Slow or Stop a Train

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 slow or stop trains before strong shaking arrives. 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 earthquake early warning alert automatically causes trains to slow or stop, reducing the potential for derailment and injury. In the case of trains operated by a supervisory control and data acquisition (SCADA) system such as the Bay Area Rapid Transit (BART) system, an alert causes automatic braking to slow or stop the train (Figure 1). In the case of the Shinkansen, the alert causes power to be shut off at the substation, triggering emergency brakes on all moving trains. On BART, train control is switched from automatic (SCADA control) to manual (engineer control) mode. In the case of a train controlled by the engineer but equipped with positive train control, the alert will bring the train to a stop.

A B

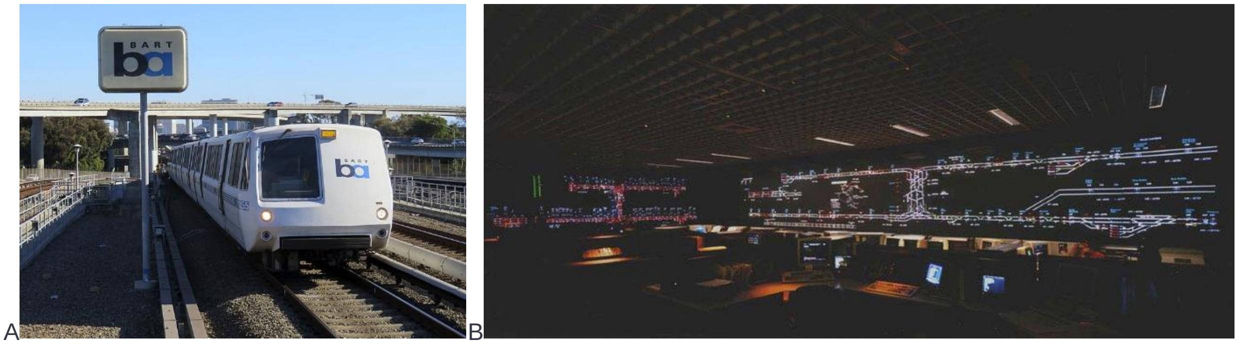

Figure 1. Bay Area Rapid Transit implemented earthquake early warning in 2012. (A) Pittsburg/Bay Point-bound train approaching MacArthur station in June 2018. (B) BART Operations Control Center at the Lake Merritt station, 2016. (Image credits: A: Pi.1415926535 [2018] Creative Commons Attribution-Share Alike 3.0 Unported; B: public domain.)

Context in Which the Use Case Would Work

Earthquake early warning has worked in electrically powered trains where a SCADA system can shut off power at the substation and where loss of electric power automatically causes braking to occur (as in the case of the Shinkansen). It has also worked in trains under supervisory control (that is, where the vehicles are operated by a SCADA system as in BART). It seems likely to work in engineer-controlled trains with positive train control, but as of this writing, rail operations staff at the California High Speed Rail Authority are unaware of any transit or rail operator in North America using earthquake early warning technology with positive train control (M. Flores, Information Officer, California High Speed Rail Authority, written commun., May 6, 2020).

Realistic Expectations

Earthquake early warning has successfully fully stopped trains in real earthquakes. However, once an alert reaches a train, it can take 10 seconds for the train to decelerate by 30 mph, e.g., from 70 mph to 40 mph. Alerts can reach trains too late to fully stop. Thus, earthquake early warning will not prevent all damage and injury. But a speed reduction should reduce derailments and injuries and increase the chance of keeping the system operational. Expect some false alerts, in which trains stop without an earthquake occurring. False alerts have not caused significant delays for BART.

Clear Behavior

Train braking is automated; no human action is required. In the case of BART, operators can then determine whether it is safe to proceed, e.g., at slower speed, how far to proceed, and where to stop. In other cases, the alert could trigger preestablished response procedures based on distance, shaking, or other earthquake parameters.

Potential Vulnerabilities

The potential exists for false alarms and missed alarms from the earthquake early warning system, and for a train to be so close to the earthquake that strong shaking arrives before the warning. Even if the warning arrives promptly, it takes time to slow trains, so they could still be traveling fast when shaking arrives. Train control logic can involve incorrect assumptions about soil conditions and the shaking at which damage can occur. Thus, the railroad might set the system's action triggers too high or too low. The format of the alert occasionally changes (in California, formats have changed as frequently as every two months), and the earthquake could happen while the vendor or railroad is upgrading its system to support the changes to the alert format. The potential exists for earthquake shaking, ground failure, or other secondary hazards to damage viaduct, at-grade rail, or tunnels close to the train, so that despite slowing, vehicles are still damaged.

Implementation Costs

Software development to add modules to train control took BART a few hundred hours of labor. BART also spent some time consulting with experts. The total cost to BART amounted to less than $100,000. Metrolink expects implementation to cost on the order of $5 million.

Hardware and Software Requirements

BART required no additional hardware. BART information technology personnel wrote new control modules to receive and interpret the warning data, estimate ground motion at approximately 10 locations, and code train control decisions.

Training, Education, and Outreach

BART train operators and personnel at operations control centers perform quarterly drills related to several perils. Earthquake early warning is added to this training.

Maintenance Requirements

Minimal system maintenance is required, but the user should maintain an ongoing relationship with the provider of the alert data. The railroad must commit to long-term maintenance and monitoring to ensure that the system continues to operate as expected.

Examples of Past Use

Japan Rail introduced the Urgent earthquake Detection and alarm System (UreDaS) to its Shinkansen (bullet train) system in 1992. In the March 11, 2011, Tohoku earthquake, UreDaS triggered the emergency brakes on 27 bullet trains ten seconds before shaking reached mainland Japan. None of the 19 trains running through the affected area were derailed and no casualties were sustained on the trains (Southgate et al. 2013).

BART adopted earthquake early warning in 2012 (Associated Press 2012, KPIX5 2012). When the alarm is triggered, the train control system sends a speed restriction command to trains. This system removes human response time and can even slow trains down before the shaking arrives, depending on how far away the earthquake is centered. Trains are converted to manual operation with automatically reduced speed. They proceed slowly to the next destination to make sure that no tracks are damaged. Once tracks are deemed safe, trains resume normal operations. For more information, contact Chung-Soo Doo, BART Principal Engineer, Structural Engineering Division Maintenance & Engineering Department, CDoo@bart.gov, 1-510-287-4753.

The author could find no instance of earthquake early warning yet implemented in engineer-controlled trains with positive train control. Metrolink is in the process of adding earthquake early warning to its positive train control technology and expects to be the first such railroad. For more information, contact Metrolink, 1-800-371-5465.

References

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