Public Warning for Self-Protective Action

Earthquakes threaten 1 in 4 Americans. Earthquakes currently cannot be predicted, but people can act beforehand to reduce the harm when earthquakes occur. One way to do that is to implement earthquake early warning, which refers to a system that rapidly detects earthquakes just after they begin, quickly calculates how strongly the ground will shake, and notifies people or systems just a few kilometers or tens of kilometers from the epicenter before the shaking arrives. With a few seconds' warning, people and systems can take useful protective actions. The next few pages answer key questions for people deciding whether and how to adopt earthquake early warning to issue public warning for self-protective action. This material was written by leading earthquake engineers, seismologists, emergency managers, and other pioneers of earthquake early warning, including people who developed, implemented, and use earthquake early warning in real life.

Essence of the Practice

An audible warning, visible warning, or both are announced by a mobile app, by a public address system with speakers or sign-speakers, IP telephone, or dedicated appliance. The warning alerts people to imminent shaking and may instruct them to take immediate self-protective action such as drop, cover, and hold on.

A B C D

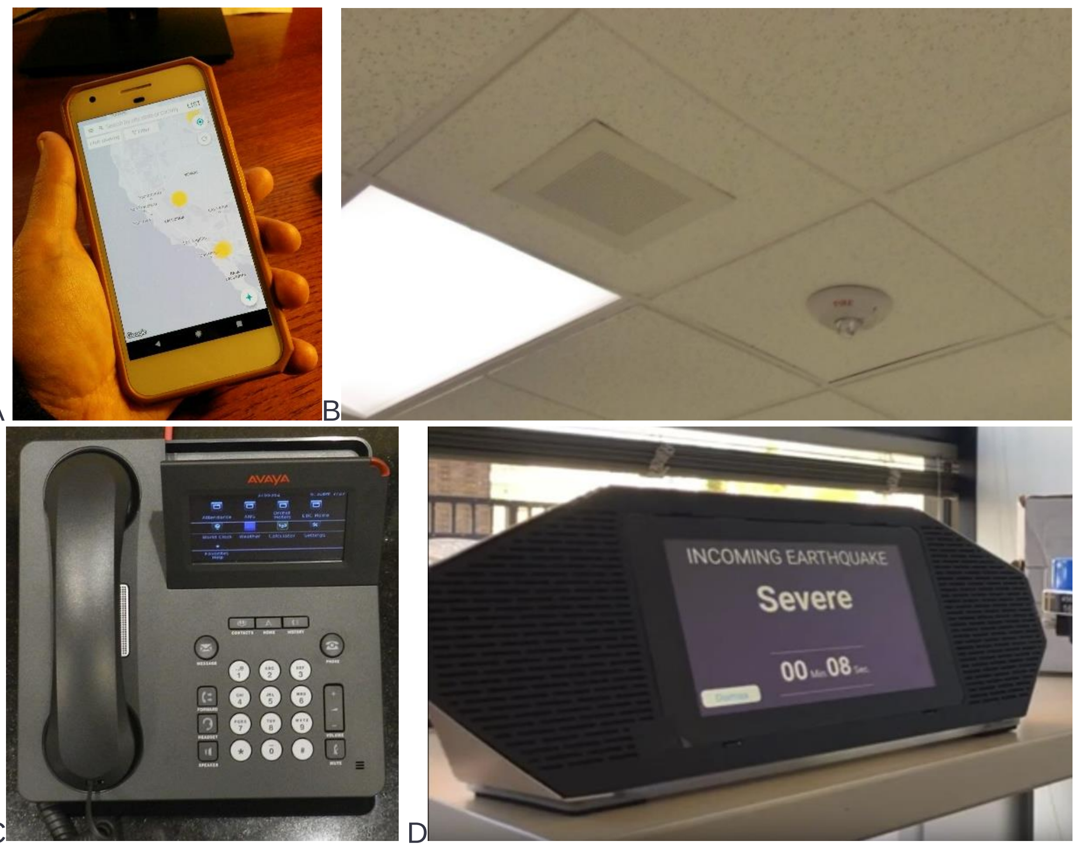

Figure 1. Public warning can be delivered by (A) MyShake mobile app, (B) public-address system, (C) IP telephones, or (D) a dedicated appliance. (Images: A,B: author, C: Geek2003 Creative Commons Attribution-Share Alike 3.0 Unported, D: A. Cantu, 2020, with permission.)

Context in Which the Use Case Would Work

Works in places with Internet connectivity and (except for mobile app) electric power. Audible-only warnings may not work in places with ambient noise that is so loud that an alarm cannot be heard.

Realistic Expectations

Some fraction of users will be so close to the rupture that strong shaking arrives before the alert can reach them. Some fraction of users will take self-protective action. In Japan during the 2011 Tohoku earthquake, approximately 75% of people successfully took self-protective actions. Comparable U.S. statistics are not yet available. See "potential vulnerabilities" below for reasons why people might not successfully take self-protective actions. Expect injuries to be reduced but probably not eliminated through successful self-protective action; efficacy statistics for injury avoidance are unavailable.

Clear Behavior

Drop, cover, and hold on, and its alternative context-dependent actions are described in https://www.earthquakecountry.org/step5/. These include instructions for people with disabilities, in bed, in a highrise, in a store, outdoors, driving, in a stadium or theater, near a shore, or below a dam. In settings with a lot of warning time, such as Mexico City, users may evacuate buildings.

Potential Vulnerabilities

The system may fail to send an alarm because of

- Unexpected changes to the upstream warning system's application programming interface (API) or insufficient time to accommodate the API change. At least one vendor is less susceptible to such changes.
- Electric power or Internet connectivity is lost or cut off before the message is received or announced. This potentiality can be somewhat mitigated by the vendor monitoring power and Internet connectivity and alerting end users to loss of power and by providing backup power to the alerting system.
- Prior unnoticed or uncorrected damage to hardware. Constant monitoring by the vendor and following a frequent testing protocol can mitigate this problem.
- Failure to start software. The same monitoring and testing protocols can mitigate this problem.

The warning may or may not arrive long enough in advance of strong shaking because of proximity to the rupture and because of the time it takes for successful self-protective action. If the warning arrives before strong shaking, people may still fail to take self-protective action for any of several reasons. Users may be unable to hear or understand the alarm because of:

- Sleep
- Ambient noise (a crowd, a loud television, etc.)
- Hearing or vision impairment
- Language
- Ambiguous message. All these possibilities can be mitigated to some extent.

Users may be slow to react appropriately because of:

- Unfamiliarity with earthquake early warning
- Lack of drilling or experience
- Checking first to see what everyone else is doing
- Waiting for an authority figure to confirm the message
- Bravado
- Belief that the alarm is a mistake, false alarm, or meant for others

Physical constraints may prevent effective self-protective action because of:

- Mobility impairment
- Crowded or enclosed space (e.g., movie theater lobby, jail cell, toilet stall)

- Prevented or injured by others taking inappropriate action

Users may take inappropriate actions because of

- Misinformation (believing in the triangle of life)
- Obsolete advice (standing in a doorway)
- Panic (such as attempting to run out of the building). Panic can be reduced by greater preparation, such as through regular drills, and possibly through occupants' confidence in the strength of their building.

Implementation Costs

The user's cost of a mobile app such as MyShake is negligible. Cost to implement an audible or visible alarm through a public address system: $10,000s if done through a vendor, potentially $1,000s if the earthquake early warning is added to an existing IP-controlled system. Unknown cost to develop in-house. Drilling can involve 1 hour of staff preparation per drill, perhaps annually. In 2018, Los Angeles Unified School District estimated a cost of approximately $450,000 to implement an earthquake early warning system to issue public audible warning for its 724,000 students, plus faculty and staff (Los Angeles Unified School District 2018, p 5-28), ().

Hardware and Software Requirements

In the case of a mobile app such as MyShake, the user must have an Android or iOS mobile device with Internet connectivity. In the case of public address (PA) systems, the user must have a public address system that is capable of receiving and relaying messages. Systems are available for both digital and analog public-address systems.

Training Materials, Requirements, and Frequency of Training

Earthquake Country Alliance provides ample training materials and requirements. See https://www.earthquakecountry.org/step5/. In the US, annual training on ShakeOut day seems to represent the consensus on appropriate frequency. See https://www.shakeout.org/ for information about ShakeOut day. Beaverton School District performs monthly evacuation drills with annual training and hands out 1-2 pages of written materials with the annual training.

Maintenance Requirements

Maintain the public address system, perform annual testing, and ensure remote monitoring and system updates from the vendor or in-house developer.

Examples of Past Use

Hoshiba (2014) summarizes a mail and web survey of 817 Tohoku District residents who received warnings by television, radio, cellphone, or other, prior to the 201 Tohoku earthquake. Most Tohoku District respondents (74.3%) successfully acted. Of this group, 61.6% had decided on the actions to take before the earthquake, and most of those (66.0%) succeeded or mostly succeeded in taking their pre-planned self-protective action. The survey does not quantify the efficacy of injury avoidance.

A condominium building in Marina del Rey, California, Regatta Seaside Residences, installed such a system in 2017. The alert is sent through the fire control system, causing it to emit an audible alarm through each of the building's 224 condominium units in the event of an imminent earthquake expected to cause shaking above a specified intensity. The building demonstrates that earthquake early warning has significant market value; a sales agent asserted that "someone could pay up to 10 percent more just to have that survival comfort." (Zhao 2017).

Biola University, in La Miranda, California, implemented a campus-wide audible alert system (Loumagne 2019), alongside seismic assessment and retrofits of campus buildings, new emergency response teams, awareness initiatives, guidebooks, a campus public address system, and a full functional emergency operations center with an emergency generator. For information, contact Biola University Office of University Communications, 1-562-903-6000.

People with a smart device in Los Angeles, California, can use ShakeAlertLA, an app for users physically in Los Angeles County (City of Los Angeles 2020, Lin 2020). People with a smart device anywhere in California can use the QuakeAlertUSA app, currently available for Android and iPhone.

Other facilities with such systems include Los Angeles City Hall and Los Angeles School District. Los Angeles School District implemented earthquake early warning at Eagle Rock High School in 2019 (Lara 2019). For information, contact Jill Barnes, Los Angeles Unified School District Emergency Services, jill.barnes@lausd.net, 1-213-241-3889.

Beaverton School District in Oregon is trying to implement a pilot program for drop, cover, and hold on, but it is also considering earthquake early warning for evacuation purposes. It is considering evacuation because of its inventory of about 50 highly vulnerable buildings and its unusual seismic setting: in the event of a rupture of the Cascadia Subduction Zone, schools could have up to 3 minutes of warning. Children exercise monthly in fire evacuation, and the school district has found that it can evacuate up to 90 percent of 40,000 building occupants within 90 seconds.

Vendors as of spring 2020 include at least the following, although more may currently exist and new vendors may enter the market after this writing:
Early Warning Labs, 1-424-238-0060, Info@EarlyWarningLabs.com
RH2, 1-541-326-4437, rballard@rh2.com
SkyAlertUSA, 1-415-374-1214, contact@skyalertusa.com
Valcom, 1-352-359-0579, rsteinberg@valcom.com

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