APPLICATION OF EARTHQUAKE EARLY WARNING SYSTEMS FOR DISASTER PREVENTION IN SCHOOLS

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ABSTRACT :

Sophisticated technology like the Earthquake Early Warning System (EEWS) based on the nation wide earthquake observation networks in Japan can be applied for earthquake damage mitigation in various fields. As chief of a project team, the author has contributed to develop an application of Real-Time Earthquake Information (RTEI) for disaster prevention in schools. This paper describes first the EEWS for schools, a demonstration test at an elementary school in Sendai and the extended demonstration tests for other three elementary schools and one junior high school. Then, the Transmission System of RTEI using an Intranet connecting schools is introduced, together with a demonstrative test using the School in Wide Area Network in Miyagi prefecture (Miyagi-SWAN), Japan. These demonstration tests were performed as one of the major tasks of a government project. The experience of a real earthquake, the June 14, 2008 Iwate-Miyagi Inland earthquake (M7.2), is additionally addressed. For future applications of EEWS in schools, a performed questionnaire investigation is also described. The lessons from the demonstration tests and future perspectives of expansion of the EEWS in schools are also addressed.

KEYWORDS: Earthquake Early Warning, Application in schools, Demonstration test

1. INTRODUCTION

For damage mitigation, some countries are deploying Earthquake Early Warning Systems (EEWS) using Real-Time Earthquake Information (RTEI), which can offer precious seconds before strong ground shaking occurs. It is a fact that EEWS can save lives by stopping trains before they pass over damaged tracks, evacuating elevators, etc. EEWS are very useful, especially for subduction zone earthquakes. Systems that can detect earthquakes near their source and issue warnings before strong ground shaking starts are in place or being deployed in Japan (Horiuchi et al., 2005), Mexico and Taiwan. Similar kinds of systems are also being studied for local earthquakes in locations like Southern California and Istanbul.

Japan Meteorological Agency (JMA) started to issue RTEI for particular users from August 1, 2006, and warning information for public users, through TV and radio, from October 1, 2007. A one million population city in Japan, Sendai, can be strongly shaken by the Miyagi-Ken Oki earthquake, a subduction zone earthquake with a very high probability of occurrence in the near future. In this city, an early warning can be issued about 15 seconds before S-wave arrival in many locations. Not only that, but various applications can be considered for human and material damage reduction. The principle of RTEI is shown in Figure 1.

The author has contributed as chief of a project team to develop an EEWS, and has performed a demonstration test at Nagamachi Elementary School in Sendai (Motosaka et al., 2006a), as a leading project sponsored by Ministry of Education, Culture, Sports, Science, and Technology (MEXT). The ideas of the EEWS are: to give an alarm before strong shaking occurs, to countdown the time for S-waves arrival to the site, and to predict the expected seismic intensity of ground motion.

In the fiscal years from 2004 to 2006, the author developed a project named 'Communization of Regional

Earthquake Disaster Information and Strategy for Disaster Prevention Advance against the Approaching Miyagi-ken Oki Earthquake', sponsored also by MEXT. The demonstration test was extended to three elementary schools and one junior high school (Motosaka et al., 2006b). A demonstration test of RTEI transmission using the School in Wide Area Network in Miyagi prefecture, Japan (Miyagi-SWAN), has been also performed by the same project (Motosaka, 2007). For future application of EEWS in schools, a questionnaire investigation was performed in the project. In 2007, the EEWS using SWAN was extensively installed at two junior high schools in Kakuda City, Miyagi prefecture.

During June 14, 2008 Iwate-Miyagi Inland earthquake (M7.2), the EEWS in schools worked successively. At a junior high school with a hypocentral distance of 110 km, about 100 students were evacuated by the earthquake warning announced 21s before S-wave arrival.

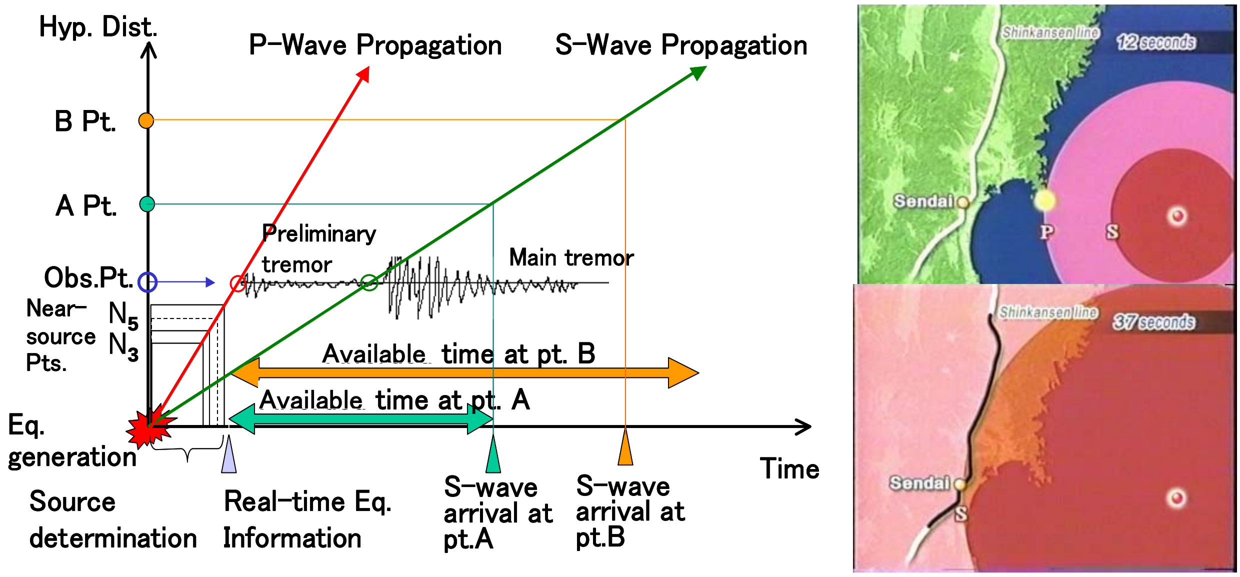


Figure 1 Principle of earthquake early warning information and Miyagi-ken Oki earthquake

2. OUTLINE OF THE SYSTEM

Figure 2 shows the diagram of the EEWS. The information about the magnitude and the hypocenter is sent via satellite or IP-net form the Japan Metrological Agency (JMA), based on the nation wide JMA-NIED earthquake network systems. The information is transferred to the receiver computer at the teacher's room. The computer estimates the countdown to the S-wave arrival and the expected seismic JMA intensity. Based on this information, the broadcasting system issues a warning voice to all the area of the school. Voice/image warning information is transmitted to a TV receiver at each classroom. The automatic connection from the receiver to the broadcasting system is controlled by an ON/OFF switch. Usually, on school days the switch is set to ON and on weekends to OFF.

The early warning system installed in schools has three functions: 1) Evacuation mode, 2) Training mode and 3) Education mode. The evacuation mode secures the safety of pupils and teachers and persuades the evacuation when the expected intensity becomes more than a specified intensity e.g. JMA IV, issuing a warning via speakers and showing a warning image on screen (ref. to Figure 3). The training mode supplies functions for evacuation drills, issuing early warnings for earthquakes with JMA intensity less than III or a manually set intensity. In both cases, the drill is mainly based on voice broadcast in order to secure the pupils' safety when a teacher is not present. The education mode provides "Static Screen" and "Dynamic Screen" modes, which show pictures of earthquake damage and animations of human and structural behavior during earthquakes respectively (ref. to Figure 4). After an evacuation drill, pupils can have a quasi-experience of earthquakes using these screens, which leave important impressions in pupils' minds.

Application of EEWS in schools affects the realization of the social basis for utilization of RTEI and ensures teachers' and pupils' safety.

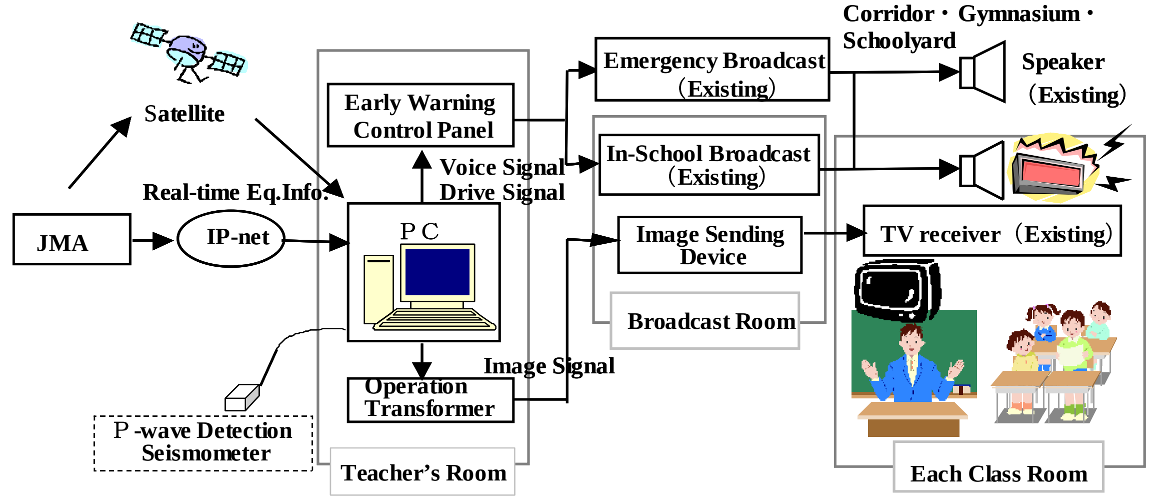


Figure 2 Diagram of the Earthquake Early Warning System in Schools

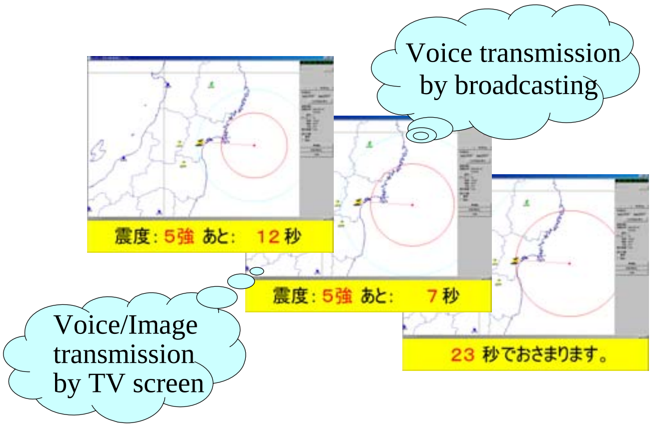


Figure 3 Flow of images during earthquakes

Figure 4 Example of Dynamic Screen Mode: Animation of earthquake shaking at classroom

3. DEMONSTRATION TEST OF THE EEWS IN SCHOOL AND ITS EXTENTION

3.1 Description of the Demonstration tests

The demonstration tests at Nagamachi Elementary School in Sendai, started from February in 2004 with the installation of the EEWS. Evacuation drills have been performed three times per year. Through the demonstration tests, the system has been modified based on the feedback and discussions between the teachers in charge at the school and the project team members. Major points are as follows: 1) Modification of the contents of the announcement during countdown, 2) Appropriate words for pupils at elementary school, 3) Modification of the alarm's sound, 4) Connection to the broadcasting systems at school and addition of uninterruptible power supply and 5) Users' voice recording function for the broadcasting contents.

Evacuation drills using the system have been performed considering the 15 seconds available time till S-wave arrival for the expected Miyagi-Ken Oki earthquake. Compared to previous evacuation drills without the EEWS, pupils indicate a psychological surplus in evacuation actions such as ducking under their desks. Teachers also indicate the effectiveness in the evacuation induction for opening doors to prevent blocking of escape ways and closing the curtains to prevent injuries by glass breaking. The authors summarized the different points in the evacuation flow comparing the evacuation drills using the EEWS with those without it (Motosaka et al., 2006a). In the fiscal years from 2004 to 2006, the demonstration test was extended to three elementary schools and one junior high school in Miyagi prefecture, Japan, as a project for earthquake disaster prevention against the Miyagi-ken Oki earthquake. A questionnaire investigation performed by Nagamachi E.S. concluded that all the pupils felt the effectiveness of the early warning system for earthquake evacuation (Motosaka et al., 2006a).

3.2 Experience of a Real Earthquake

The effectiveness of the EEWS in schools described above, was verified through a real earthquake, the June 14, 2008, Iwate-Miyagi Inland earthquake (M7.2). For this earthquake, JMA issued RTEI improving source parameters (magnitude and hypocenter) 10 times as observation points increased. It is noted that the estimated magnitude was 5.7 initially in the 1st information, and improved to 6.1 in the 2nd, 6.2 in the 3rd, and 7.0 in the l0th information. The EEWS in schools are set to connect to in-school broadcasting if the predicted seismic JMA intensity exceeds a preset intensity, and if a switch is set to 'ON'. If the switch is set to 'OFF', warnings are not broadcasted. The source parameters issued the 3rd time, are used to connect to the in-school broadcasting system at 5 schools. Figure 5 shows the available time before the arrival of S-waves together with the predicted seismic intensity based on the tentative magnitude estimated at the time of the source parameters issued the 3rd time. The soil amplification factors are set differently at each school.

The earthquake occurred at 8:43 in the morning of Saturday, not a school day. As usual, the broadcasting connection of the RTEI receiver was set to 'OFF' during the weekend at 4 elementary schools, but at Shiroishi Junior High School, the broadcasting connection was ON because about 100 students were at school attending a regional athletic meeting. They could actually do the drilled evacuation actions, e.g. duck under the desk, cover their head and hold the legs of the desks based on the warning announce issued 21s before S-wave arrival. It was a nice coincidence that an evacuation drill was performed 3 days before the earthquake occurrence. This was reported by some media (TVs and Newspapers) as a successful example of EEWS in schools. The RTEI was also received at other 4 schools before S-wave arrival. The available time at Furukawa 3rd E.S. was 3s, at Kama E.S. in Ishinomaki, 9s, at Tsurugaya E.S. in Sendai, 11s, and at Nagamachi E.S. in Sendai, 13s.

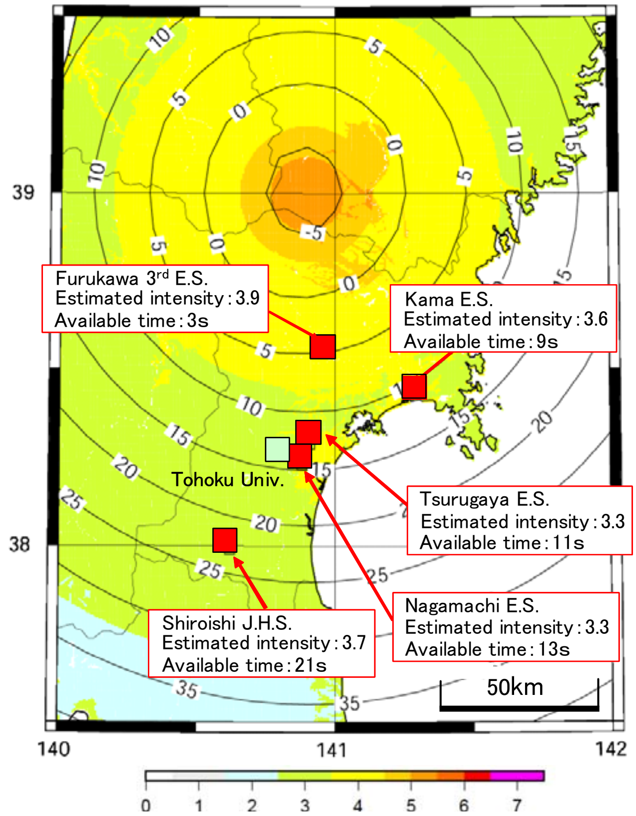


Figure 5 Available time and the estimated seismic JMA intensity at 5 schools for the 3rd issued source information from JMA

4. EEWS FOR A SCHOOL GROUP USING SCHOOLS' WAN AND ITS DEMONSTRATION TEST

4.1 Description of the demonstration test

For spreading EEWS in schools, it is important to consider the Education Committee of the Local Government, not to cause inequality among schools. Considering this point, the intranet connecting groups of schools can be used. The essential thing for a fast spread of EEWS in schools is to use efficiently the existing internet network and the existing broadcasting equipment in each school.

The author has proposed to the Education Committee of Miyagi prefecture the use of the Miyagi-SWAN for transmitting the RTEI, which may make possible a faster spread of EEWS in schools. As of March 2008, a total of 108 prefecture schools and 181 elementary and junior high schools of 24 local governments are connected to the Miyagi-SWAN. Sendai West High School was selected for a demonstration test using the Miyagi-SWAN. A specific receiver having Evacuation and Training Modes and a PC having the Education Mode was installed at the mentioned school and the calculated available time and estimated intensity are transmitted to the school broadcasting system as outputs. The PC has display function for Education Mode (ref. to Figure 6).

In fiscal year 2006, a receiver of RTEI from JMA was installed at the education training center, where the server of Miyagi-SWAN is installed. The information was transmitted to a model school connected to Miyagi -SWAN. The materials for Disaster Prevention Education are transferred to each class room, the audiovisual classroom and distributed as handouts. On March, 2007, an evacuation drill was performed at Sendai West High School, the model school, using the developed EEWS using the Miyagi-SWAN. It is noted that each prefecture government in Japan has intranets similar to the Miyagi-SWAN. The demonstration test promotes the faster spread of EEWS in schools.

In fiscal year 2007, an EEWS using the Miyagi-SWAN was installed at two junior high schools in Kakuda City, Miyagi prefecture. In these schools, the buildings were found to be weak based on seismic diagnosis.

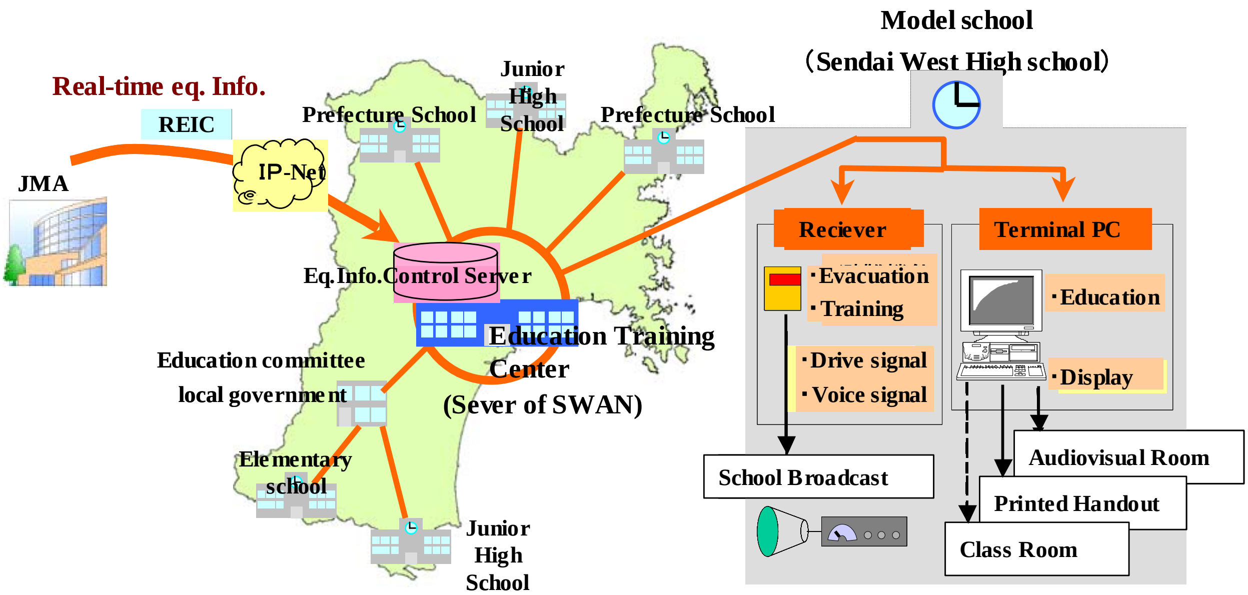


Figure 6 Schematic figure of earthquake early warning system in schools using Miyagi-SWAN

4.2 Experience of a Real Earthquake

During the June 14, 2008 Iwate-Miyagi Inland earthquake, RTEI from JMA was received at three schools through the Miyagi-SWAN. At the 2 junior high schools in Kakuda City, the warning announces were actually broadcasted at the time when the predicted seismic intensity exceeded the preset intensity level, which was set to 4. At Sendai West High School, the receiver connected to the school broadcast system had troubles, though the terminal PC received the RTEI. It is concluded that the RTEI transmission using the Miyagi-SWAN was successfully performed.

5. QUESTIONAIRE INVESTIOGATION FOR FUTURE EEWS APPLICATIONS IN SCHOOLS

5.1 Objective and background

A questionnaire investigation was preformed from January to February in 2007 in order to promote the utilization of EEWS in schools, to check the awareness of the EEWS and also to identify needs for merging the

EEWS for disaster prevention with other fields taking advantage of system maintenance (ref. to Motosaka and Manabe, 2007).

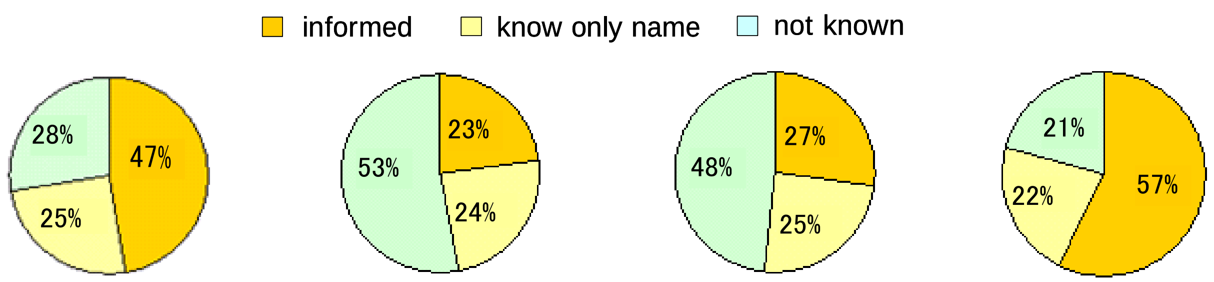
5.2 Target of the questionnaire investigation and its contents

The targets of the investigation were teachers and PTAs of public schools in 4 cities in Miyagi pref. and the metropolitan area (23 wards of Tokyo and Yokohama City). Two types of investigation were performed. One is a questionnaire for a representative of a school, described here in as "general school". The other is a questionnaire for all teachers, staff and also 30 PTAs, described here in as "model school". All the schools of 4 cities in Miyagi prefecture (299 schools in total) and Yokohama City (350 schools in total) were selected as general schools. 26 schools including the schools for the demonstration tests, were selected as model schools, namely 4 from Sendai City, 3 from Ishinomaki City, 3 from Ohsaki City, 2 from Shiroishi City and 14 from Tokyo.

Through the contents of the questionnaire it was investigated: 1) the awareness of real-time earthquake information, 2) the transmission means of the earthquake warning, 3) the need of additional functions, and 4) the merge of Disaster prevention due to EEWS and criminal prevention. Question sheets for teachers and PTAs were prepared.

5.3 Results of the questionnaire investigation

Figure 7 shows the results regarding the awareness of real-time earthquake information. From Figure 7(a) it is possible to observe that the teachers 'informed' and those who 'know only name' are 47% and 25%, respectively. This means that a total of 72% of the teachers knew somewhat about real-time earthquake information. Comparing Figure 7(b) and (c), the difference of awareness in the different areas can be recognized. It is found that awareness in Miyagi is slightly higher than in Tokyo. This may be due to some media reports on the demonstration test of EEWS in schools in Miyagi prefecture executed by the MEXT projects. Figure 7 (d) shows the results of awareness at test schools in Miyagi pref. By comparing the results in Figure 7(c) at non-test schools, it is evident that the awareness at test schools is very high.



(a) Teachers (Non-test schools) (b) PTA in Tokyo metro.. (Non-test schools) (c) PTA in Miyagi pref. (Non-test schools) (d) PTA in Miyagi pref. (Test schools)

Figure 7 Results of awareness of real-time earthquake information

Figure 8 show the results of awareness of the distinctive features of RTEI for PTAs. It is found from this figure that 'prediction of available time' is the highest, with 80%, followed by 'Currently distribution only to specific users' and 'prediction of seismic intensity'. 'Distribution by JMA', and 'Not available for near-source earthquake' is the lowest, showing only 30%. Almost the same results were obtained from teachers.

Figure 9 show the results of transmission means' preferences by PTAs. It is found form this figure that PTAs expect highly (about 90%) 'Transmission of RTEI by the in-school broadcasting system', then they expect 'alarm/broadcasting devices on school-commuting streets'. They don't expect 'mobile terminals'. The results are due to PTAs' request for simple systems to be understood by children easily. It is noted that the results from teachers also show a high request for the in-school broadcasting system.

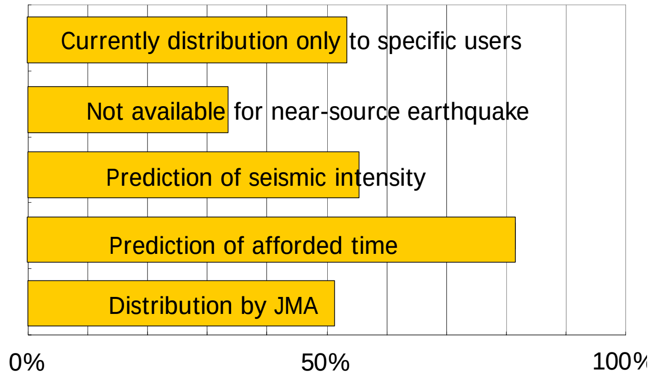


Figure 8 Awareness of distinctive features of RTEI (PTA)

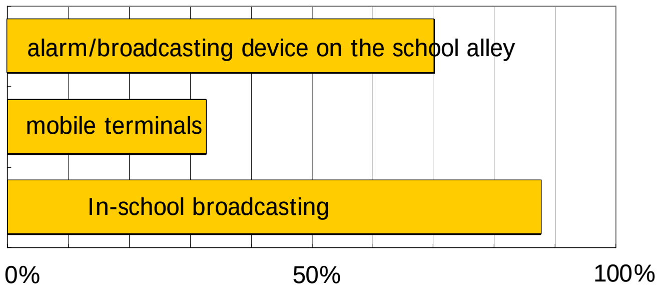


Figure 9 Transmission means' preferences (PTA)

In the questionnaire investigation, besides disaster prevention and criminal prevention, additional functions in emergency were investigated considering mobile devices for children. Figure 10 show the results of the need of additional functions for teachers. It is found that about 70 % of teachers expect combined effects. It is noted that the results of PTAs are almost the same. Figure 11 show the results from teachers who answered 'necessary' or 'rather necessary' about the need of additional functions. The highest request is 'position identification function', with 90%, followed by safety confirmation (70%), criminal prevention buzzer and receiving RTEI. The need of position identification becomes high for safety confirmation of children in emergencies. Considering the need of daily maintenance of the disaster prevention system in schools, it is suggested that EEWS would have additional functions, e.g. criminal prevention function.

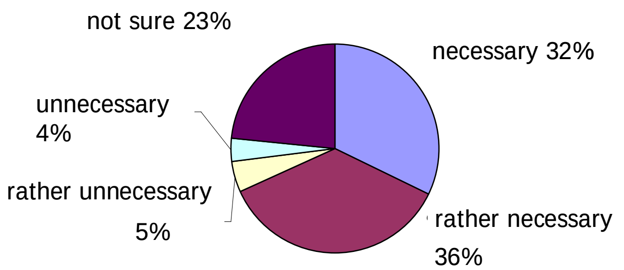


Figure 10 Necessity of combining disaster and crime prevention functions

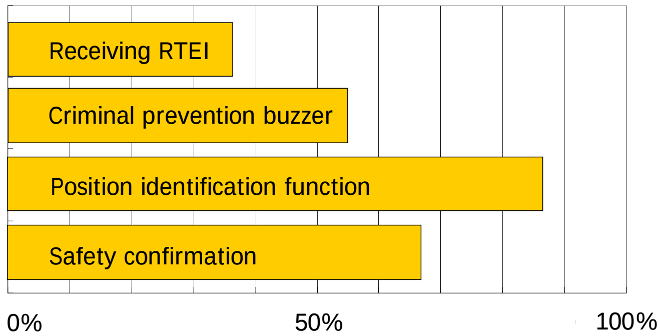


Figure 11 Desirable emergency functions put into mobile devices for children

6. CONCLUDING REMARKS

In this study, an EEWS is demonstratively applied to schools in Miyagi prefecture, Japan, and it is described together with a questionnaire investigation for future applications of EEWS in schools. Effectiveness of the system has been verified not only by evacuation drills using the system but also by a real earthquake. The findings obtained through the demonstration tests for promoting, spreading and extending EEWS utilization in schools are as follows:

1) Voice transmission using the existing school broadcasting equipment is most effective for spreading EEWS in schools considering the unpredictable time when earthquakes occur. Existing TV sets can also be used for image transmission. The utilization of existing equipment leads to the spread of the system at lower cost.
2) Schools' Intranet, like Miyagi-SWAN, can be effectively used for transmitting real-time earthquake

information to all schools, fairly under an education committee of a local government.

3) Disaster prevention maps and disaster simulation images of the local area of the elementary school can be incorporated into the education mode of the system. Development of the disaster prevention education information by collaboration between school and community is recommended in order to improve effectiveness.
4) Together with the three functions described in this paper, additional functions can be considered to enhance the additional value of EEWS. The verification of the seismic performance and safety of school buildings could be added by connecting structural monitoring systems. Disaster prevention could also be merged with crime prevention. Both can be promoted by collaboration between school and community.
5) The three health concepts of the World Health Organization: Mental health, Social health, and Physical health would be the base for disaster prevention education. Based on this conception, Disaster prevention education would be considered to enhance the human ability to predict danger, understand coexistence and the ability to respond quickly to disasters (Fujii, 2005).

ACKNOLEDGEMENTS

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The extended demonstration tests of the EEWS in schools have been performed as one of the topics of the project for earthquake disaster prevention against the Miyagi-ken Oki earthquake, sponsored by MEXT, named 'Communization of Regional Earthquake Disaster Information and Advance Strategy for Disaster Prevention Against the Approaching Miyagi-ken Oki Earthquake'. The author thanks the Education Division of Miyagi prefecture, Education Committees of Sendai City, Ohsaki City, Ishinomaki City and Shiroishi City. The author also thanks all the persons related to the model schools of the demonstration tests, Nagamachi Elementary School, 3rd Elementary School, Kama Elementary School, Shiroishi Junior High School, Tsurugaya Elementary School and Sendai West High School respectively.

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