whether data is publicly available and whether data is updated
   - Format is different and information handled is different
   - Format changes as time goes by
   - Location information is missing, which makes it difficult to spatially visualize data

3.1. Map of the Buildings within Areas under the Nuclear Disaster Evacuation Advisory and Evacuation Directive

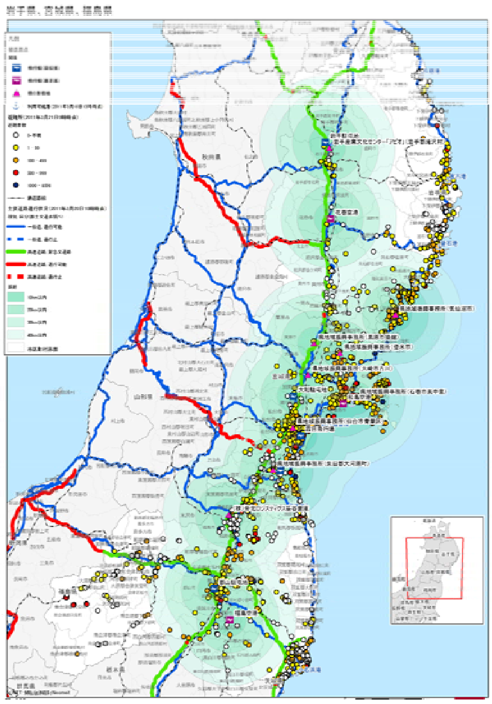
The map that launched the Emergency Mapping Team (Figure 4 Left). This map is based on a hazard scenario of "radioactive substances have leaked from the Fukushima Nuclear Plant." Affected areas are identified by concentric circles drawn in areas under evacuation advisory and directive, centering on the XY coordinate of the Fukushima Nuclear Plant using the buffer feature. More time would have allowed us to consider wind directions, wind speed, and other environmental factors to make a more realistic estimate of the shortage of time necessitated us to use concentric circles as the first-order approximation. Furthermore, for companies, point data was used to indicate locations of their buildings. The actual number of buildings was calculated by superimposing this data with a help of spatial statistical method. An explosion had not happened at the Fukushima Nuclear Plant when we started the mapping work. This enabled us to grasp the number of buildings that might be exposed to an explosion. Although the number of occupants in each building was not known, it was possible to estimate it by comparing the population and the number of buildings in each region based on the social statistical information. This map is considered "estimated damage information" because it allowed us to find out an estimated number of people exposed to radioactive materials. In addition, this map was a means to support an emergency response even before an emergency strikes. However, an emergency occurred as soon as the map was generated; therefore, it was not used before an emergency.

Estimated number of buildings in areas under evacuation directive around the Fukushima Nuclear Plant



Address points within each evacuation zone are spatially tallied to visualize possibility of impact

Locational relationship among transportation and evacuation centers



Evacuation center data from municipalities, relief materials transportation center data from the Ministry of Land, Infrastructure, Transport and Tourism, and actual traffic data from ITS Japan are spatially consolidated to indicate levels of difficulty for relief materials to reach victims (easy to difficult) by the distance from each transportation center.

Figure 4. Information that the EMT team mapped for a common operational picture

3.2. Relationship between Transportation Centers and Transportation Possibility

This map superimposes transportation centers for various relief materials and actual transportation routes to show transportation possibilities to evacuation centers where relief materials are needed (Figure 4 Right). Although air transportation was used, land transportation was the usual mode of transportation to evacuation centers where relief materials were needed. While the major emergency transportation routes had a priority in securing its function, an investigation was needed to determine whether local road emergency transportation routes should have been evacuated.

To gauge the passability, we employed "actual traffic data" from the GPS industry. We superimposed routes that the government planned to use with originating points and terminating points (evacuation centers) to not only identify the roads that were passable, but also "whether or not relief materials could be delivered." This map showed a low possibility of relief materials reaching the northern part of the coastal areas of Iwate Prefecture as seen in Figure 4 right.

4. Information Processing Procedures for a Comprehensive Common Operational Picture in a Wide-Area Complex Disaster

Figure 5 shows the flow of information processing towards sharing a common operational picture that was proposed through initiatives for the Chuetsu Offshore Earthquake of 2007. It is imperative that we share a common operational picture in order to come up with an Incident Action Plan (IAP). To this end, it is necessary to understand the external situation surrounding an organization, and damages and response situations within each sector of the organization. For this purpose, we collected information from the various information systems, other organizations, and various sectors of the organization. An assumption for this information processing flow was that data regarding damages comes from each related organization quickly and accurately. However, for complex and wide-spreading disaster such as the Great East Japan Earthquake of 2011, information to understand the situation itself was not sufficient due to reasons including the large number of missing people and the number of buildings that were washed away. This forced us to spend a significant amount of time researching this data. While information collection was given a priority in disaster response, the establishment of an initial action system and executing relief activities tended to lag behind until the information collection was completed and we had a good idea of the extent of damages. It is possible to call it as an "information collection imperative principle." It then became an important issue to account for damages that were not known to establish initial response system and to carry out disaster relief activities as soon as possible in order to share a common operational picture such as shown in Figure 5.

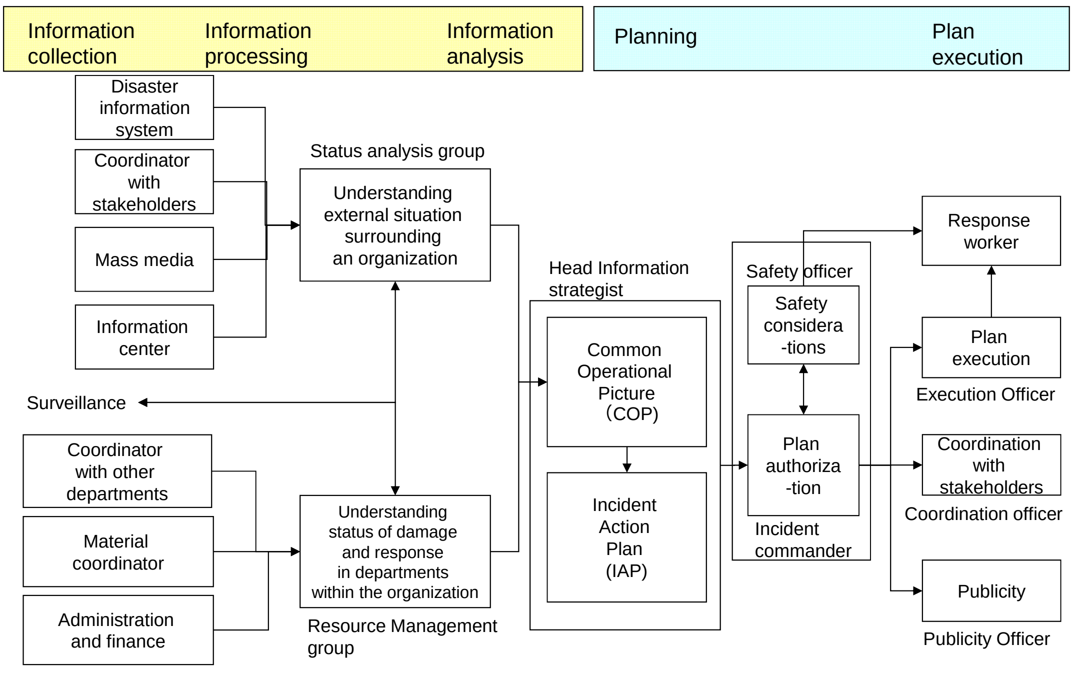


Figure 5. Information flow towards sharing a common operational picture

Based on our experiences in this disaster, we proposed an information-processing framework as shown in Figure 6. Areas enclosed with dashed lines show a flow to obtain a common operational picture based on an assumption that actual damage situation is known. However, in the event that an actual damage situation cannot be determined, a flow to directly connect hazard observation information from hazard observation equipment was used, This was implemented in normal time, in response to the initial response system in order to minimize a delay in disaster response. It is important to utilize a simulation in normal times in order to connect hazard observation information to disaster response. In normal times, the relationship between a hazard scenario and social asset information (vulnerability) draws a possible damage result. With the aid of this framework, it is necessary to minimize a delay in disaster response by establishing an initial response system without an input of actual damage information and by having preparation based on possible damages. As disaster response progresses and actual damages gradually become known, approximated damages can be replaced with actual damages by area or by type of damage. Figure 7 shows an acceleration of disaster response from the point of view of combination of different information during a disaster and normal time. In this scheme, data on actual damages and estimated damages are combined to supplement the deficiencies in damage information in order to accelerate the disaster response.

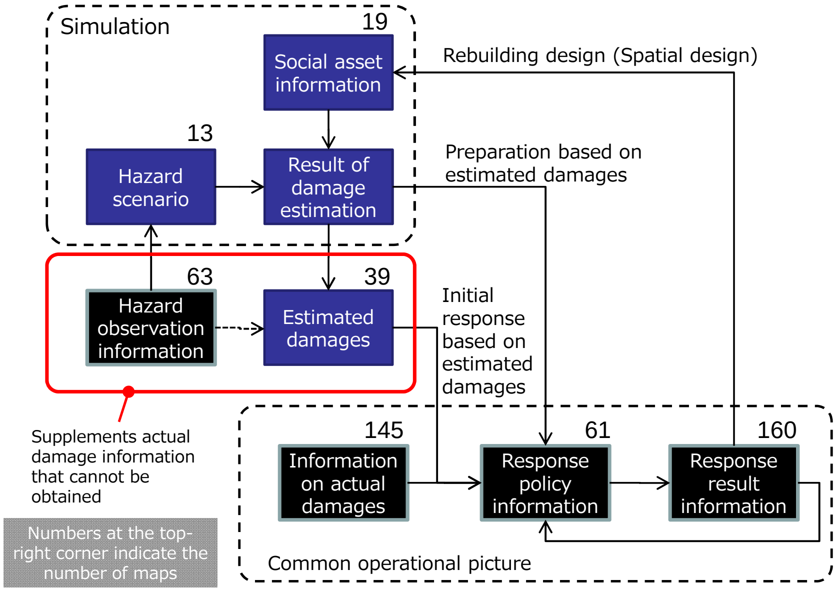


Figure 6. Information processing framework to achieve a comprehensive common operational picture

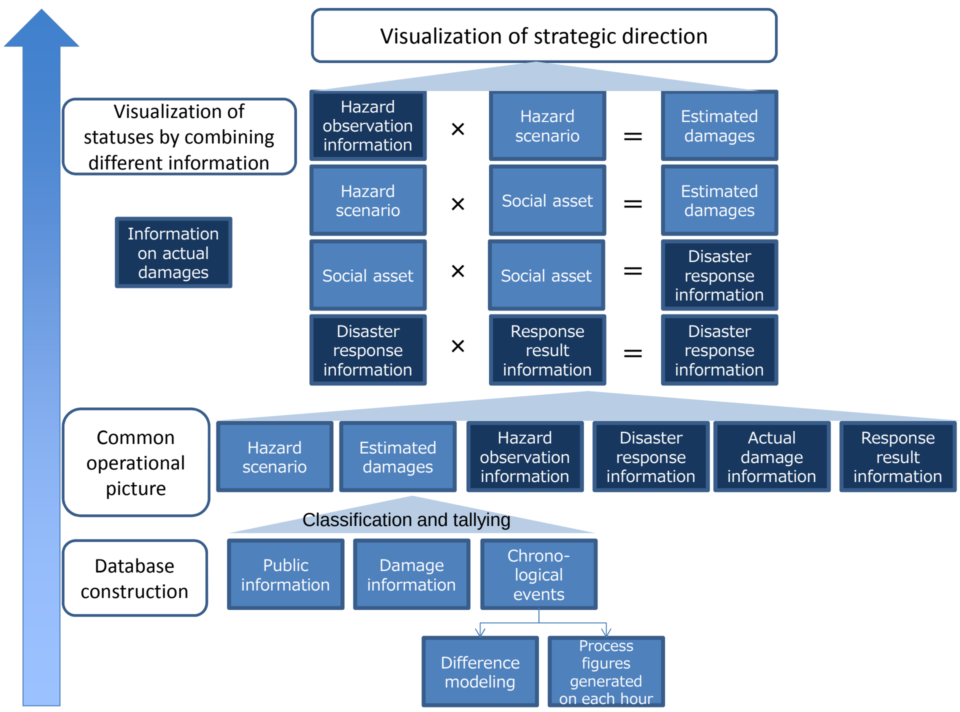


Figure 7. Acceleration of disaster response by combining pieces of information

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