Image 1: A derailed Shinkansen bullet train, Niigata Prefecture, Japan, 2004. *Source: Japanese Transportation Safety Committee*.

CASE STUDY 4:

An Earthquake Early Warning for Japanese Bullet Trains

The problem

Lying on the 'Ring of Fire' around the Pacific Ocean, Japan is prone to major earthquakes. These earthquakes pose significant risks to infrastructure, especially to the Shinkansen – the Japanese high speed railway system – whose bullet trains travel at speeds of up to 300 km per hour (188 miles per hour). If a train were travelling at such speeds when an earthquake hit it could be derailed, leading to disastrous loss of life. Image 1 shows a Shinkansen bullet train derailed in the Niigata Prefecture, Japan, 2004; none of the 154 passengers on board were injured or killed[1].

The science

Scientific study of ground movements before and during earthquakes led to the discovery of two different types of seismic wave that transmit an earthquake's energy through the ground: P-waves (P stands for Primary), and S-waves (S for Secondary). P-waves travel fastest from the earthquake's hypocentre but cause only a few preliminary earth tremors. The main earth movements we feel in an earthquake, and that cause most damage, are caused by the slower-moving S-waves (Figure 1)[2]. Scientists have used this understanding to develop better and better seismometers, sensitive measuring instruments which can detect even very weak P-waves[3–5].

1 Ogura M. The Niigata Chuetsu Earthquake - Railway Response and Reconstruction. Japan Railway & Transport Review. 2006; 43; 46-63.

2 *Ibid.*
3 *Ibid.*
4 Shimamura M, Yamamura K. A study on the performance of Seismic Early warning system. Proceedings of Railway Mechanics. 2008; 12:131-138.
5 Ashiya K, Sato S, Iwata N, Korenaga M, Nakamura H. Application of earthquake early warning information to earthquake alarm systems in railways. Exploration Geophysics. 2007; 60:387-397.

Based on this scientific advance, the technology of earthquake early warning was developed. When a seismograph detects fast-travelling P-waves, we know that destructive S-waves are likely to follow in a few seconds (depending on where the seismograph is relative to the earthquake's hypocentre). Given that electrical signals travel at much faster speeds than S-waves, automatic response signals can be activated within these few seconds, sending out warnings and activating mechanisms that reduce the vulnerability of transport systems, manufacturing plants, and nuclear and chemical processes [6, 7].

The application to policy and practice

The Urgent Earthquake Detection and Alarm System (UrEDAS) was introduced to the Shinkansen in 1992. Seismometers are placed at points along the train tracks and at the coast (to sooner detect seismic waves from earthquakes off the coast, Figure 1). If P-waves are detected, it is assumed that a large earthquake is coming and the power supply from electricity substations to the tracks is automatically stopped, triggering emergency brakes on all moving trains. The trains therefore come to a halt in the seconds before the earthquakes hit, making them far less likely to derail [8].

Alongside the UrEDAS, anti-seismic reinforcement works – such as quakeproof bridges and tunnels – as well as anti-derailing systems have been introduced to increase the resilience of the physical rail network.

Did it make a difference?

On the afternoon of 11th March 2011, a seismometer at Kinkazan Island on the north east coast of Japan detected seismic P-waves and sent an automatic stop signal via the UrEDAS to the Shinkansen's electric power transmission system, triggering the emergency brakes on 27 bullet trains. Ten seconds after the warning signal went out, a massive 8.9 Magnitude earthquake hit mainland Japan. Although this 'Great East Japan Earthquake', and the following tsunami, caused immense destruction and loss of life in eastern Japan, none of the 19 trains running through the affected area were derailed and no casualties were sustained on the trains.

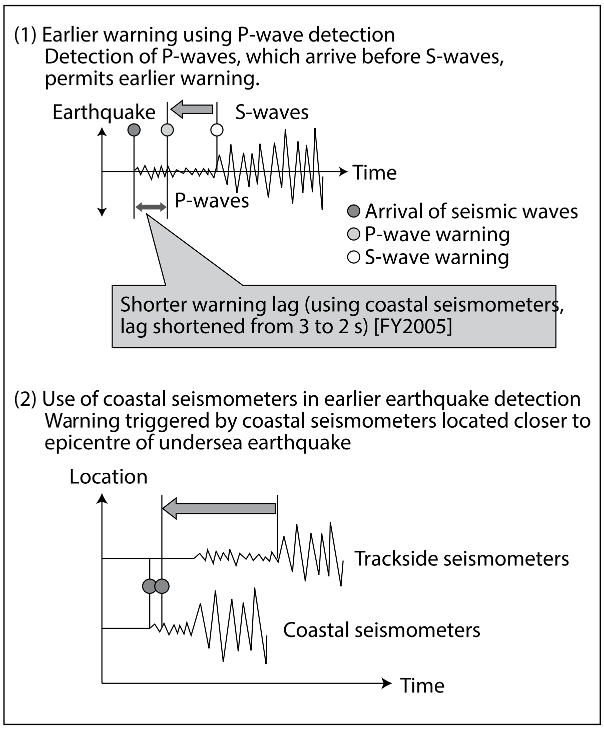

Figure 1: Diagrams showing the additional seconds of warning time given by improved detection of P-waves and use of coastal seismometers. *Source: Ogura, 2006* [9].

6 Shimamura M, Yamamura K. A study on the performance of Seismic Early warning system. Proceedings of Railway Mechanics. 2008; 12:131-138.
7 Ashiya K, Sato S, Iwata N, Korenaga M, Nakamura H. Application of earthquake early warning information to earthquake alarm systems in railways. Exploration Geophysics. 2007; 60:387-397.
8 Ogura M. The Niigata Chuetsu Earthquake - Railway Response and Reconstruction. Japan Railway & Transport Review. 2006; 43; 46-63.
9 *Ibid.*