ESSENSE OF EARTHQUAKE EARLY WARNING SYSTEMS

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***Abstract**: The aim of this article is to describe the general methodology of earthquake early warning systems. The common disaster monitoring system was analyzed, and the construction system of disaster information management system was discussed particularly. This paper addresses traditional views of early warning systems and what is needed to turn them into efficient, people-centred systems.*

KEY WORDS: EARLY WARNING SYSTEMS, DISASTER INFORMATION, NATURAL HAZARDS, GEOINFORMATION TECHNOLOGY, REMOTE SENSING SYSTEM.

1. Introduction

The ground motion of an earthquake resembles thunder in a sense. A person who witnesses bright lightning in the night sky prepares himself or herself for the thunder that is anticipated to follow. This time lag results from the velocity difference between light and sound. In the case of an earthquake, the velocity difference between the primary wave (P-wave) and the secondary wave (S-wave; generally, the S-wave has a larger amplitude than the P-wave, and, in the case of a nearby earthquake, the peak ground motion (principal motion) often arrives immediately after the S-wave) generates a time allowance which enables a person to start preparing for the principal motion as soon as he or she detects the preceding P-wave. Moreover, by installing seismographs near the source and analyzing the P-wave data detected by the seismographs, it will be possible to give warnings to distant locations before the P-wave arrives at those locations. If an advance warning of ground motion can be given effectively, the number of casualties from collapse of buildings and other earthquake damages could possibly be reduced. Even when the ground motion is not so strong, such warning could contribute to reducing economic losses through automatic shutdown of machines. Furthermore, system development related to such warnings may create new business opportunities. The idea of a system for advance warning of ground motion, which was considered to be promising in various aspects as explained above, already existed from long ago. However, in order to actually build such a system, an appropriate observation network, analysis system, and communication system would essentially be required.

Because of the extreme complexity involved in the earthquake processes, reliable earthquake prediction is not currently possible. Present technological advances in seismic instrumentation and in digital communication and processing permit the implementation of a real-time earthquake monitoring system. From the point of view of seismic hazards mitigation, earthquake early warning (EEW) is becoming a practical tool to reduce the loss caused by a damaging earthquake.

Earthquake early warning is the rapid detection of earthquakes, real-time assessment of the shaking hazard, and notification of people prior to shaking [5]. Warning times range from a few seconds to a few minutes depending on your location and how big the earthquake is. The further you are away from the epicenter, the more warning time. The bigger the earthquake, the stronger the shaking at greater distances. An early warning should tell you how strong the shaking will be at your location, and how long until that shaking starts (the warning time).

2. Basics of early warning systems.

Early warning is a major element of disaster risk reduction. It prevents loss of life and reduces the economic and material impact of disasters. To be effective, early warning systems need to actively involve the communities at risk, facilitate public education and awareness of risks, effectively disseminate alerts and warnings and ensure there is constant state of preparedness [5]. A complete and effective early warning system supports four main functions: risk knowledge, monitoring and warning; dissemination and communication; and a response capability.

Risk knowledge involves systematically collecting data and undertaking risk assessments of predefined hazards and vulnerabilities. It should answer questions like: Are the hazards and the vulnerabilities well known? What are the patterns and trends in these factors? Are risk maps and data widely available?

Monitoring and warning involves a study of the factors that indicate a disaster is imminent, as well as the methods used to detect these factors. The questions to be answered are: Are the right parameters being monitored? Is there a sound scientific basis for making forecasts? Can accurate and timely warnings be generated?

Dissemination and communication concerns communicating the risk information and warnings to reach those in danger in a way that is clear and understandable. The questions of this part are: Do warnings reach all of those at risk? Are the risks and the warnings understood? Is the warning information clear and useable?

Response capability requires the building of national and community response plan, testing of the plan, and the promotion of readiness to ensure that people know how to respond to warnings. And the questions that this part should answer are these: Are response plans up to date and tested? Are local capacities and knowledge made use of? Are people prepared and ready to react to warnings?

Putting it all together Good early warning systems have strong linkages between the four elements. The major players concerned with the different elements meet regularly to ensure they understand all of the other components and what other parties need from them. Risk scenarios are constructed and reviewed. Specific responsibilities throughout the chain are agreed and implemented. Past events are studied and improvements are made to the early warning system. Manuals and procedures are agreed and published. Communities are consulted and information is disseminated. Operational procedures such as evacuations are practiced and tested. Behind all of these activities lies a solid base of political support, laws and regulations, institutional responsibility, and trained people. Early warning systems are established and supported as a matter of policy. Preparedness to respond is engrained in society.

An early warning system can be implemented as a chain of information communication systems and comprises sensors, event detection, decision support, and message broker subsystems. They work together to forecast and signal disturbances that adversely affect the stability of the physical world, providing time for the response system to prepare for the adverse event and to minimize its impact.

An early warning system is more than a warning system, which is simply a means by which an alert can be disseminated to the public.

Developing and implementing an effective early warning system requires the contribution and coordination of a diverse range of individuals and groups. The following list provides a brief explanation of the types of organizations and groups that should be involved in early warning systems and their functions and responsibilities.

Communities, particularly those most vulnerable, are fundamental to people-centered early warning systems. They should be actively involved in all aspects of the establishment and operation of early warning systems; be aware of the hazards and potential impacts to which they are exposed; and be able to take actions to minimize the threat of loss or damage.

Local governments, like communities and individuals, are at the centre of effective early warning systems. They should be empowered by national governments, have considerable knowledge of the hazards to which their communities are exposed and be actively involved in the design and maintenance of early warning systems. They must understand advisory information received and be able to advice, instruct and engage the local population in a manner that increases public safety and reduces the possible loss of resources on which the community depends.

National governments are responsible for high-level policies and frameworks that facilitate early warning and for the technical systems that predict and issue national hazard warnings. National governments should interact with regional and international governments and agencies to strengthen early warning capacities and ensure that warnings and related responses are directed towards the most vulnerable populations. The provision of support to local communities and governments to develop operational capabilities is also an essential function.

Regional institutions and organizations play a role in providing specialized knowledge and advice which supports national efforts to develop and sustain early warning capabilities in countries that share a common geographical environment. In addition, they encourage linkages with international organizations and facilitate effective early warning practices among adjacent countries.

International bodies can provide international coordination, standardization, and support for national early warning activities and foster the exchange of data and knowledge between individual countries and regions. Support may include the provision of advisory information, technical assistance, and policy and organizational support necessary to aid the development and operational capabilities of national authorities or agencies.

Non-governmental organizations play a role in raising awareness among individuals, communities and organizations involved in early warning, particularly at the community level. They can also assist with implementing early warning systems and in preparing communities for natural disasters. In addition, they can play an important advocacy role to help ensure that early warning stays on the agenda of government policy makers.

The private sector has a diverse role to play in early warning, including developing early warning capabilities in their own organizations. The media plays a vital role in improving the disaster consciousness of the general population and disseminating early warnings. The private sector also has a large untapped potential to help provide skilled services in form of technical manpower, know-how or donations (in-kind and cash) of goods or services.

The science and academic community has a critical role in providing specialized scientific and technical input to assist governments and communities in developing early warning systems. Their expertise is central to analyzing natural hazard risks facing communities, supporting the design of scientific and systematic monitoring and warning services, supporting data exchange, translating scientific or technical information into comprehensible messages, and to the dissemination of understandable warnings to those at risk.

If disasters arise from the concatenation of multiple factors, natural and social, then in principle at least, an early warning system should address all of the factors relevant to the particular risk. From this perspective it is desirable to monitor and provide early warning and foresight not only on the short-term precipitating hazards and geophysical conditions but also on the relevant longer-term factors such as declining environmental state, risk-raising development practices and projects, risk-altering policy changes, the status of social communications and capacities, trends in food markets, settlement trends and migration, conflict and health status. This involves a wide range of time frames, and diverse methodologies for monitoring and forecasting [4]. Extending this line of thinking, one can argue that the citizen and the public risk manager is not so concerned with the specifics of particular hazards, but rather the package of risks faced and how to mitigate and prepare for them. This implies that an approach that addresses all relevant hazards in an integrated fashion, and not as separate unconnected systems, is more appropriate to the management of natural risks. Such a 'multi-hazard' or 'all-hazard' approach should provide synergies and cost-efficiencies, e.g. in data gathering and processing and in public preparedness efforts, and should assist in sustaining warning capabilities for the more infrequent hazards, such as tsunamis.

3.In common about earthquake warning system

An earthquake warning system is a system of accelerometers, seismometers, communication, computers, and alarms that is devised for regional notification of a substantial earthquake while it is in progress. This is not the same asearthquake prediction, which is currently incapable of producing decisive event warnings.

Earthquake early warning systems (EEWS) use earthquake science and the technology of monitoring systems to alert devices and people when shaking waves generated by an earthquake are expected to arrive at their location. The seconds to minutes of advance warning can allow people and systems to take actions to protect life and property from destructive shaking.[1]

Even a few seconds of warning can enable protective actions such as:

- Public: Citizens, including schoolchildren, drop, cover, and hold on; turn off stoves, safely stop vehicles.
- Businesses: Personnel move to safe locations, automated systems ensure elevators doors open, production lines are shut down, sensitive equipment is placed in a safe mode.
- Medical services: Surgeons, dentists, and others stop delicate procedures.
- Emergency responders: Open firehouse doors, personnel prepare and prioritize response decisions.
- Power infrastructure: Protect power stations and grid facilities from strong shaking.

[1] http://earthquake.usgs.gov/research/earlywarning/ [Looked at 11.05.2017].

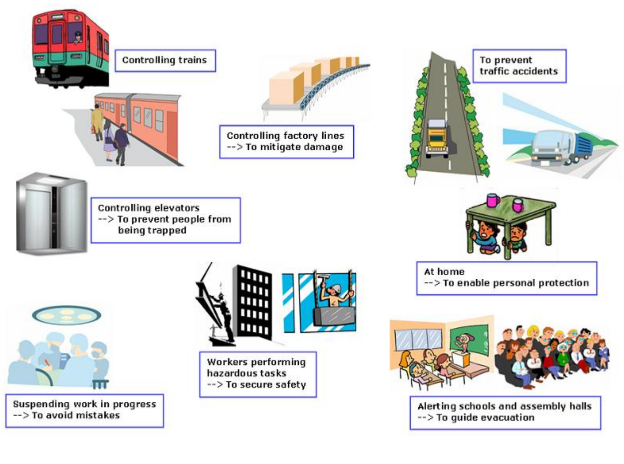

Figure 1 Extend of Earthquake early warning.

EEW systems are currently operating in several countries, and others are building them. Since 2006 the USGS has been working to develop EEW for the United States, with the help of several cooperating organizations including the California Geological Survey (CGS), the California Institute of Technology (Caltech), the California Office of Emergency Services (CalOES), the Moore Foundation, the University of California, Berkeley, the University of Washington, and the University of Oregon [13]. The goal is to create and operate an EEW system for the highest risk areas of the United States beginning with the West Coast states: California, Washington, and Oregon.

A demonstration EEW system called ShakeAlert began sending test notifications to selected users in California in January 2012 [1]. The system detects earthquakes using the California Integrated Seismic Network (CISN), an existing network of about 400 high-quality ground motion sensors. CISN is a partnership between the USGS, State of California, Caltech, and University of California, Berkeley, and is one of seven regional networks that make up the Advanced National Seismic System (ANSS).

In February of 2016 the USGS, along with its partners, rolled-out the next-generation ShakeAlert early warning test system in California. This “production prototype” has been designed for redundant, reliable operations. The system includes geographically distributed servers, and allows for automatic fail-over if connection is lost. This next-generation system will not yet support public warnings but will allow selected early adopters to develop and deploy pilot implementations that take protective actions triggered by the ShakeAlert warnings in areas with sufficient coverage - Figure 2. The USGS has published an Implementation Plan with the steps needed to complete the system and begin issuing public alerts. [2]

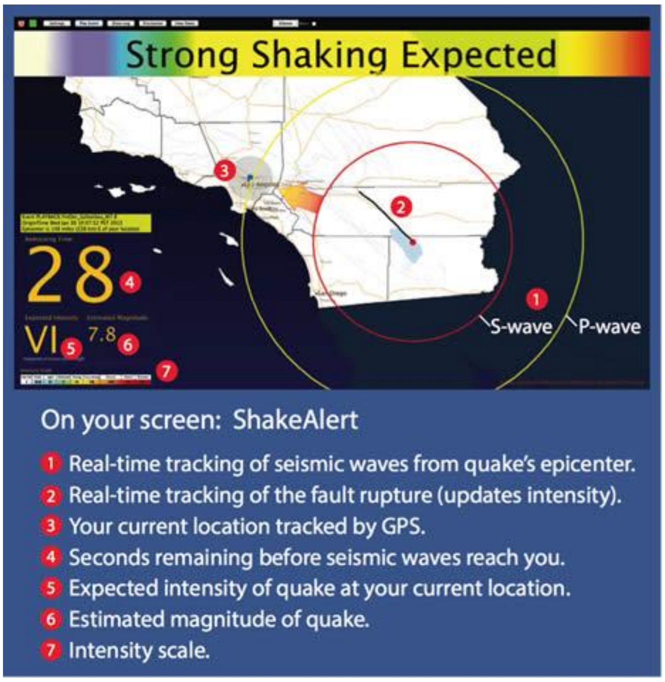

Figure 2 Importance of shake alert.

4.Mode of operation EEWS

Earthquake early warning systems like ShakeAlert work because the warning message can be transmitted almost instantaneously, whereas the shaking waves from the earthquake travel through the shallow layers of the Earth at speeds of one to a few kilometers per second (0.5 to 3 miles per second). Figure 3 shows how such a system would operate. When an earthquake occurs, both compressional (P) waves and transverse (S) waves radiate outward from the epicenter. The P wave, which travels fastest, trips sensors placed in the landscape, causing alert signals to be sent ahead, giving people and automated electronic systems some time (seconds to minutes) to take precautionary actions before damage can begin with the arrival of the slower but stronger S waves and later-arriving surface waves. Computers and mobile phones receiving the alert message calculate the expected arrival time and intensity of shaking at your location. [3]

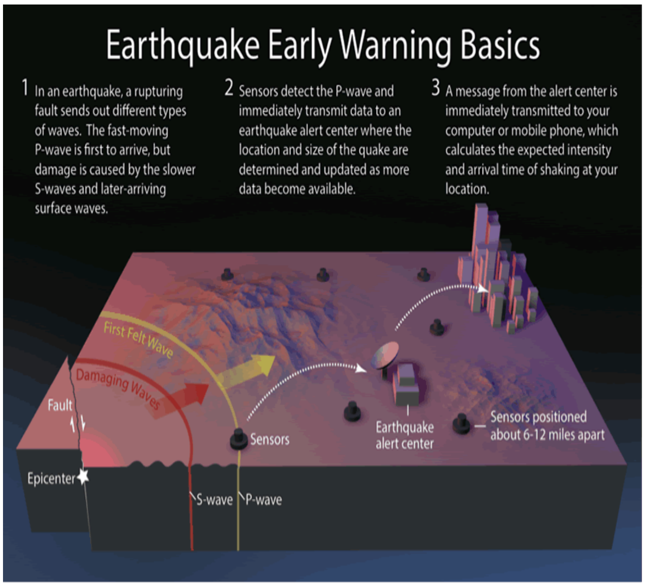

Figure 3 Earthquake early warning basics.

[2] http://earthquake.usgs.gov/research/earlywarning/ [Looked at 11.05.2017].

[3] http://earthquake.usgs.gov/research/earlywarning/ [Looked at: 11.05.2017]

We use this to estimate the anticipated ground shaking across the region to be affected. The method can provide warning before the S-wave, which brings the strong shaking that usually causes most of the damage, arrives.[4] It is important to know that all earthqueakes radiate two types of waves: P-waves move quickly through the crust, about 20 times the speed of sound. They are very weak, however, and you can only feel them for earthquakes that are very strong or very close by. They don't cause any damage. S-waves move at about half the speed of P-waves, but carry most of the shaking evergy of an earthquake and cause the most damage. [5]

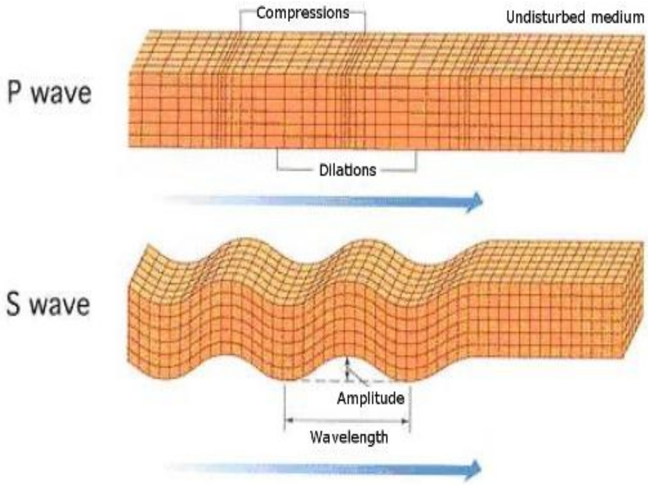

Figure 4 Earthquake Waves.

EEWS also have one big minuse – blind zone. Eartquake warnings are a race between the electronic warning signals and the S-waves of an eartquake. The S-waves of an eartquake emanate from the epicenter at over 2 miles per second. So every second that the warning is delayed means that several more square miles feel the shaking. If the signal gets to a user before the shaking begins, that user gets some benefit over what would be possible with a seismic switch, or simply by feeling the shaking if the shaking gets to the user before the signal does [6], then no eartquake warning is provided. This race heavily favors the eartquake near the epicenter, where the seismic waves are felt within a few seconds of the start of the quake. This area near the epicenter is often called the „blind zone". It can encompass hundreds of square miles in which nobody gets an earthquake warning. The blind zone is a feature of every other networked earthquake warning system, the QuakeGurad earthquake system has no Blind Zone, because of a hybrid approach that uses a network of standalone earthquake warning stations.

Even with the inevitable time sinks, the method can provide warning before the arrival of the S-wave, which brings the strong shaking that usually causes most of the damage. Similar EEW systems are already in place, or are being developed, throughout the world. Warning systems currently exist in Japan, USA Taiwan, Mexico, Turkey and Romania.[6]

5.Conclusion

1. Natural hazards have been increasing and their damage is more severe, because most of the disasters occur in poor regions, where infrastructure is not established enough to be safer from natural disasters. Thus, the loss of property and people's lives are also more severe than in a developed country.
2. There is a wide range of variety of natural hazards, so early warning systems have to be developed always, trying to readjust to the region and countries economic or geographical situation.
3. To make early warning system effective and efficient, the whole system that is made of a lot of variables, starting from personal information of a person to national government. Every aspect of the system has to contribute it's part for the system to be efficient.
4. There are many practical examples where people see the importance of early warning systems, especially in endangered regions, and they establish and develop early warning systems the most.

6.Literature

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