Information Technology and Natural Disasters: Japan Case Study

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ABSTRACT

While natural disasters are generally unavoidable and largely unpredictable, the scientific community can make use of science and technology in order to help the public be as prepared as possible. They can take preventative measures, they can assess and minimize damage and they can record data for future reference. Scientific and technological advancements enable us to deal better with emergency situations, they can help to minimize the risks through early warning, deal with the response in case a disaster occurs and help with plans for recuperation afterwards.
This paper will discuss the role of information technology within the context of natural disasters, with a focus on the Great East Japan Earthquake of March 11th, 2011. It will present various technologies used currently in Japan that can help forecast and offer warnings of natural disasters, that can assess damage and contribute to its minimization and play an important role in disaster response and recovery.

Keywords: natural disasters, disaster management, information technology, warning systems

1. INTRODUCTION

Natural disasters represent the effect of natural hazards, like earthquakes, volcanic eruptions, tsunamis, avalanches, landslides, floods, wildfires, droughts, tropical cyclones etc. According to the United Nations International Strategy for Disaster Reduction, the past two decades have seen an increased occurrence of such disasters [1], with people, communities and even whole countries affected.
According to the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) statistics on the effects of natural disasters [2], between 2000 and 2010, the Asia-Pacific area has been the most affected, in terms of people who have lost their lives, people who have been affected in general, as well as with regard to economic damages. In our paper, we intend to focus on the specific example of Japan, as one of the Asian countries recently affected by one such natural disaster (the March 11th, 2011 Great East Japan Earthquake).
We intend to emphasize the role of information technology within the context of natural disasters.
Given the extended scope and dimension of the problem, in this paper we will cover only a small part of this vast area. We will present various information technology-based used in Japan, and we will discuss their role in natural disasters in general, as well as before, during and after the March 11th, 2011 earthquake.

The remainder of our paper is organized as follows. Section 2 will deal with general considerations regarding disaster management and will introduce data about Japan's March 11, 2011 earthquake. Section 3 will present the Japanese Earthquake Early Warning System, while Section 4 will describe the Tsunami Warning System. In section 5 we will introduce other information technology-based systems used before, during and after a natural disaster; concluding remarks will be included in section 6.

2. NATURAL DISASTERS AND THEIR MANAGEMENT; JAPAN CASE STUDY

Disaster management

The main purpose of disaster management in general (natural disasters management included) is to reduce and, if possible, avoid the damages due to the disaster, as well as aid in a rapid and effective recovery. The disaster management cycle considers four important phases: mitigation, preparedness, response and recovery (Fig. 1).

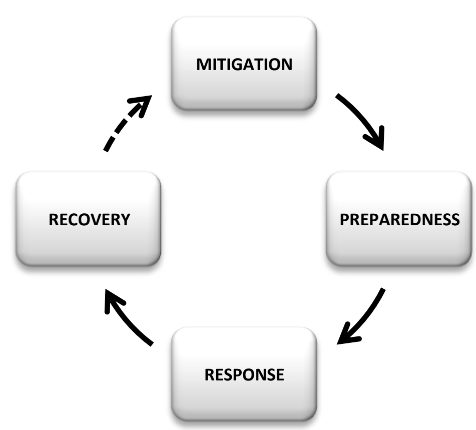


Fig. 1 Phases in disaster management

Mitigation refers to the efforts of minimizing the effects of a disaster, focusing on long-term measures. It is considered the most cost-efficient method for reducing these effects. Preparedness deals with plans and procedures for how to respond if a disaster occurs. Response involves putting the preparedness procedures into action when a disaster has occurred. Finally, recovery aims the reverting to the state previous to the disaster. These four phases often overlap and the length of each phase depends largely on the severity of the occurring disaster.

Information technology can offer various means of support during all these phases. Throughout the world, various systems exist, capable of forecasting and warning, remote sensing, global positioning, geographic information, communications systems and so on.

According to UNESCAP, the Asia Pacific region suffers disproportionately from natural disasters, in principal floods, earthquakes, tsunamis and cyclones. Between 2000 and 2010, more than 70.000 people were killed in these areas and more than 200 million were affected. These figures represent 90% and 65% of the world totals, respectively [2].

In Fig. 2 we can see the effects of natural disasters between 2000 and 2010, by comparing Asia-Pacific, Latin America/Caribbean, Europe, Africa and North America [2].

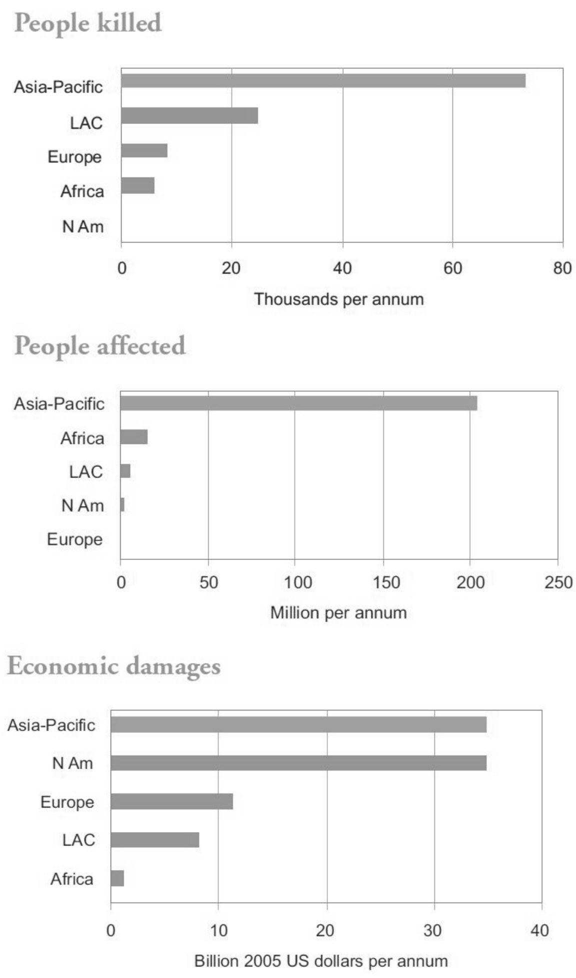


Fig. 2 Effects of natural disasters during the 2000-2010 decade (according to UNESCAP)

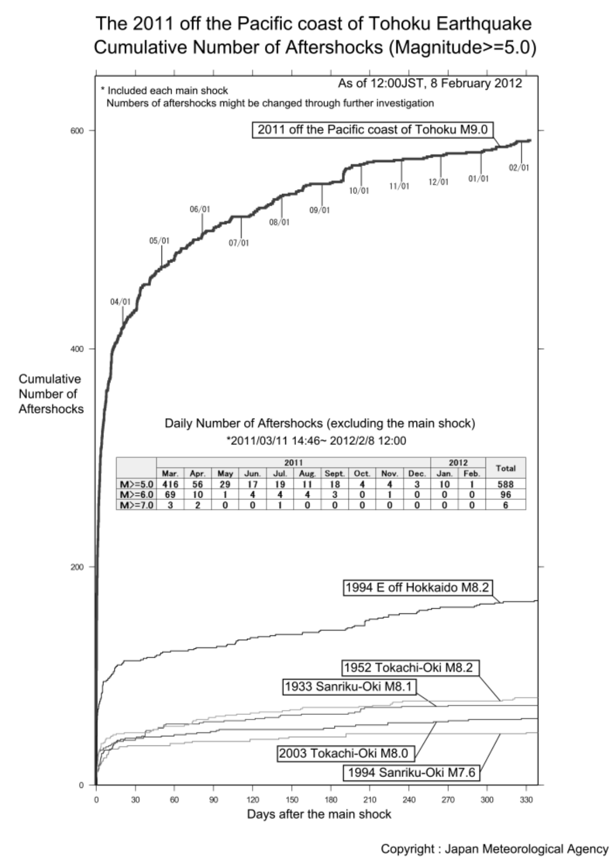
As one of the Asian countries regularly affected by earthquakes, we will use Japan as an example and describe some of the systems it has put in place for use in the event of a natural disaster.

The 2011 Great East Japan Earthquake

The Great East Japan Earthquake (also called the 2011 off the Pacific coast of Tohoku Earthquake [3], or simply the Tohoku Earthquake) occurred on March 11th, 2011, at 14:46. With a duration of approximately 6 minutes, its epicentre was located about 130km ESE off Oshika Peninsula of Tohoku, on the Pacific coast. It was a megathrust earthquake of magnitude 9.0, the strongest ever to hit Japan and one of the worst five earthquakes ever recorded. The subsequent tsunami reached 40.0 m in Ofunato, Iwate prefecture [4].

According to data released by the National Police Agency, as of February 17th, 2012, more than 19.000 thousand people were killed or are still missing, more than 6.000 people were injured and about 125.000 buildings were destroyed [5]. The earthquake, followed by tsunami, led to flooding, landslides, fires, building and infrastructure damage, as well as nuclear incidents. The Japanese Cabinet Office estimated in March 2011 that the cost of damaged houses, factories and infrastructure in the 7 most affected prefectures can reach a value between 19 and 25 trillion yen [6].

According to the Japan Meteorological Agency, in comparison with prior earthquakes, the aftershock activity of the Great East Japan Earthquake has been very high. A table showing the cumulative number of aftershocks, as of February 8th, 2012, can be seen in Fig. 3 [3].



	2011										2012		Total
	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	
M>=5.0	416	56	29	17	19	11	18	4	4	3	10	1	588
M>=6.0	69	10	1	4	4	4	3	0	1	0	0	0	96
M>=7.0	3	2	0	0	1	0	0	0	0	0	0	0	6

Fig. 3 Aftershocks after the March 11th, 2011 earthquake (source: Japan Meteorological Agency)

3. EARTHQUAKE EARLY WARNING SYSTEM

One of the most important systems used in Japan in case of an earthquake is the "Earthquake Early Warning System" (EEW), provided by the Japan Meteorological Agency (JMA) [7].
This system (started on October 1st, 2007) offers advance announcement of the estimated seismic intensities and expected arrival time of the principal motion of an earthquake. These estimations are based on a prompt analysis of the focus and magnitude of the earthquake, using waveform data observed by seismographs near the epicentre [7]. An overview of this system can be seen in Fig. 4.

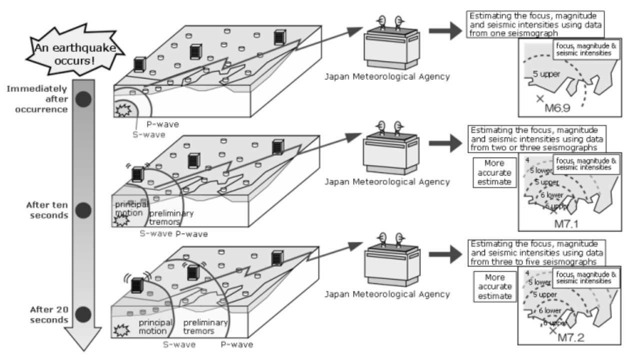


Fig. 4 Overview of Earthquake Early Warning (source: JMA)

Earthquakes can be recorded by seismographs situated at great distances, because of the travelling of seismic waves. There are 3 main types of seismic waves, which travel with different velocities: longitudinal P-waves, transversal S-waves and surface waves. P-waves represent the initial set of waves produces. They can travel through gases, elastic solids and liquids. They can be twice as fast as the S-waves (the principal motion in an earthquake).
The EEW system automatically calculates the focus and magnitude of the earthquake and estimates the seismic intensity for each location by detecting the P-wave (the preliminary tremor) near its focus. If a P-wave is detected by any two or more of the seismographs, an Earthquake Early Warning is given in a matter of seconds (i.e. a few seconds to a few tens of seconds) before the arrival of strong tremors (i.e. the S-wave) (Fig. 5).

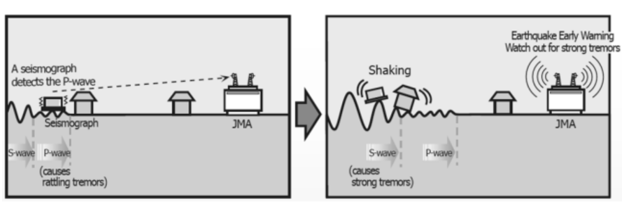


Fig. 5 Earthquake Early Warning principle (source: JMA)

As of April 2010, in total, there are 4,235 seismographs installed throughout Japan. 626 belong to the JMA, 2852 belong to local organizations throughout the country and 757 belong to the National Research Institute for Earth Science and Disaster Prevention.
The earthquake early warnings are deployed on television, radio, as well as on mobile phones. Japan's three major mobile phone carriers have provided the phones with this service since 2007. All 3G cellular phones after 2007 have mandatorily received this service (not all overseas manufacturers are supported, though). Following the 2011 devastating earthquake, Apple's iOS 5 iPhone platform supports early warning notification.
A specific chime sound alerts about the impending earthquake; the alarm sound was developed by the NHK, Japan's national public broadcasting organization ([8]).
Certain radio receivers are capable of detecting the specific chime tone; they turn on automatically if in sleep mode, then play the chime tone and the early warning message.
It should also be noted that RC Solution Co. [9] has developed a free smart phone application called “Yurekuru”, which receives its information from the EEW System. It has interfaces in both English and Japanese. The user can customize the application to give warnings when earthquakes of a certain intensity or higher are expected. Information about past earthquakes is also displayed.
The EEW system can sometimes issue warnings as early as 30 seconds in advance. However, in areas that are close to the epicentre of the earthquake, strong tremors may arrive at the same time as the warning. In the case of the March 11th, 2011 earthquake, the warning was issued 8.6 seconds after the detection of the first P-wave at the nearest seismic station.
The Earthquake Early Warning is aimed at mitigating earthquake-related damage by allowing countermeasures such as promptly slowing down trains, controlling elevators to avoid danger and enabling people to quickly protect themselves in various environments such as factories, offices, houses and near cliffs [7]. Some examples of response to the Earthquake Early Warning are given in Fig. 6.

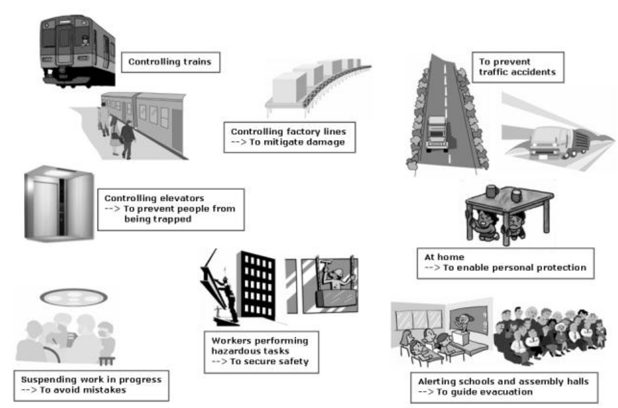


Fig. 6 Response to Earthquake Early Warning (source: JMA)

EEW for railways
An early earthquake warning system for railway systems has been developed by The Railway Technical Research Institute. In 1992, UrEDASU (Urgent Earthquake Detection and Alarm System) was developed as the first practical EEW in the world [10]. It was replaced by Compact UrEDASU in 2007. Seismographs exclusively for railways have been installed along the railway tracks at intervals of approximately 20km.

These seismographs are termed "railway-track seismographs". In this system, trains are stopped when a single seismograph detects an earthquake. Moreover, along the coast, at intervals of approximately 100km, "coastline seismographs" have been installed as well [10]. These seismographs are located in coastal areas with a high degree of seismicity so they can detect earthquakes at the earliest possible moment.

The first time the usefulness of this system was proved was during the May 26, 2003 Miyagiken-Oki earthquake [11]. It had an estimated magnitude of 7.0; 23 columns of the rigid frame viaducts were severely cracked. As expected, coastline "Compact UrEDAS " along the Shinkansen issued the early P-wave alarm before the destructive earthquake motion and all the trains were safely stopped [11].

Since 2000, a new algorithm for the EEW has been developed by RTRI, in cooperation with JMA. An update of the whole system for the whole bullet train ("shinkansen") network has been completed in 2007. An overview of the system can be seen in Fig. 7.

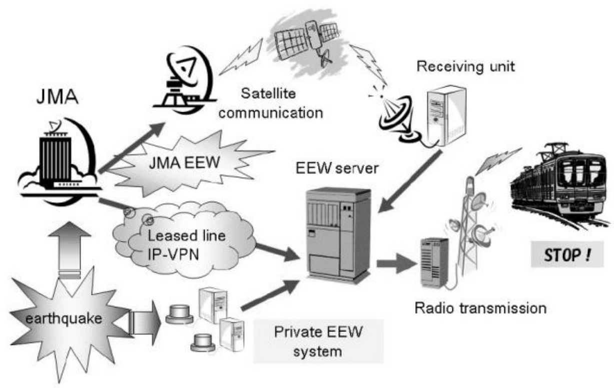


Fig. 7 EEW system for railways
(source: Railway Technical Research Institute)

One of the improvements made to the original system is a complete two-way communication of warning information about the P-wave and S-wave between seismographs ([10]). This means that warning information that will enable the automatic breaking system is transmitted to regions not yet reached by the earthquake's P-wave and S-wave. Fig. 8 shows the practical use of the EEW for shinkansens.

Success story: Tohoku shinkansens on March 11th, 2011

On March 11th, 2011, a coastline seismograph in Miyagi Prefecture (50 km from the tracks) detected ground acceleration of 120 gals, which is the benchmark for stopping train operations (1 gal: 1 cm/s²). All 27 scheduled bullet trains running in the north-eastern part of Japan (i.e. Tohoku shinkansens) reduced their speed at the first sign of tremors, before the main impact of the earthquake arrived. They were travelling with speeds up to 300 km/h.

The railway operator found that the first tremor occurred 9 to 12 seconds after 2 trains near Sendai applied their brakes. The strongest tremor came one minute and 10 seconds later. Consequently, all trains were stopped safely, despite the magnitude of the earthquake.

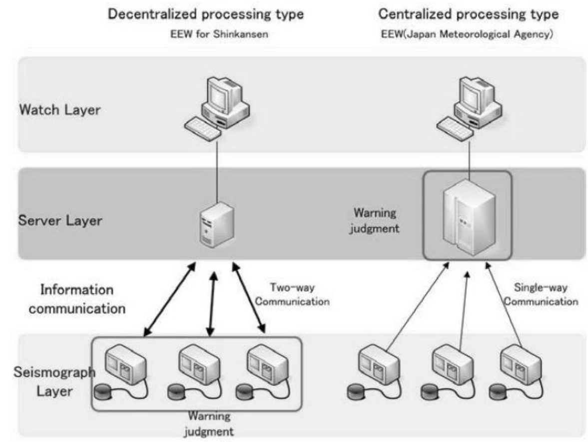


Fig. 8 Practical use of the EEW for shinkansen
(source: Railway Technical Research Institute)

4. TSUNAMI WARNING SYSTEM

Another important warning system is the Tsunami Warning System, used to detect tsunamis in advance and issue warnings to prevent loss of life and damage. This system consists of two equally important components: a network of sensors to detect tsunamis and a communications infrastructure to issue timely alarms to permit evacuation. Warning is issued using radio, television, sirens etc. Tsunami warnings take longer than earthquake warnings, because more complex calculations are involved.

In Japan, the tsunami warnings are issued by the Japan Meteorological Agency. When an earthquake occurs, JMA estimates the possibility of tsunami generation from seismic observation data [12]. If a damaging tsunami is expected in the coastal regions, JMA issues a Tsunami Warning/Advisory for each region. If tsunamis are generated by seismic events far from Japan, JMA communicates and coordinates with the Pacific Tsunami Warning Center (PTWC) in Hawaii and issues warnings for long-propagating tsunamis [12].

A view of the time sequence for issuance of information on tsunamis and earthquakes by JMA can be seen in Fig. 9.

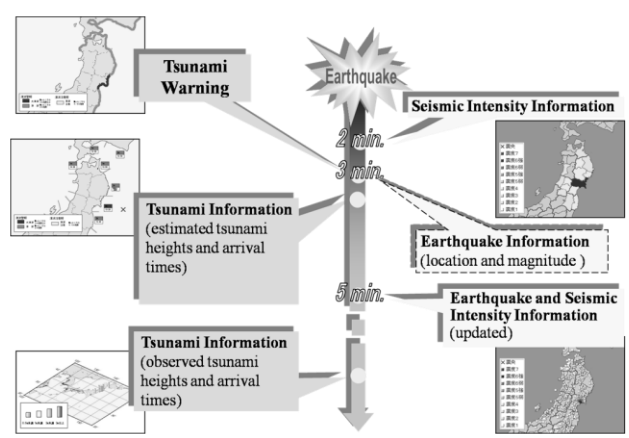


Fig. 9 Issuing information on tsunamis and earthquakes
(source: JMA)

On March 11th, 2011, JMA issued a “major tsunami” warning, only 3 minutes after the earthquake. While the earthquake started at 14:46, a 12m high wave struck Sendai Airport at 15:55. The tsunami reached levels of 40.0 m in Ofunato, Iwate prefecture [4].

The tsunami damage was much more destructive than the earthquake itself, with an unexpectedly large size of the water surge. The wave was so strong that it broke icebergs off the Sulzberger Ice Shelf in Antarctica, 13.000 km away. Chile, at 17.000km distance, experienced a 2m tsunami 22 hours later.

It is important to emphasize that no system can protect against a very sudden tsunami, where the coast is very close to the epicenter. One example is the Hokkaido, July 12, 1993 earthquake, followed by a tsunami, which claimed 230 lives. The wave reached Okushiri between 2 and 7 minutes after the earthquake, insufficient time to evacuate, even though a tsunami warning was given by the JMA 5 minutes after the earthquake.

5. OTHER SYSTEMS

There is a wide range of technologies that can be used before, during and after a natural disaster. In this section we would like to mention the role of several other information technology systems in this context.

Geographic Information Systems (GIS) are systems that integrate, store, edit, analyze, share and display geographic information. They can help emergency planners to easily calculate emergency response times and the movement of response resources (for logistics) in case of a natural disaster.

Global Positioning System is a satellite based navigation system that provides location and time information, anywhere on or near the Earth, regardless of the weather conditions. It is maintained by the United States government and can be accessed freely by anyone with a GPS receiver. It can be very useful in search and rescue operations; this is particularly true in recent years when many mobile phones are equipped with GPS. Disaster relief/emergency services depend largely upon GPS for location and timing capabilities.

Communications systems can be effectively used in all phases of disaster management. They include the internet and e-mail, mobile phones, radio and television, HAM radio etc. Immediately after the March 11th, 2011 earthquake in Japan, mobile and land lines were overloaded or simply stopped working. There were areas without any electricity (and/or water); nevertheless, the internet connections were functional. People were using their mobile phones or other mobile devices to connect to the internet and this allowed them to communicate with their relatives. By updating their information on the Facebook social network, this information could reach concerned friends or relatives, both in Japan and abroad. The internet, along with social networks, proved their importance as a means of communication post-disaster.

Last, but not least, information technology can support medical response during/after disasters. To give only two examples, wireless local area networks are crucial in hospitals with disaster medical response capabilities, while electronic health records can be life-saving in case classical, paper-based records are destroyed and medical personnel need immediate information regarding the patients’ records.

6. CONCLUSIONS

Our paper highlighted the role of information technology within the context of natural disasters. We chose Japan as our case study; we introduced various warning systems used in Japan and described their role in the specific example of the 2011 Great East Japan Earthquake.

We believe that science and technology in general, and information technology in particular, can be a valuable tool in emergency situations, by assisting in all major phases of disaster management. In the future, we strongly believe that the role of information technology before, during and after natural disasters will continuously increase.

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