KNOWLEDGE NOTE 5-1

CLUSTER 5: Hazard and Risk Information and Decision Making

Risk Assessment and Hazard Mapping
Hazard and risk assessments are the crucial first step in disaster risk management (DRM) and the basis for formulating DRM policies. They must take into account worst-case scenarios in the event of the largest possible hazard, while recognizing that hazard assessments of earthquakes and tsunamis will always have their limitations and associated uncertainties. In Japan so-called hazard maps, that combine hazard information with evacuation routes and locations of evacuation centers, are effective tools for promoting evacuation procedures and risk awareness among the public. However, in the case of the Great East Japan Earthquake (GEJE), these hazard maps, created before the event, may have given people a false sense of security by underestimating the disaster’s potential impact. Hazard maps should be designed to guide and facilitate prompt evacuation. They should be easy to understand and readily available.

Risk assessment involves estimating the hazard levels of possible earthquakes and tsunamis to be considered when formulating disaster management policies. It is the first step in developing disaster risk management (DRM) plans and countermeasures. In Japan, the responsibility for risk assessment rests with government agencies at multiple levels. Implementing agencies at the national, prefectural, and municipal levels normally conduct risk assessment to inform their planning and the design of preventive measures. The national government is responsible for providing information and technical assistance to help prefectural and municipal entities assess risks properly and to reflect these risks in DRM measures.

**FINDINGS**

**MEGADISASTER HAZARDS CONSIDERED IN RISK ASSESSMENT**

In Japan, countermeasures against earthquakes and tsunamis have been based on the risks associated with five large earthquakes that have occurred over the past several hundred years (figure 1 and box 1). The Central Disaster Management Council has set up a committee to investigate and assess the potential hazard levels and expected damages...
from each of these scenarios. The committee also developed DRM strategies and a master plan for preventive actions as well as postdisaster response and recovery measures. DRM measures implemented at the national, prefectural, and municipal levels have traditionally been based on these strategies and plans.

The March 11 disaster occurred in the vicinity of the Japan and Chishima trenches—the region where the Central Disaster Management Council’s committee had investigated trench-type earthquakes. From the list of past earthquakes in the region (figure 2), eight were selected for consideration, based mainly on their intensity, frequency, and the possibility of recurrence in the same area. The selected historic earthquake scenarios included the Meiji-Sanriku Earthquake Tsunami of 1896, which generated a giant 20-meter-high tsunami, and Miyagi-ken-oki (Miyagi Prefecture) earthquakes that have been occurring at 40-year intervals. On the other hand, earthquakes such as those off the coast of Fukushima Prefecture were not selected because their probability of occurrence was estimated to be low, at 7 percent (figure 3). Furthermore, the Jogan Earthquake of 869, believed to have caused massive tsunamis in the east Japan region, was excluded because the available modeling techniques were unable to replicate its seismic intensity and tsunami height, and the probability of recurrence in the same area was considered to be very low.
The magnitude of earthquake and tsunami hazards exceeded predisaster estimates

As illustrated in figure 2, the March 11 earthquake had a very large epicentral and tsunami source area, larger than any earthquake recorded in Japan’s history. Furthermore, its magnitude of Mw9.0 exceeded the hazard level of any earthquake in the country ever considered for purposes of disaster management. Thus, the extent of the high seismic intensity area of the actual earthquake was much larger than expected, and the area that experienced Japanese seismic intensity of 5+ or larger was about 10 times the estimate (figure 4). Furthermore, the actual tsunami height was twice the height used in the predisaster tsunami hazard predictions (figure 5).

Because the magnitude of the GEJE and tsunami far exceeded the predisaster estimates, the Japanese government has been revising its methods of assessing earthquakes and

BOX 1: Principles for selecting large-scale earthquake scenarios and the actual earthquakes selected

- Repeated occurrence
- High probability of future occurrence
- Possibility of occurring within the next 100 years
- Not considered if an active fault earthquake has occurred in the last 500 years
- A significant number of occurrences can be identified in historical records
- Magnitude is between M7 to M8
- Consider the economic and social activities and central administrative functions to be protected

Earthquakes meeting the above criteria:

- Tokai earthquake (M8.0)
- Tonankai/Nankai earthquake (M8.6)
- Japan and Chishima trenches earthquake (M7.6-8.6)
- Tokyo Metropolitan inland earthquake (M6.9-7.5)
- Chubu and Kinki inland earthquake (M6.9-8.0)

THE MAGNITUDE OF EARTHQUAKE AND TSUNAMI HAZARDS EXCEEDED PREDISASTER ESTIMATES

As illustrated in figure 2, the March 11 earthquake had a very large epicentral and tsunami source area, larger than any earthquake recorded in Japan’s history. Furthermore, its magnitude of Mw9.0 exceeded the hazard level of any earthquake in the country ever considered for purposes of disaster management. Thus, the extent of the high seismic intensity area of the actual earthquake was much larger than expected, and the area that experienced Japanese seismic intensity of 5+ or larger was about 10 times the estimate (figure 4). Furthermore, the actual tsunami height was twice the height used in the predisaster tsunami hazard predictions (figure 5).

Because the magnitude of the GEJE and tsunami far exceeded the predisaster estimates, the Japanese government has been revising its methods of assessing earthquakes and
FIGURE 2: Historical occurrence of trench-type earthquakes in the vicinity of Japan and the Chishima trenches

Source: CAO.
FIGURE 3: The probability of occurrence, magnitude, and location of potential earthquakes in Japan

Source: Headquarters of Earthquake Research Promotion.
FIGURE 4: *Actual versus predicted seismic intensity*

![Figure 4: Actual versus predicted seismic intensity](image)

*Source: CAO.*

FIGURE 5: *Actual versus predicted tsunami height*

![Figure 5: Actual versus predicted tsunami height](image)

*Source: MLIT.*
tsunami hazards. The Basic Disaster Management Plan, revised after the GEJE, provides the following guidelines for estimating earthquakes and tsunamis.

- Earthquake and tsunami countermeasures should be based on scenarios that take into account the largest-possible earthquakes and tsunamis, which should be considered from every possible angle using all scientific means.

- Earthquake and tsunami scenarios should be based on the most accurate earthquake records available, going as far back in history as possible, and in combination with an analysis of historical literature, topographical and geological studies, as well as other scientific findings.

ESTIMATING DAMAGE

Because of the underestimation of the earthquake and tsunami hazards, the damage caused by the GEJE far exceeded the predisaster damage estimates. The number of completely destroyed buildings was about six times the estimated amount, and the number of human lives lost was more than seven times the estimation (table 1). The conventional methodology for estimating damages can be characterized as follows.

- Quantitative estimation including direct physical damage, human loss, damages to lifeline and transportation infrastructure, economic losses (direct and indirect).

- Qualitative estimation including fires induced by tsunami; critical lifeline infrastructure facilities such as power plants, gas production plants, water and wastewater treatment plants, and so forth.

- Three scenarios reflecting different seasons and times of day (winter 5 am, summer 12 pm, winter 6 pm), which are likely to affect fire scale and incidence.

<table>
<thead>
<tr>
<th>TABLE 1: Comparison of estimated and actual damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimation</td>
</tr>
<tr>
<td>Area with seismic intensity of 5+ or larger (km²)</td>
</tr>
<tr>
<td>Inundation area (km²)</td>
</tr>
<tr>
<td>Buildings completely destroyed</td>
</tr>
<tr>
<td>Disaster waste (tons)</td>
</tr>
<tr>
<td>Deaths (includes missing)</td>
</tr>
</tbody>
</table>

*Note:* The figures for estimation reflect the larger of the damage estimates for the Miyagi-ken-oki and Meiji-Sanriku earthquakes.

- Estimation of deaths uses the case of the Meiji-Sanriku earthquake case with a low disaster awareness level.
- Deaths from the GEJE as of January 31, 2012.
A facility is considered to have received no damage if it is equipped with enough mitigation measures against ground motion and fire.

A quantitative estimation of the impact was carried out using the relationship between the magnitude of the hazard (seismic intensity, maximum ground velocity, tsunami inundation depth, and so on) and the actual damage (number of destroyed houses, human loss, and so on), which was established based on historical earthquakes. For example, tsunami damage to buildings was estimated using the assumption that a building is completely destroyed if the inundation depth is 2.0 meters or more based on empirical evidence. Human losses caused by tsunamis were estimated based on the tsunami-affected population and historical records of death by tsunami inundation depth and estimated evacuation rates (percentage of people who can obtain warning information and the time it takes for people to evacuate). These were calculated for 50-meter-by-50-meter grid cells, and overlaid on exposure data, such as spatial socio-demographic data, available nationwide from the Geospatial Information Authority of Japan (GSI). Furthermore, infrastructure damage was estimated on the basis of the estimated number of destroyed buildings, lifeline failure rates and the number of days required for restoration, for which empirical relationships have been established based on previous disasters.

The underestimation of damage in the case of the GEJE was largely due to an underestimation of the magnitude of the hazards involved. Also, it has been pointed out that some factors—such as evacuation rates—used for damage estimation purposes were higher than actual rates, which could have further contributed to an underestimate of human losses. At the time of this writing, the damage estimation methodology is being revised.

EARTHQUAKE AND TSUNAMI SIMULATION AND HAZARD MAPPING

Hazard maps provide important information to help people understand the risks of natural hazards and to help mitigate disasters. Hazard maps indicate the extent of expected risk areas, and can be combined with disaster management information such as evacuation sites, evacuation routes, and so forth. In Japan, hazard maps are prepared and made available for various hazards such as earthquakes, tsunamis, floods, landslides, liquefaction, and volcanic eruption (KN 5-2 and 5-3).

Japan’s prefectural governments conduct hazard mapping, and the hazard data they prepare, for example, expected inundation depth and extent, is in turn used by the municipalities to prepare disaster management maps called hazard maps, that indicate not only the expected hazard but also information such as evacuation routes and evacuation sites (figure 6). The Act on Special Measures for Earthquake Disaster Countermeasures, passed in 1995, mandates the prefectural governments and local municipalities to prepare these maps to promote awareness of earthquake and tsunami risks in their respective jurisdictions. As of 2010, more than 80 percent of the prefectures had prepared tsunami inundation maps and 50 percent of coastal municipalities were equipped with tsunami hazard maps.

The national government provides technical assistance and guidelines to promote hazard mapping by local governments. In 2004, the central government prepared Tsunami and Storm Surge Hazard Map Guidelines to help the municipalities in creating hazard maps and to promote the use of hazard maps throughout the country. The guidelines provide infor-
FIGURE 6: An example of a tsunami hazard map, Miyako City, Iwate Prefecture

![Tsunami Hazard Map](image)

Source: Miyako City.

TABLE 2: Methods for defining inundation risk areas

<table>
<thead>
<tr>
<th>Method</th>
<th>Procedure</th>
<th>Advantages/disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical simulation in time series</td>
<td>Use numerical models to estimate inundation area as well as inundation depth and flow velocity, inundation time.</td>
<td>Precise assessment is possible and can take into account the effects of the disaster mitigation structures. Resource intensive.</td>
</tr>
<tr>
<td>Level-filling method</td>
<td>Calculate the inundation based on the height and width of the tsunami and estimate the extent of inundation based on the topographical data.</td>
<td>Not so resource intensive. Ignores the effects of structures and buildings and the momentum of water flow (tsunami run-up).</td>
</tr>
<tr>
<td>Prediction based on past inundation</td>
<td>Define the risk area based on the inundation area of historical tsunami events.</td>
<td>Simple and low cost. Cannot be used for areas with no historical records. Cannot reflect changes such as construction of disaster reduction facilities.</td>
</tr>
<tr>
<td>Estimation based on ground elevation</td>
<td>Define high-risk areas as those areas lying lower than the expected tsunami height.</td>
<td>Simple and low cost. Cannot take into account the effects of structures and buildings and the momentum of water flow (tsunami run-up).</td>
</tr>
</tbody>
</table>
mation on the basic concepts of tsunami and storm surge hazard maps, and the standard methodology for preparing them. The guidelines explain in depth the numerical simulation methodology for identifying inundation risk areas, which is the principal means of tsunami hazard mapping. Alternative methodologies, as shown in table 2, are also explained so that the best method can be selected according to the resources and data available. Numerical simulation of tsunamis generally requires the following steps.

**FIGURE 7: Hazard map usage patterns**

Source: CAO.

**FIGURE 8: Inundation area: hazard map versus actual**

Source: CAO.
Development of a fault model

Topographic data

Setting of initial water level conditions (typically uses the vertical displacement calculated by the fault model)

Calibration and verification of the model

Predictive simulation

Hazard maps in Japan have been used by the municipalities to design evacuation procedures. But they have not been utilized for land use or development planning. The lessons learned from the GEJE have prompted the Japanese government to implement a new act to create tsunami-resilient cities. The new legislative framework calls for the prefectural governments to prepare an inundation risk map, which is to be used for regulating land use and mitigating the effects of a tsunami (KN 2-7).

HAZARD MAPS IN THE DISASTER-AFFECTED AREAS

All municipalities hit by tsunamis during the GEJE had prepared hazard maps before the earthquake and tsunami. But surveys show that only 20 percent of the people knew about these hazard maps (figure 7); and the extent of flooding indicated on the hazard maps was in many cases underestimated compared to the actual inundation area (figure 8). It is likely that these maps provided residents with a false sense of safety, and prevented people from evacuating, resulting in greater human losses.

LESSONS

- Hazard assessment is critical since it serves as the basis for DRM policies. Earthquake and tsunami hazard assessment is conducted extensively in Japan to raise public awareness and to prepare for disasters.

- Predisaster damage estimation was low due to the underestimation of hazard levels. Past assessments did not adequately consider certain kinds of damage, including from long-period seismic waves, tsunami-induced fires, and nuclear accidents.

- Recognizing the uncertainties associated with hazard assessment, the largest-possible hazard scenario should have been used, drawing on all available information including not only seismological but also geological, archaeological, and historical studies looking at tsunami deposits, ancient documentation, and so on.

- Hazard maps were developed by all municipalities in the disaster-hit areas, and served as important tools for designing evacuation procedures.

- Hazard maps should facilitate and guide people’s evacuation efforts and should not contribute to a false sense of safety. Providing information on inundation risk zones
for multiple levels of hazards including low-frequency events, or information directly linked with tsunami warnings would be effective. The meaning of the information provided on the maps needs to be clear and adequately explained to the users.

• Risk information must be communicated to the public effectively. In the GEJE, only 20 percent of the people made use of hazard maps.

**RECOMMENDATIONS FOR DEVELOPING COUNTRIES**

• Understanding hazard and risk is a vital component of DRM. Quantitative estimation of potential damage is important as it informs the appropriate strategies and measures to be taken. Risk exposure data should be collected, mapped, and shared as they are vital components of risk assessment.

• While bearing in mind that the hazard assessment of earthquakes and tsunamis has limitations and uncertainties, the largest possible hazard should be investigated and considered in formulating DRM policies. Hazard assessment should not rely solely on statistical analysis based on historically recorded earthquakes and tsunamis, because historical records may not account for the maximum-possible hazard levels that may occur in the future. Also, disasters have occurred for which there are no records available. The level of hazard to be used in designing structural measures should be selected based on local conditions. Hazard and risk assessment should be revised and updated periodically with the latest findings and in light of more recently experienced disasters.

• Hazard maps are effective tools for promoting risk awareness, for designing evacuation procedures, and for deciding the locations of evacuation facilities and shelters. Hazard maps should be easy to understand and easy to use for purposes of prompt evacuation, and users should be aware of the limitations and uncertainties of the information they contain. Considering budget and technical constrains, risk estimation methods can be selected as explained in table 2.

• Sharing hazard and risk data and information is crucial. Data can be shared through central depositories that are open to the public, among other means (see KN 5-2).

**REFERENCES**


KNOWLEDGE NOTE 5-2

CLUSTER 5: Hazard and Risk Information and Decision Making

Risk and Damage Information Management
In Japan, municipalities are mandated to produce hazard maps for floods, storm surges, volcanic eruptions, tsunamis, stagnant water, and landslides to which the municipality may be exposed. By combining exposure data with satellite images and aerial photographs, post-event damage assessments can be carried out with reasonable accuracy. Japan’s experience with the disaster of March 2011 demonstrates that having exhaustive data on exposure expedites the damage assessment process, thereby reducing the time required for compensation payments and insurance payouts.

Japan is known for its disaster preparedness. Less well known but no less important for disaster response is the country’s “data preparedness.”

Communities need to understand the risks they face, and to have access to early warnings. In Japan, maps that illustrate the likely extent of hazards and the location of evacuation centers and routes are distributed to households and public institutions, such as schools and hospitals, in an effort to raise public awareness of disaster risk. Immediately after the Great East Japan Earthquake (GEJE) and tsunami, information on the damage caused by the disaster was collected rapidly and shared among responding agencies using a variety of top-down and bottom-up tools, including remotely sensed data, public and private datasets, and online tools such as the Ushahidi-based sinsai.info Web site. The data-collection and dissemination effort underpinned assistance to the affected population, timely allocation of resources to areas in need, and effective reconstruction planning.

FINDINGS

EX ANTE PUBLIC INFORMATION CONCERNING RISKS FROM NATURAL DISASTERS THROUGH THE MLIT HAZARD MAP WEB PORTAL

In Japan, municipalities are mandated to produce maps related to the following hazards: floods, storm surges, volcanic eruptions, tsunamis, stagnant water, and geological hazards (landslides). These hazard maps include not only information on the expected intensity and...
extent of the hazard but also the location of evacuation centers and designated evacuation routes (KN 5-1). The hazard map Web portal prepared by the Ministry of Land, Infrastructure, Transportation, and Tourism (MLIT) includes a link to all available hazard maps, providing a one-stop shop where information on risks from natural hazards can be accessed (figure 1).

**EX POST COLLECTION OF DAMAGE DATA**

Learning from their experiences with past events, the Japanese Self-Defense Force (JSDF) has been upgrading its emergency response plans. One of the JSDF’s tasks is to capture video footage of the affected region immediately following a major disaster event. In the case of the GEJE, a helicopter was dispatched immediately after the main shock. It trans-
In the immediate aftermath of a natural disaster, the collection of information on the damage allows appropriate resources to be allocated for response activities. Traditionally, data have been collected by sending people to the affected areas. During the past decade, however, the use of remotely sensed data has become viable for damage data collection thanks to improvements in the spatial resolution of such data (less than one meter with optical satellite images) and reductions in acquisition costs.
Following a disaster, satellite data are the first to become available, followed by aerial photographs, which provide more detailed images. Aerial surveys are subject to logistical delays, whereas satellites are already in orbit and can generally deliver data within 24 hours to a few days, depending on the satellite. With aerial surveys, by contrast, weather conditions must be good, and the area that a single image can cover is smaller than the area covered by a satellite image, prolonging the time required to photograph a given area.

The International Charter organization provides member states with a unified system of space data acquisition and delivery. Member states can request satellite data at no cost in the event of emergencies following natural or manmade disasters. Remotely sensed data are analyzed by predesignated value-adding vendors to derive and deliver the information requested by the affected country. After the GEJE, the International Charter was activated through the Cabinet Office of Japan, the designated authorized user in Japan. Products produced through the Charter ranged from maps of the extent of inundation from the tsunami to areas of liquefaction, spot checks in areas of interest, and estimates of the volume of debris (table 1).

Public-private partnership between aerial survey firms and the Geospatial Information Authority of Japan (GSI)

Japan has been using remotely sensed data following major natural hazard events for some time. In 1995, following the Hanshin-Awaji earthquake, the National Broadcasting Corporation (NHK) flew helicopters with high-definition video cameras over Kobe city to capture the damage. Private aerial survey firms deploy aircraft to take aerial photographs and other types of remotely sensed data (for example, LiDAR data, in the case of landslides or volcanic eruptions) following every natural disaster event in Japan. Currently the major aerial survey companies have a public-private partnership with GSI under which they jointly capture damage information, thus avoiding duplication of effort. The agreement has been in effect for some years, resulting in an archive of records documenting the changes caused by natural disasters in Japan.

Following the GEJE and tsunami, the partnership spent a month taking aerial photographs of the coastline of the entire Tohoku region coastline (approximately 500 kilometers).

Tsunami inundation mapping using remotely sensed data

As early as five days after the tsunami, the GSI announced the first estimate of the total inundation area as 400 km², based on manual interpretation of aerial photographs taken on March 12 and 13. One month after the event, on the April 18, the government officially announced the total inundation extent to be 561 km². The increase reflected the availability of additional aerial photographs and high-resolution optical satellite images of areas previously not covered.

Although GSI’s inundation mapping was considered the official information, other organizations used various methodologies and data sources to map the extent of inundation. A list of these can be found in EEFIT (2011).
TABLE 2: Examples of the difference between estimates of affected population in municipalities in Miyagi Prefecture using two different estimates of extent of inundation

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Population total (2007 census)</th>
<th>Population within inundated area</th>
<th>Difference between GSI and private company</th>
<th>Difference as percentage of total population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miyagino-ku</td>
<td>182,678</td>
<td>17,375</td>
<td>5,517</td>
<td>3.0</td>
</tr>
<tr>
<td>Wakabayashi-ku</td>
<td>129,942</td>
<td>9,386</td>
<td>686</td>
<td>0.5</td>
</tr>
<tr>
<td>Taihaku-ku</td>
<td>222,447</td>
<td>3,201</td>
<td>682</td>
<td>0.3</td>
</tr>
<tr>
<td>Ishinomaki</td>
<td>167,324</td>
<td>112,276</td>
<td>9,606</td>
<td>5.7</td>
</tr>
<tr>
<td>Shiogama</td>
<td>59,357</td>
<td>18,718</td>
<td>18,545</td>
<td>31.2</td>
</tr>
</tbody>
</table>

For 30 municipalities the Statistics Bureau of Japan compared the difference between the estimate of the population affected by inundation derived using GSI’s aerial photographs with that produced by a private company. Some of the differences are shown in table 2. In most cases, the differences between the two estimates are negligible in relation to the total population in the respective municipalities. In a few cases, however, the difference amounted to more than 20 percent of the total population of that municipality. In Shiogama the difference between the estimates was more than 30 percent of the total population. The full comparison results can be found on the Statistics Bureau’s Web site.

In an independent validation of the mapping performed using JAXA’s ALOS satellite image and GSI’s aerial photographs, Sawada and his team (2011) found a substantial difference in the area shown as inundated: interpretations based on aerial photographs reported twice as much inundated area as interpretations based on satellite images.

**SPATIAL DATA PREPAREDNESS IN JAPAN**

Decision makers need spatial data to make informed decisions about disaster preparedness, post-event responses, and recovery planning. Spatial data provide information on the location of key infrastructure, populations, agriculture, industrial facilities, education and health facilities, and so on. In Japan these datasets are freely available from the GSI Web site in both raster and vector formats. Building-specific data on exposure levels are also commercially available for the entire country. Overlaying these datasets with the mapped hazard (for example, the extent of tsunami inundation) permits a rapid damage assessment. Commercial building-specific datasets were made available at no cost to enable response agencies to assist in the relief and recovery activities (figure 2).
Quick determination of government compensation and insurance payments through the use of aerial photographs

Aerial photographs were used in an innovative way to determine compensation payments from local governments and insurance payouts by the General Insurance Association of Japan. Because the area of inundation was clearly visible from aerial photographs, and because the tsunami was so powerful, it was deemed that structures located within the coastal inundation zones were 100 percent destroyed. The owners, therefore, were eligible for full compensation.

The innovation in these cases lies in the fact that payouts were made without sending an inspector or a loss adjuster to the address—that is, the aerial photographs were the sole source of claim verification. This system expedited the claim-payment process, resulting in an average payout by the earthquake insurance schemes of $250 million per day during the last week of April 2011—1.5 months after the earthquake (see KN 6-2).

Although data preparedness is advanced in Japan, some of the information is available only in Japanese, and navigating the Web sites where data are available can be difficult. Open Street Map (OSM) is an international volunteer technical community dedicated to producing freely available, detailed topographic data for the entire globe. Local volunteers donate their time to trace satellite images made available for the purpose. To accommodate the international community’s need for topographic maps and English annotation, OSM volunteers created detailed maps of the entire Tohoku coastal region and began publishing the resulting topographic maps online just a few hours after the main shock.

Source: All311 website.
When hazard information is combined with geocoded data on key infrastructure and mechanisms to analyze “big data” (for example, crowd-sourcing), it has the potential to provide damage information rapidly and with reasonable accuracy. In the case of the tsunami damage assessment following the GEJE, a binary damage-assessment system was used, in which building-level data on structures that had been geocoded before the event was overlaid on data on the extent of the disaster, permitting a high-confidence assessment of whether a building was destroyed.

Similar methodologies have been used and continue to be tested for earthquake damage assessment in Haiti and in Christchurch, New Zealand. Large-scale crowd-sourced earthquake damage assessments have been carried out with a view to operationalizing the methodology. Accuracy assessments are being performed to ascertain the level of accuracy that is achievable using these tools. Remotely sensed data has also been used for flood damage assessment. In all cases, it is clear that the accuracy of the damage assessment increases where pertinent data on key infrastructure are available, making a strong case for data preparedness.

Source: gdms.jp.

**BOX 1: Crowd-sourced damage assessment using remotely sensed data in Haiti and Christchurch**

**FIGURE 3: Online interface of Geospatial Disaster Management Mashup Service Study (GDMS)**

Source: gdms.jp.
The OSM maps are open, that is, the data can be used across different platforms and without any restrictions. Another characteristic of the maps is that all annotations are available in the local language as well as in English. Moreover, the styles used in the maps are standardized, providing a consistent feel. In some countries, the OSM platform is being used as a tool to raise awareness in communities at risk from natural disasters by involving them in collecting data on their own communities.

**ONLINE PLATFORMS TO STORE AND DISTRIBUTE SPATIAL DATA FOLLOWING THE EARTHQUAKE AND TSUNAMI**

Much of the spatial data created following the GEJE is open data. Several online platforms have been created to host and distribute these open datasets to assist in damage assessment, to facilitate response and relief activities on the ground, and to help local communities. Two such platforms are the Emergency Mapping Team (EMT) and the Geospatial Disaster-management Mashup Service Study (GDMS, figure 3). Most of these platforms use a map interface, against which the data hosted on the system are visualized spatially.

**USE OF SOCIAL MEDIA FOR BOTTOM-UP INFORMATION SHARING**

In recent years, the use of social media in postdisaster settings has spread around the world. Even after the tsunami, when the entire phone network and Internet were down, information from the affected areas came through on social media such as Twitter and Facebook (KN 3-2). Many families stayed in touch using these media in the immediate aftermath. Japanese mobile networks and telecommunication companies have well-established systems that allow subscribers to leave messages for their loved ones. Google set up an online person finder after the GEJE.

Twitter, Facebook, and new types of social media such as Ushahidi are establishing themselves as a global standard for collecting information on needs in local communities. Ushahidi is an open source online interface that allows bottom-up information sharing. Developed to ensure a fair election in Kenya in 2008, the platform is designed to allow anyone to upload information or requests for help, using Twitter or emails, which are visualized on a map interface (figure 4), thus making them actionable items. Sinsai.info, a combination of Ushahidi and OSM Japan, was launched in the immediate aftermath of the GEJE, when OSM data was being used as the base map to display requests for help coming in from communities in the Tohoku region.

All311 is another site that was launched immediately after the event. Hosted by the National Research Institute for Earth Science and Disaster Prevention (NIED) and built using an e-community platform developed by NIED, the site is a one-stop shop for information on ongoing activities, both top-down and bottom-up, in the recovery process. Information is provided in Japanese only. E-community is an open source tool for developing information-sharing platforms with spatial content.
LESSONS

- Satellite images are available before aerial photographs, but they do not reveal as much detail. After the GEJE, a standing public-private partnership between the major aerial survey companies and GSI captured aerial photographs of the areas affected by the GEJE. GSI published an estimate of the inundated area five days after the event, based on manual interpretation of the aerial photographs then available.

- The limits of technology for response activities should be recognized. In the GEJE, the inundation area mapped from aerial photographs was much larger than that mapped from satellite images.

- By overlaying the tsunami inundation estimates with commercially available building-level datasets, it was possible, for insurance purposes, to designate structures that had been completely destroyed by the tsunami.

- Crowd-sourced methods for collecting damage information have great potential. After the GEJE, Open Street Map volunteers were mobilized to create topographical maps of the region with annotations in English and Japanese.

Source: http://www.sinsai.info.
Online platforms were created to host and distribute spatial data useful for response and recovery. Sinsai.info and All311 are two examples.

RECOMMENDATIONS FOR DEVELOPING COUNTRIES

- A one-stop online portal is a good way of disseminating hazard maps for a given country. However, in countries where Internet access is not readily available, an online portal may not necessarily be optimal. Conventional methods, such as paper maps and booklets, should be utilized as well.

- Data preparedness is a key ingredient for both pre-event disaster risk management and post-event damage assessment and reconstruction planning. Data collection on key infrastructure should be carried out during normal times and kept up to date. The data can be used for other purposes such as town planning.

- Satellite images and aerial photographs are now routinely used for post-event damage assessment. Damage assessment can be carried out with reasonable accuracy by combining data on infrastructure with exposure data. Collected data should have a specific, well-managed repository and be paired with appropriate tools to analyze the data for risk-assessment purposes.

- New ICT tools are increasingly being used in emergency situations. 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. Creating protocols for how these volunteer-based communities can work with official government entities is increasingly important.

REFERENCES


Risk Communication

Risk communication is an important component of disaster risk management (DRM) because it shapes people’s perceptions of risk and influences their actions with respect to disaster preparedness and disaster response. It also influences the intervention decisions that are made throughout the disaster management cycle. The credibility of the information source takes a long time to build and needs to be well established before a disaster strikes. In Japan, the level of trust in government and other official communications was sorely tested following the nuclear accident at the Fukushima Daiichi nuclear power station.

Disaster preparedness is often perceived as being mainly a governmental responsibility, with information and directives traveling from the top down. That is the case to some extent, since local communities generally lack the tools and skills needed to conduct scientific risk assessments and fully understand the underlying risk in their localities without expert assistance. The problem with the top-down approach is that policies may be imposed on communities without taking local conditions onto account, and communities may become overly dependent on information coming from the government. Recent experiences from the Great East Japan Earthquake (GEJE) showed that when the local community was involved in planning for disaster preparedness, and people took ownership of their own safety plans, they were better prepared and better able to take the necessary actions to protect themselves.

Successful risk communication occurs when there is holistic learning, facilitation, and trust. In holistic learning, the gap in knowledge between the information sender and receiver is minimal (figure 1). Hazard maps, booklets, and videos can all help narrow that gap when it comes to disaster education and risk communication.

Normally, the information generators or senders are government agencies, universities, or research institutions that have the capacity to assess risk and the political mandate to implement DRM measures. The information receivers are the communities, businesses, and individuals who have knowledge of the local area and are the ultimate users of the risk information (figure 2).
FINDINGS

THE IMPORTANCE OF TRUSTING THE INFORMATION PROVIDER

Early warnings greatly influence how people perceive and evaluate the risks from the imminent hazard and their subsequent decision to evacuate. In this respect, the level of trust in and the credibility of the person, institution, or medium issuing the warning is of crucial importance.
importance. Furthermore, factors such as fatalism can affect evacuation decisions. People who have responded to too many false alarms may not take the warnings seriously.

In some cases, the underestimation of the height of the tsunami in the warnings that went out on March 11 likely delayed evacuation and possibly increased fatalities (KN 2-5). Japan’s proposed new early warning scheme will not include any numerical values for tsunami height in the first warning but will use more descriptive expressions, such as “massive” or “very high” waves, in the event of earthquakes larger than magnitude 8. These terms will be further qualified by expressions such as a “tsunami height equivalent to the GEJE is expected.”

**OFFICIAL RISK COMMUNICATION TOOLS: HAZARD MAPS**

In Japan, hazard maps indicate expected hazard levels and locations as well as the location of evacuation centers and routes (KN 5-1). The map shown in figure 3 was prepared by the village of Toni (Kamaishi City, Iwate Prefecture) in a local workshop with community members. It includes predicted inundation depths indicated by colors, historical records of inundated areas, lead times, evacuation shelters, and telephone numbers for warnings. The hazard map was printed and distributed to all families in Toni before the GEJE.

Developing this type of disaster map through a participatory process is an effective way of communicating risk to the community at large. A post-disaster survey in the Toni area identified citizens’ motivations for participating in the mapmaking process (figure 4).

**PROBLEMS WITH THE HAZARD MAPS IN USE**

Mapping schemes differ in the colors and symbols used to convey hazard information. In the United States, efforts are being made to ensure the consistency of the content of hazard maps, as well as their design.

While hazard maps are useful tools to help communities understand the risks they face, there are, nevertheless, uncertainties associated with the assessment of the hazard risk itself—future disasters may exceed the levels indicated on the maps. In addition to producing and delivering the maps, their content should be presented to local communities, as was done in Toni Village. In the course of such presentations, governments and experts must explain the limitations of prediction technology. In the GEJE, the maps provided residents with a false sense of safety. Only 20 percent of residents utilized hazard maps for their evacuation in the GEJE (KN 5-1).

Another way of raising awareness of risk is through evacuation drills carried out under as many different scenarios as possible, for example, at night or in rainy weather (KN 2-6). Education at school is also effective to prepare for disasters (KN 2-3).

Although risks from tsunamis are now well understood in the wake of the March 11 event, communities must also become aware of the risks from other possible disasters, such as landslides or cyclones. A Web portal maintained by the Ministry of Land, Infrastructure,
Transport, and Tourism provides access to all hazard maps created throughout the country. See KN 5-2 for details.

INFORMAL TOOL: LOCAL KNOWLEDGE ALONG THE SANRIKU COAST

The Tohoku region has two contrasting topographic characteristics: the Sendai plain, south of Sendai City, which is relatively flat and offers little access to higher ground close to the coast. The other is the Sanriku-rias coast north of Sendai, where the mountains are near the coast. These topographical characteristics influence the kinds of informal evacuation strategies used in the respective areas.
**FIGURE 4: Reasons given by people in Toni Village for participating in the hazard mapping exercise before the GEJE**

- I suffered from disaster in the past: 42
- I felt danger in the past: 35
- I want information about potential disasters: 59
- I want to go along with my neighbors: 29
- I am a jichikai administrator: 9
- I am a firefighter: 7
- I am interested: 40
- Other: 2

*N=231*

*Tendenko* is a term used in the Sanriku coastal area, referring to self-evacuation without stopping to look for family members, neighbors, or relatives. The assumption is that everyone will be self-evacuating, and therefore there is no need to be concerned about others. Depending on the location of an earthquake’s epicenter, the lead time between the main shock and the arrival of the tsunami can be short. In these cases it is imperative that people self-evacuate without delay. This is practical in the coastal area of Sanriku because of the proximity of higher ground (figure 5).

But the *tendenko* concept does not apply in the Sendai plain because there is no higher ground nearby (figure 6). There, public buildings such as schools or community centers are used as evacuation centers.

**RISK COMMUNICATION FOLLOWING THE ACCIDENT AT THE FUKUSHIMA DAIICHI NUCLEAR POWER STATION**

The accident at the Fukushima Daiichi nuclear power station highlighted the issue of risk communication in nuclear emergencies. The Investigation Committee on the Accident at the Fukushima Nuclear Power Stations (2011) reported that “Communication from the government had been far from ideal. The government delayed providing urgent information, withheld press releases, and was unclear in its explanations. Neither those directly affected by the accident at the Fukushima station nor the public at large believed that the government was providing truthful and accurate information in a timely manner. Examples include the government’s information about the status of the reactor cores—core melt-downs in particular—and the critical condition of unit 3, as well as the unclear statement, repeated several times, that the radiation ‘will not immediately affect human bodies.’”
Nuclear and Industrial Safety Agency (2012) reported that “Seventy-four percent of people at the affected areas were dissatisfied with the information provided because:

- The background and the reasoning behind the reports and recommendations coming from the official sources were not well explained and therefore could not be trusted.
- The briefings did not include enough detail.”

Also, the government committee pointed out that “water contaminated by radiation was discharged into the ocean without notifying neighboring countries. Although this did not violate any relevant international conventions, it may have led the international community to question Japan’s competence in responding to nuclear disasters.”
LESSONS

EARTHQUAKE AND TSUNAMI RISK COMMUNICATION

Risk communication is meant to help people save their own lives. For communication to be effective, people must be able to trust the information and its source, and it takes a long time to build that trust.

There are formal and informal tools for communicating risk. Hazard maps and early warnings systems are the formal tools that Japan has used, both of which are being revised in light of the GEJE, since both underestimated the actual risk. Hazard risk information should be continuously updated.

Informal communication tools include local knowledge such as tendneko practiced on the Sanriku coast, where self-evacuation without waiting for family members and others is encouraged as soon as a large ground shaking is felt. These types of approaches and local knowledge based on experiences with large tsunamis should be preserved and passed from generation to generation.

Participatory DRM planning by the local community is an effective way of communicating risk. Different forms of communication may have to be used for different age groups. The local social structure can be leveraged to facilitate emergency planning, for example, by enlisting local leaders in their various roles and functions.

Regular drills and education also have an important role in shaping the perception of risk in local communities.

Complacency is a constant problem. Even people who have already experienced disasters need to be reminded of the importance of being prepared. People can also become overly reliant on early warning systems.

NUCLEAR ACCIDENT

Japan’s Nuclear and Industrial Safety Agency, a government regulatory body, has proposed the following actions to improve risk communication in the event of nuclear accidents:

**Develop technical capacity.** The technical capacity of staff to analyze information on accidents and to implement countermeasures should be enhanced through specialist training programs.

**Develop communication capacity.** Communication officers should be trained in disaster risk communications. Preparing manuals, communication materials, and answers to frequently asked questions is also necessary. Communication channels should be established with the mass media, the public, embassies, and local agencies.

**Develop coordination capacity.** Mechanisms for information sharing should be established among relevant agencies such as the Office of the Prime Minister and the Ministry of Foreign Affairs. Communication equipment and manuals are also necessary.
RECOMMENDATIONS FOR DEVELOPING COUNTRIES

Establish trust between information senders (for example, the government) and receivers (local communities). Trust is a big part of effective risk communication. If the information source cannot be trusted, real communication is impossible—and it takes a long time to establish trust. Complacency is also an issue: Overreliance on early warnings, hazard maps, and incoming information should be discouraged.

Use a variety of tools to communicate risk. Risk communication tools range from sophisticated communication systems to participatory emergency planning, including community hazard mapping, disaster evacuation drills, neighborhood watches, instruction in schools, and the passing of experience from generation to generation based on previous events.

The way in which risk is communicated in the early warning system is also important. Although sophisticated early warning systems and technologies are important during a disaster, the public should understand limitations of prediction technology.

Leverage the interest that local leaders may have in community preparedness and be aware of social structures, which vary from country to country and place to place. Work with local change agents to provide training and to develop an appropriate risk communication strategy.

Take a multihazard approach. The difference in Japan’s preparedness for the earthquake and tsunami versus its preparedness for the nuclear accident following the GEJE demonstrates the importance of considering all hazards, not just those that are most likely to happen. A good communication strategy is one piece of an overall response plan, which was lacking for the nuclear accident at Fukushima Daiichi.

Update and monitor. Risks are dynamic and change over time depending on population increases or decreases, the development of new industrial facilities and commercial properties, the availability of new hazard information, and scientific innovations (KN 2-8). Risk information should be updated regularly and reflected in risk communication strategies.

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