

EFFORTS OF EARTHQUAKE DISASTER MITIGATION USING EARTHQUAKE EARLY WARNING IN JAPAN

Y. Fujinawa¹, Y. Rokugo¹, Y. Noda¹, Y. Mizui¹, M. Kobayashi¹, and E. Mizutani¹

¹*Real-time Earthquake Information Consortium (REIC), Japan*

Email: fujinawa@real-time.jp, rokugo@real-time.jp, noda@real-time.jp, mizui@real-time.jp, kobayashi@real-time.jp, mizutani@real-time.jp

ABSTRACT

In Japan MEXT, NIED, JMA and NGOs (JWA and REIC) cooperated to develop an earthquake early warning (EEW) system of the general use, for mitigating earthquake disasters during 2003-2007. Data are from the network of JMA and the network (Hi-net) of NIED. Those data are collected in real-time with small transmission delay and analyzed by the system developed by NIED and JMA. Present information officially issued from JMA has seismic focal parameters and estimated strength of seismic motions at chosen place of sites. REIC and JWA have taken charge of R/D of application system and social response, respectively. Once earthquakes occur, the focal parameters are calculated as quickly as enough number of observation sites sense seismic waves. EEW are transmitted generally in several seconds after detecting seismic signal at the nearest sites. The disseminated parameters can be used by any people and organizations. REIC and its members developed special application systems to help various countermeasures including automated and/or semi-automated responses. These systems estimate specific information for particular users at particular site for triggering the systems. Now we have developed 14 kinds of application systems. From October 1, 2007 EEW has been in the practical utilization: the general use by broadcasting companies (TV, radio, and mobile phone) and contracted use by private companies and REIC using special application instruments. The systems have been gradually adopted for earthquake disaster mitigation.

KEYWORDS:

Earthquake, Disaster Mitigation, Early Warning, Real-time, Counter-measure Equipment,

1. INTRODUCTION

Previous real-time earthquake information for public use in the 1990s has focused on time ranging from several tens of minutes up to 24 hours after earthquake hits. It aims to provide information for emergency management products which help local governments and enterprises to carry out disaster prevention activities. Those available systems work primarily for the loss estimation using data obtained by dense strong-motion seismometer network of local government after large earthquakes occur.

This paper presents efforts to develop EEW (e.g., Cooper, 1868, Hakuno and Takahashi, 1972; Nakamura, 1988; Kanamori, 2005) in Japan. The National Research Institute for Earth Science and Disaster Prevention (NIED) and the Japan Meteorological Agency (JMA) established nationwide extensive seismic networks after the 1995 Kobe earthquake. In these networks the high-sensitivity seismograph network (Hi-net) of NIED and the Tsunami and Earthquake Observation and Monitoring of JMA transmit data in real-time. The two organizations independently developed EEW systems. The former uses network data for a practical application of the resource (Fujinawa *et al*, 2003; Horiuchi *et al*, 2005). And the latter uses data for development of the "Nowcast" Information (Tsukada *et al*, 2004; Kamigaichi, 2004). Although there may typically be a mere 1 to 10 seconds before the earthquake ground motion, this brief lead time can be useful not only for safety of lives, but also for protection of property and information in numerous fields of application.

After the efforts by two organizations, a new R/D was started aiming at practical applications during 2003-2007. The project was conducted through the collaboration of industries, academic community, governmental organizations of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), NIED and JMA, and NGOs (REIC, Japan Weather Association (JWA)) (MEXT and NIED, 2003; 2004; 2005; 2006). In Japan we

assumed the users to be the whole people and organization. Here, we will present outline of this project, and describe how the EEW technology was developed into effective utilization. Especially we focus on the research and development of the application system for various fields to assist each disaster mitigation efforts.

2. METHOD

In the general use, it is necessary to take a different approach in R/D: a scheme of cooperation among central and local governments, and NGOs as shown in Figure 1. The data is essentially from the seismic network by government or national institute. But user's seismometers could be subsidiary used in the near future. Data collection and analyses for EEW are conducted by the governmental organization as JMA in Japan. Another important difference is in the substantial participation of private companies and individuals in the "business". Application systems should be developed, sold and maintained in the market. EEW information is delivered to any of contracted users. Instruments, service and data should also be developed in the market. There are many units in the society involved in EEW business. REIC was established as a liaison organization to promote the project in 2003. .

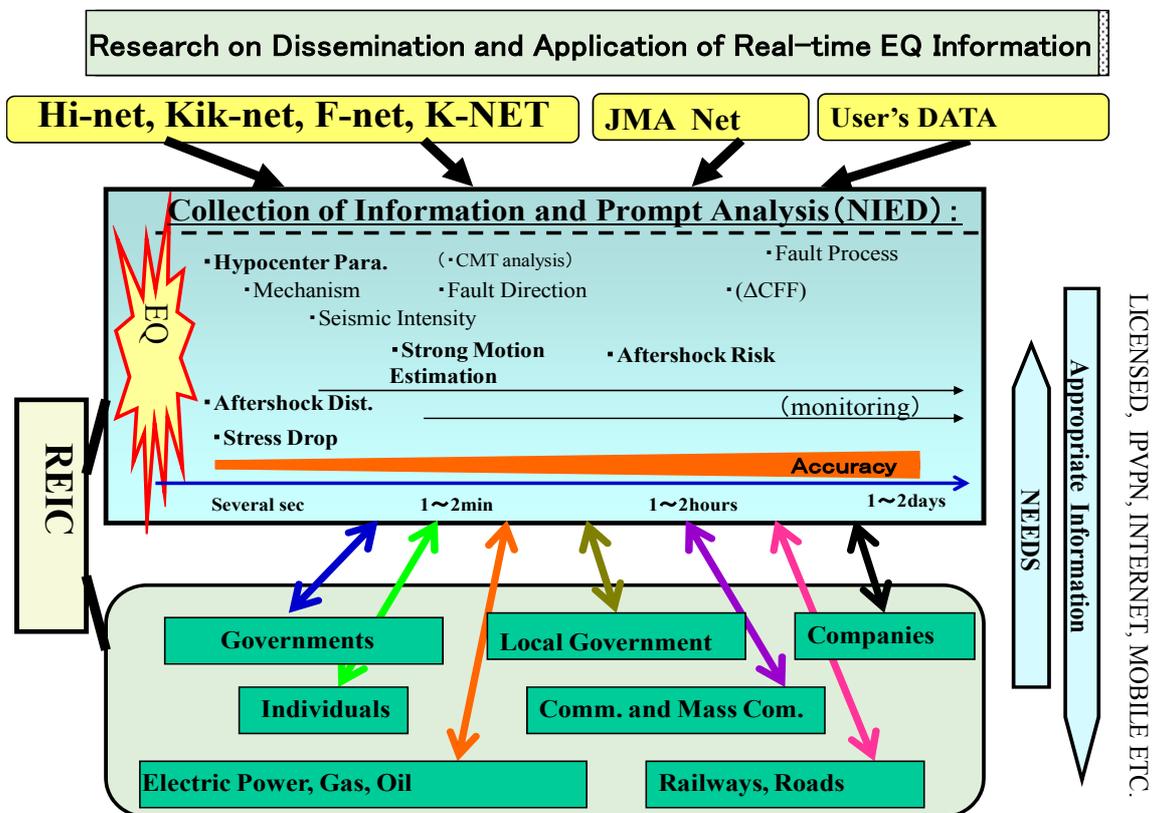


Figure 1 Liaison scheme of cooperation to develop and maintain the EEW

In the first stage R/D conducted by NIED in 2001-2002, the system was introduced in 2002 for testing and trial in Fujisawa City of Kanagawa Prefecture (Fujinawa *et al.*, 2003). After achieving several positive results by NIED and JMA, MEXT determined to make a second stage R/D for practical utilization.

2.1 Seismic Data

At present, there are several seismic observation networks set up by JMA and three extensive ones by NIED under coordination by the Headquarters for Earthquake Research Promotion (HERP). The JMA operates observation networks that aim to provide information to help citizens and disaster prevention organizations in charge of tsunami and earthquake disaster prevention. The tsunami and earthquake detection network stations (of which are 200) are used to install the special seismometer. The seismometer can get hypocentral parameters on the method of UrEDAS (Nakamura, 1988). Of the basic observation networks set up by HERP, only Hi-Net

consisting of some 800 seismometers transmits data in real-time, enabling use for EEW. Hi-net is an extensive seismic network originally for the earthquake prediction research. The EEW project was started to promote a practical utilization of resources of NIED as well as original utilization for basic research of disaster mitigation.

2.2 EEW Systems

2.2.1 NIED Method

NIED's new seismic source determination system allows focal parameters to be estimated when P-waves are detected at the first two observation stations. The parameters of the seismic source are determined to a reasonably high level of accuracy (Horiuchi *et al.*, 2005). And the first solution is mostly obtained in just a few seconds after detecting seismic waves at the first site, several ten times faster than ordinal manual method. The parameters are revised successively when seismic signals arrive at larger number of sites in time. Figure 2 is a real example of seismic wave forecast at a moderate earthquake with M=5.3 occurred in the east of Tottori Prefecture on Sep. 16, 2002. EEW was transmitted almost immediately after sensing seismic waves at the nearest sites of the network to hypocenter. NIED also developed detailed data base of surface ground amplification to estimate seismic strength at the evaluation point with 250m mesh throughout Japan (Figure 4).

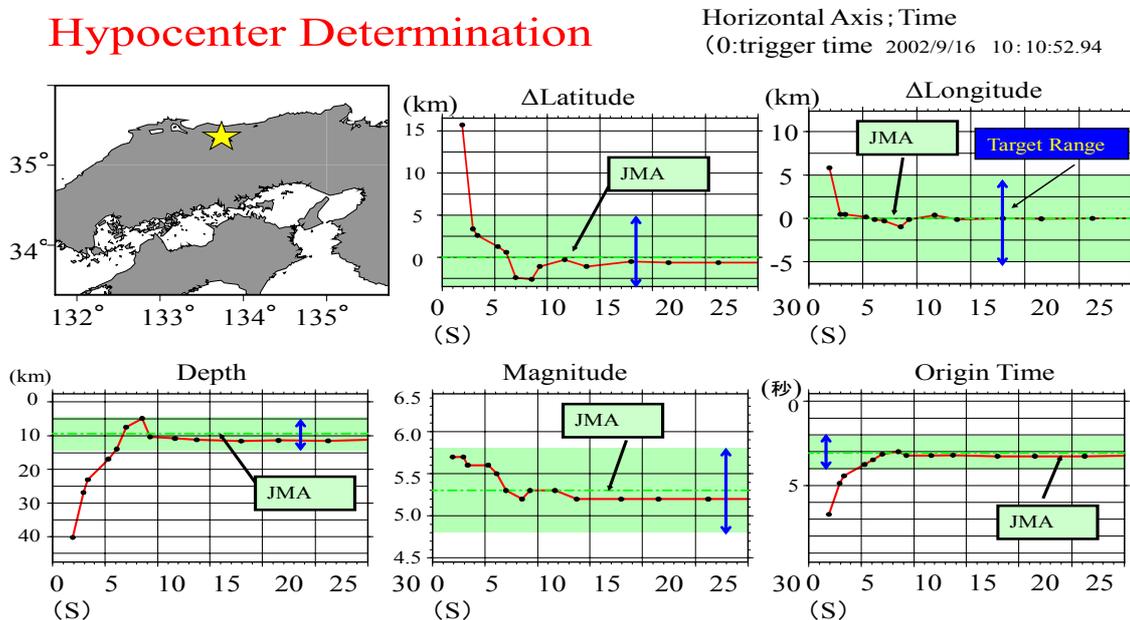


Figure 2. An example of seismic source determination analyzed by the real-time systems for the Tottori Prefecture Earthquake (September 16, 2002). In the Figure dot denote EEW result, and “JMA” means the off-line result.

Figure 3 shows an example determined by this system at the moderate earthquake off the Miyagi Prefecture based on the selection rule of successive EEW. At Sendai the lead time was estimated as 15s and seismic intensity was 4 in agreement with observed values.

2.2.2 JMA Method

JMA uses a method called “UrEDAS” to estimate the seismic source based on the envelope shape of the P-wave at one observation station. They also use the network data to estimate the location of the seismic source by the territory or grid search method (Tsukada *et al.*, 2004; Kamigaichi, 2004; Kamigaichi, this session).

Forecast for the 2005 Aug. 16 Miyagiken–Oki EQ.)

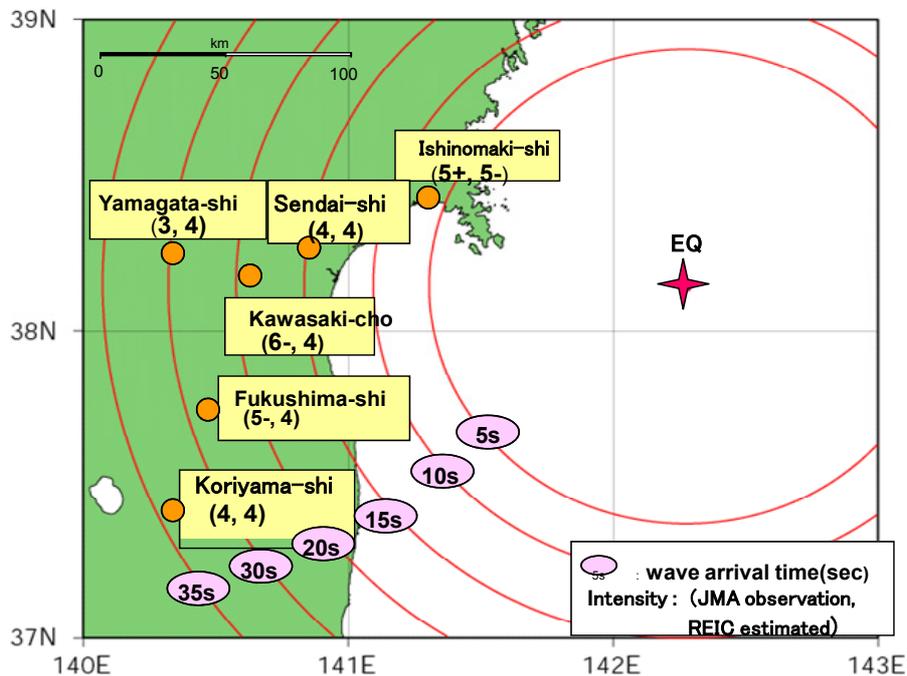


Figure 3 An example of the forecast for seismic strength and lead time by EEW. Observed strength is also shown for comparison.

2.2.3 Combined System

A combination system based on these methods was developed by JMA and NIED. The system uses the better results obtained by two different systems of parallel computing. In principle the focal position is taken from the NIED system, and the magnitude is from the JMA system. “Accuracy grade” included in the EEW indicates how the parameters are determined. Users choose the most appropriate information by balancing lead time and accuracy. Seismic source estimates using this method are continued until the seismic wave arrives at five observation stations, when seismic source estimation for EEW is completed (Kamigaichi, 2004). The total unification of the two methods is now under development by JMA and NIED.

2.3 EEW Distribution System

On March 25, 2004, the JMA, which is in charge of administrative responsibility for EEW, started verification tests. Since June 2005, JMA has been conducting trial distribution of the integrated information based on the combined system. There were about 150 organizations using the EEW to develop systems for application of their own interests as users or venders in 2005.

From 2006, JMA advanced to the next stage of preliminary distribution of EEW to limited users under the coordination of the EEW committee of government. The total utilization started on October 1, 2007 including broadcasting to general public by TV, radio and mobile phone, and contracted uses as services by private companies. As to the detail, readers may refer to manuscript by Kamigaichi (2008, this session)

2.4 Development of Disaster Prevention Systems

REIC, a liaison NGO, which is composed of private companies, specialists, and local governments, has been taking over the part of the project involving experimental study and research into making effective use of EEW (Figure 4). The aim is to develop earthquake disaster prevention systems tailored to the needs of different users. Their studies and researches are field-specific and focus on 14 themes that span typical 11 field of application (Fujinawa and Noda, 2007; MEXT and NIED, 2003, 2004, 2005, 2006).

2.4.1 Development of disaster-prevention system.

Development efforts are divided up into two fields: earthquake disaster prevention, and data transmission. Research in the former field involves looking into the following 10 themes. (1) Fire department systems, (2) Medical systems, (3) Home electronics system, (4) School system, (5) Plant system, (6) LPG systems, (7) Outdoor activity systems, (8) Building maintenance systems, (9) Elevator systems, and (10) Dam systems. Typical application systems are described briefly in the following.

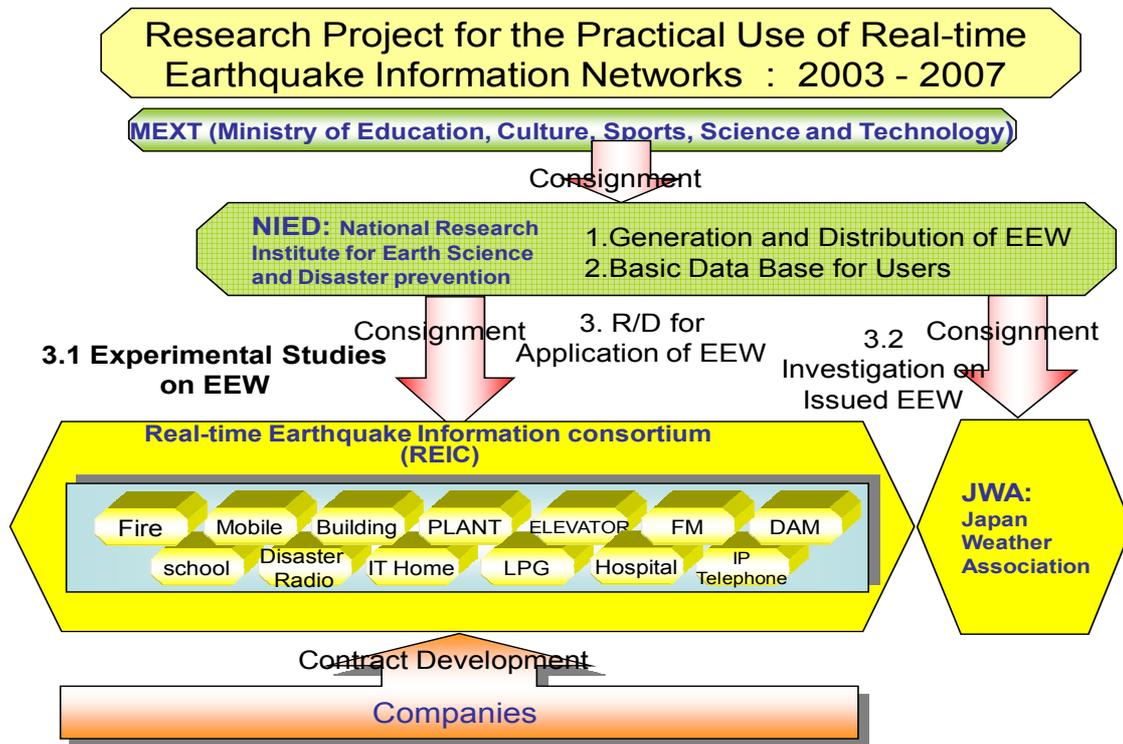


Figure 4 Scheme of the “Research Project for the Practical Use of Earthquake Early Warning System” in Japan during 2003-2007.

a. Medical systems,

The medical systems aim to ensure that EEW is issued as quickly as possible, so that the safety of patients, doctors, nurses and other staffs can be secured, unexpected situations during surgery are prevented, medical testing equipment in operation is stopped. Elevators, doors, and emergency broadcasting should be controlled automatically to start scheduled operation. And emergency system is established to support mass relief and rescue efforts. The system supports to ensure that the safety of staffs can be confirmed and mobilized before communications lines become congested.

b. Home electronics system

The design of information appliance has involved investigating on how earthquake damage can be minimized. We surveyed data on damages incurred during the 1995 Kobe Earthquake. It is shown that the moment an earthquake hits, people became panicked, and although normally they know that they need to extinguish all flames and open doorways and exits, at that moment all they can do is nothing but get down on the ground.

This finding leads to the idea that it is important and effective to automate measures for cutting off heat sources and securing evacuation routes (Figure 5). The similar system has been developed and installed in many of new buildings. However the instruments including the control of electric power and gas are not yet widely used because of lack of understanding in the energy supplier community and organizations concerned.

In addition to new houses and buildings, there is another several million of old ones waiting to be installed those equipments. In order to respond to those needs, we try to develop a new protocol of home wireless

communication on the Zigbee System.

c. School Systems

For school systems, the first aim is to save lives of pupils and teachers, the second is to promote education for disaster mitigation. Through training and drills in schools, efforts are being made to mitigate the damage incurred at earthquakes, and to educate about one million citizens a year to promote the use of emergency earthquake information. Please refer to articles of Prof. M. Motosaka (2008, this session).

d. Plant system

For plant systems, the most necessary item is higher accuracy and confidence in the application for very important and expensive facilities.

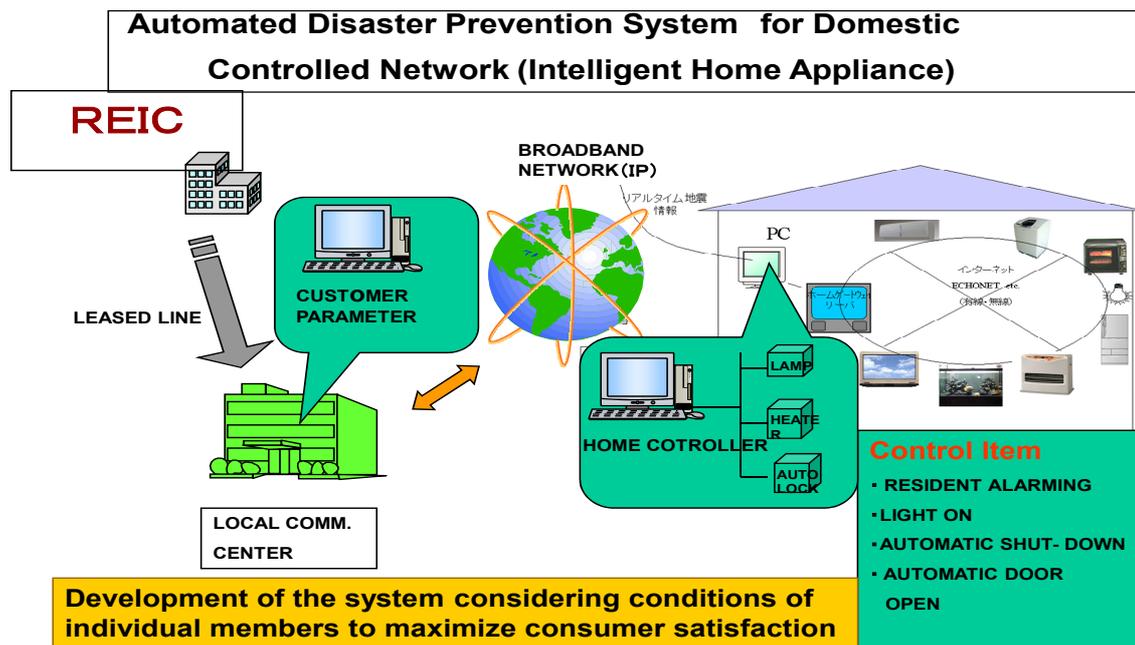


Figure 5: Overview of automated disaster prevention system for information control appliance for household.

The evaluation of EEW in the experimental utilization by JMA indicates that the accuracy of the seismic strength and arrival time estimation are in the range of ± 1 JMA scale, and ± 5 sec, respectively. The accuracy is not good enough for the sophisticate utilization as in semiconductor industry and atomic electric plants. In order to apply in these fields we developed a system of synthetic seismic hazard evaluation (Figure 6). The system uses both EEW and on-site seismic data. At the Iwate-Miyagi Earthquake (2008-6-14, M=7.0) the system worked just as it is expected.

2.4.2 Development of data transmission methods

The following four themes are focused on the development of data transmission methods. (1) Disaster prevention wireless systems, (2) IP telephone systems, (3) Public mobile communications systems, and (4) FM broadcasting systems.

In the development, new data transmission systems are not developed, but are focused just on finding ways to transmit EEW basically over existing data transmission systems. For FM broadcasting systems, the aim is to distribute information using existing FM broadcasting systems to a large number of contracted users with minimum transmission delay.

3. RESULTS

Main results are briefly shown as follows. The detail can be seen in MEXT and NIED (2003, 2004, 2005, 2006).

3.1 Introduction of Application Systems

It was recommended by the prime ministry to use EEW as a practical means of earthquake disaster mitigation in central government, local government offices and many public fields. The application system has started to prevail gradually in the whole country now, especially after the major earthquakes during the first half year.

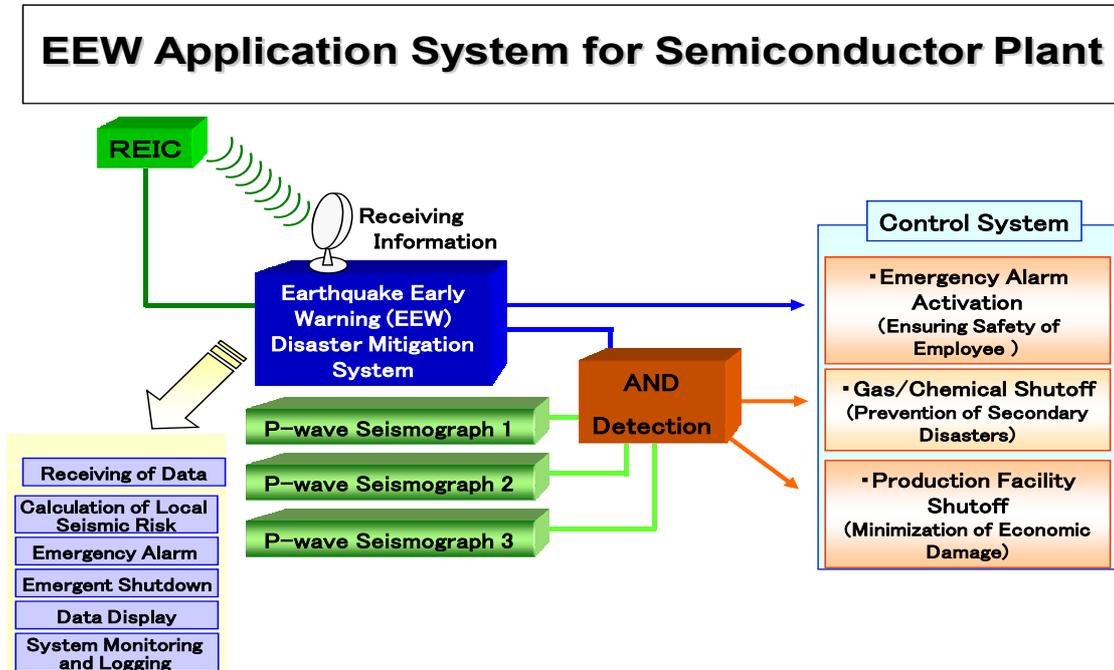


Figure 6 High accurate and confident EEW systems using both EEW and on-site seismometer

- a. Many local governments decided to install the system in each public school.
- b. Many of developing companies of apartments offer EEW equipments.
- c. About 130 CATV centers have started providing EEW service.
- d. Many of private railroad companies use EEW in addition to their own alarm system.
- e. Many of community FM radio centers broadcast EEW.
- f. About 100 local governments have introduced wireless radio wave system to broadcast EEW.
- g. The association of department stores has determined to adopt EEW by using the standard manual.
- i. Many new buildings have elevators equipped with automatic control system using EEW to prevent personnel from being shut up in the box at the occurrence of earthquakes.

3.2 Expected Disaster Mitigation by EEW

We evaluated usefulness of the EEW using scant experimental data to know the effectiveness in the application toward people.

- a. Workers can save their lives even if they get hurt seriously at dangerous event around construction site when alarms are issued some 10 seconds before.
- b. Experimental operation of EEW in a school in Sendai-Shi proved that pupils can be trained to take the appropriate actions in some 5 seconds.
- c. Shaking table test of EEW indicates that people can control themselves without any upset when they know the event is nothing but earthquake even if the lead time is only 1sec.

On the basis of these findings we made an effectiveness table of EEW for personnel. We applied the evaluation to the great Wenchuan Earthquake in Sichuan Province of China in 2008. If they have had EEW system as we have in Japan, and also they have been well educated, some 90% of victims could have been saved.

3.3 Examples of Useful Utilization

- a. About one hundred of school pupils could take emergent counter-measure by using EEW at the Iwate-Miyagi

Nairiku Earthquake (M7.0, June14, 2008).

- b. About 100 large apartments have successfully experienced on EEW alarming with lead time of several to several ten seconds at the recent major earthquake off the coast of Ibaraki Prefecture (M5.1, July 5, 2008).
- c. The internet questionnaires to EEW revealed that about 39% respondents got the EEW alarming through TV or radio at the Iwate-Miyagi Nairiku Earthquake in 2008 in Sendai, Morioka, and Fukushima City. And 14% of them answered “very useful”, 41% “considerably useful”.
- d. The higher confident EEW application system succeeded to control the expensive manufacturing machine of semiconductor in the accuracy of 30gal in the seismic strength and better than 1sec of arrival time of S wave.

4. CONCLUDING REMARKS

- a. We have started the practical application of EEW in whole of Japan. Moreover, EEW have attracted considerable public’s attention. However, the information has its intrinsic limitations as possibility of false alarm and insufficiency of lead time, which makes the complete adoption difficult. The issue to be considered to promote general utilization is how to make EEW more accurate, and more useful within the reasonable cost. The problem can be improved by increasing available seismometers on land and on the ocean bottom, developing effective algorithm and reducing data transmission delay.
- b. The development of application systems for effective use of EEW through automated or semi-automated operations has been progressing steady. But we still need efforts to prepare for huge disasters from great earthquakes. Social arrangement or regulations should be promoted for general adoption of the EEW equipments at home, in the office, and factories. These issues must be resolved through collaboration among relevant organizations including users.
- c. The recent accomplishment on EEW technology can be transferred to any of earthquake-prone countries in the world.

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