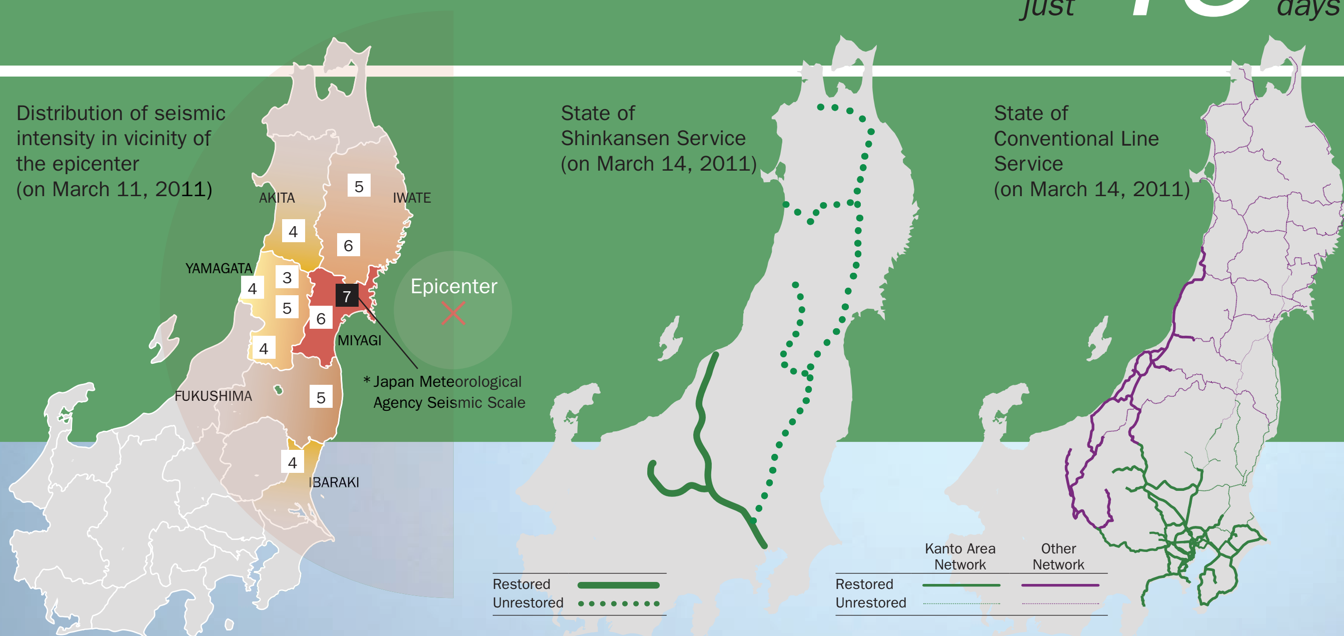
FEATURE 1: *GREAT EAST JAPAN EARTHQUAKE: HOW WE MANAGED TO RESTORE THE TOHOKU SHINKANSEN LINE IN JUST 49 DAYS*

We suffered severe damage over a wide area in the Great East Japan Earthquake, one of the largest recorded in human history, but are working swiftly and vigorously toward reconstruction.

The time it took to restore the Tohoku Shinkansen Line

just **49** *days*



OVERVIEW OF GREAT EAST JAPAN EARTHQUAKE AND EXTENT OF DAMAGE

The Great East Japan Earthquake struck at 2:46 p.m. on March 11, 2011, with its epicenter off the coast of Miyagi Prefecture's Oshika Peninsula. It was the largest earthquake recorded in Japanese history and also one of the biggest ever recorded in the world, at a magnitude of 9.0 on the Richter scale, and a source region roughly 500 kilometers north to south, off the shore between Iwate Prefecture and Ibaraki Prefecture, and around 200 kilometers east to west. The earthquake triggered a massive tsunami with wave heights in some places exceeding 10 meters and a maximum run-up of 40.5 meters, causing catastrophic damage to the Pacific coastline of the Tohoku and Kanto regions.

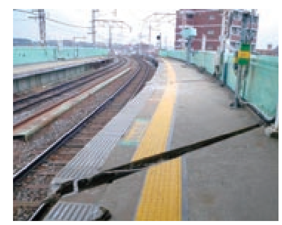
State of Damage Resulting From the Great East Japan Earthquake and Aftershocks

	NUMBER OF DAMAGED SITES			MAIN DAMAGE
	Main March 11 earthquake	Aftershocks April 7 onward	Total	
Tohoku Shinkansen Line	1,200	550	1,750	•Collapsed, tilted or cracked electric poles (810 sites) •Snapped overhead wires (670 sites) •Damage to viaduct columns (120 sites)
Other Shinkansen Lines	—	—	—	
Subtotal	1,200	550	1,750	
Conventional Lines (excluding 7 segments damaged by tsunami or segments withheld from inspection)	4,400	850	5,250	•Collapsed, tilted or cracked electric poles (1,240 sites) •Track irregularity (2,820 sites) •Platform collapse (270 sites)
Conventional Lines (7 segments with tsunami damage)	1,730	—	1,730	•Station buildings swept away (23 stations) •Tracks swept away or buried (65 sites, total of some 60 km) •Bridge piers swept away or buried (101 sites)
Conventional Lines (segments withheld from inspection)	Unknown	Unknown	Unknown	
Subtotal	6,130	850	6,980	
Total	7,330	1,400	8,730	

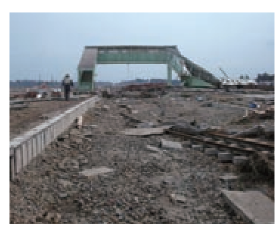
Collapsed electric poles (Tohoku Shinkansen Line, between Furukawa and Kurikoma-Kōgen)

Damaged viaduct columns (Tohoku Shinkansen Line, between Mizusawaesashi and Kitakami)

Track irregularity (Joban Line, between Mito and Katsuta)



Collapsed platform (Senseki Line, Nigatake Station)



Tracks swept away (Joban Line, within Shinchi Station)

Bridge piers swept away (Yamada Line, between Rikuchu-Yamada and Orikasa)

Notes: 1 The number of damaged sites is an approximation
2 Total of the number of damaged sites excludes conventional line segments withheld from inspection

The Tohoku Shinkansen Line sustained damage at approximately 1,200 sites along the 500 km or so stretch between Omiya and Iwate-Numakunai. Examples included collapsed or tilting electric poles, snapped overhead wires, and damage to viaduct columns. Conventional lines were also affected, with damage at roughly 4,400 sites along 36 railway segments in such forms as collapsed or tilting electric poles, track irregularity, and platform collapse. On seven segments along conventional lines suffering damage from the tsunami, 23 station buildings were swept away, and some 60 km of track was either swept away or buried, as were bridge piers at some 101 sites. Intermittent aftershocks from April 7 onward only served to exacerbate the damage.

Immediately after the earthquake struck, JR East stopped all train services. Drivers, conductors, station staff and all other employees did everything within their power to lead the evacuation of passengers in areas where tsunami warnings were issued. As a result, there were no passenger fatalities at stations or on trains in service at the time.

Great East Japan Earthquake Compared to Past Massive Earthquakes

	GREAT EAST JAPAN EARTHQUAKE	NIIGATA CHUETSU EARTHQUAKE	GREAT HANSHIN-AWAJI EARTHQUAKE
Date	March 11, 2011	October 23, 2004	January 17, 1995
Epicenter	Off the Sanriku Coast	Chuetsu region of Niigata Prefecture	Near Awaji Island
Magnitude	9.0	6.8	7.3
Maximum seismic intensity	7	7	7
Prefectures recording a seismic intensity of lower 5 or stronger	17	5	3
Full restoration date of Shinkansen (restoration time)	April 29, 2011 (49 days)	December 28, 2004 (66 days)	April 8, 1995 (81 days)

RESTORATION OF THE TOHOKU SHINKANSEN LINE

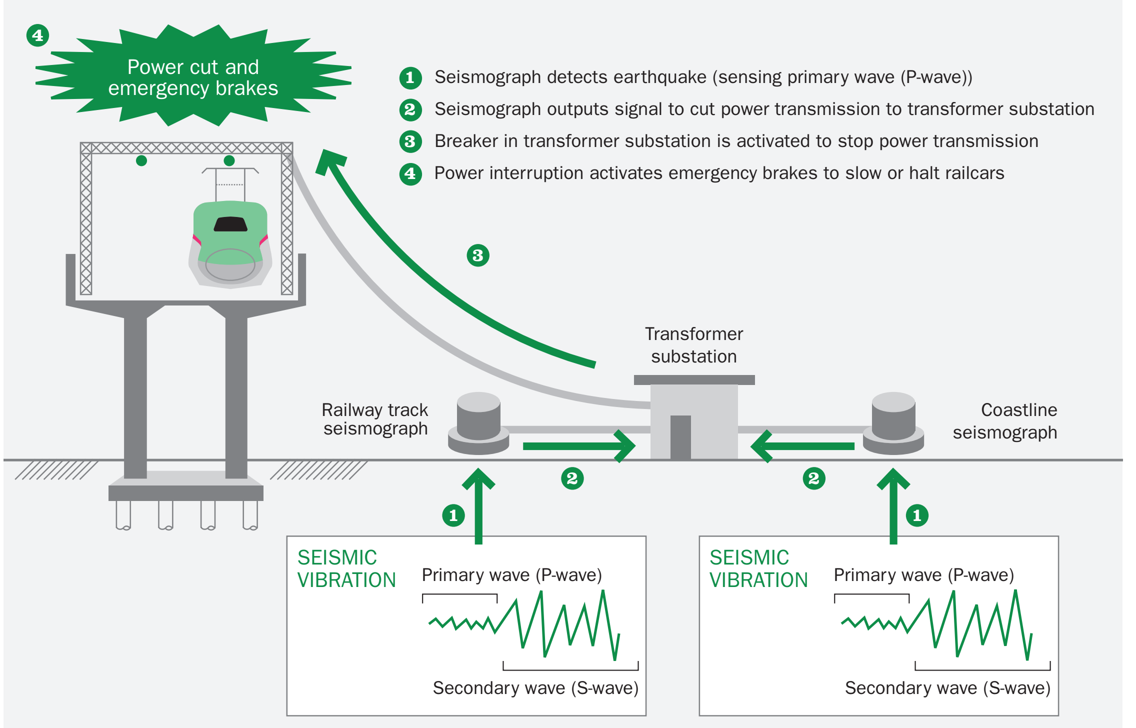
On April 29, 49 days after the earthquake, the Tohoku Shinkansen Line was fully restored to service. It took 81 days to fully restore the Sanyo Shinkansen Line after the Great Hanshin-Awaji Earthquake of January 1995 in Kobe, which caused viaduct columns to collapse, while tunnel damage caused by the Niigata Chuetsu Earthquake of October 2004 caused the Joetsu Shinkansen Line to remain out of service for more than two months. The Tohoku Shinkansen Line was restored quickly by comparison, despite the Great East Japan Earthquake being Japan's largest in recorded history. This can be attributed to a lack of fatal damage despite the earthquake's unprecedented scale, and to a group-wide restoration effort, with human and material support from outside the JR East Group. In particular, the three factors outlined below were crucial in the swift restoration of the Tohoku Shinkansen Line.

Earthquake Early Warning (EW) System for Shinkansen

When the earthquake hit, the coastline seismograph on the coastal island of Kinkasan, Miyagi Prefecture, detected seismic activity 12–15 seconds before tremors strong enough to exceed the threshold for suspending Shinkansen operations reached the city of Sendai and its vicinity. This early detection triggered an alarm, while simultaneously cutting the power to the Tohoku Shinkansen Line and activating the emergency brakes to all affected railcars. As a consequence, there were no derailments among the Shinkansen super express trains in service at the time.

JR East had been installing seismographs along its Shinkansen lines and the Pacific and Sea of Japan coasts, ever since the Tohoku and Joetsu Shinkansen lines began operations in 1982. As of March 31, 2011, the number of seismographs totaled 97, of which 81 are located along railway tracks and 16 are situated on the coastline. The Earthquake Early Warning (EW) System for Shinkansen came into service in 1998, followed in 2006 by the addition of a function for cutting the transmission of power in proportion with seismic magnitude to areas affected in an earthquake.

A Diagram of the Earthquake Early Warning System for Shinkansen



The EW System for Shinkansen functions as follows. First, railway track or coastline seismographs detect the earthquake's primary wave (P wave). Before the arrival of the secondary wave (S wave), the seismographs estimate the epicenter and magnitude of the earthquake, immediately cutting power transmission as required to areas likely to be affected, and causing trains to drop speed or come to a halt.

Aseismatic Reinforcement of Viaduct Columns

Over the years, JR East has striven to improve structures to a level of aseismatic adequacy sufficient to withstand earthquakes on the scale of the Great Hanshin-Awaji Earthquake. The Great East Japan Earthquake was larger still; indeed it was the largest in recorded Japanese history. Yet, although viaduct columns sustained some damage, there was no fatal structural damage. For example, there were no cases of viaduct columns toppling as they did in the Great Hanshin-Awaji Earthquake, or of tunnels collapsing as was observed in the Niigata Chuetsu Earthquake. It would therefore seem that aseismatic reinforcement measures have had the desired effect.

In fiscal 1996, the company commenced emergency aseismatic reinforcement work on viaduct columns susceptible to shear failure, and by fiscal 2001 had completed work in the southern Kanto, Sendai and other areas.

Following the Sanriku-Minami Earthquake, which struck in May 2003, the geographical scope of aseismatic reinforcement measures for viaduct columns was broadened, and after the Niigata Chuetsu Earthquake of October 2004, work also commenced on bridge piers. As a consequence, aseismatic reinforcement for shear-critical viaduct columns and bridge piers was completed a year ahead of schedule for the entire Shinkansen lines of JR East in fiscal 2008, and for the conventional lines in the Southern Kanto region, Sendai and other areas by fiscal 2009.

Since fiscal 2010 we have undertaken a project approximately five years in length for a second round of aseismatic reinforcements with a view to further improving safety when an earthquake strikes. Among viaduct columns of the type susceptible to flexural failure in areas such as southern Kanto and Sendai, we identified those likely to sustain damage in a powerful earthquake, and undertook reinforcement measures to jacket steel plates around the columns.

Aseismatic reinforcement
(Yokosuka Line, between Musashi-Kosugi and Shin-Kawasaki)

Viaduct columns susceptible to shear failure:
These are extremely dangerous in the event of an earthquake, as they can collapse suddenly with no resistance.

Viaduct columns susceptible to flexural failure:
Aseismatic resistance is greater than columns susceptible to shear failure. However, strong vibrations can cause damage to the head and heel of the column.

Exhaustive Restoration Effort

The Great East Japan Earthquake inflicted damage across a wide area and in many forms along the Tohoku Shinkansen Line, including collapsed electric poles, snapped overhead wires, damage to viaduct columns, and track irregularities. As the main shock on March 11 caused damage at roughly 1,200 sites, with the April 7 aftershock generating damage at another 550 locations, restoration took some time.

Not only did electric poles and overhead wires sustain widespread damage that needed to be repaired, but they also required some fine adjustment for alignment with tracks and structures before services could resume.

In total around 8,500 people a day participated in the restoration effort, comprising employees from JR East and its subsidiaries, and also from partner companies. With considerable cooperation from the government and other related parties, restoration work went ahead even in the immediate aftermath of the earthquake when gasoline and light diesel oil were in short supply. Other railway operators also pitched in, providing personnel to assist in on-site inspections and restoration work, as well as material aid in such forms as maintenance vehicles, track inspection cars, inspection equipment, and light diesel oil.

Restoration work continued day and night, as a result of which the Tohoku Shinkansen Line resumed service on all sections just 49 days after the earthquake, on April 29.

LOOKING FORWARD

As a consequence of aseismatic reinforcement work performed on viaduct columns, bridge piers and so forth in the wake of previous major earthquakes such as the Great Hanshin-Awaji Earthquake, augmented by seismographs and the associated installation of the EW System for Shinkansen, JR East's railway facilities avoided crippling damage despite going through the largest quake ever recorded in Japan. Furthermore, there were no derailments of Shinkansen trains in service at the time.

Going forward, JR East will continue taking steps to further improve safety in the event of an earthquake, starting with discussion over additional aseismatic reinforcement measures and steps to enhance seismograph accuracy.

Restoration work on the Joban Line

Aseismatic Reinforcement Measures Undertaken and Underway

		Number of viaduct columns susceptible to shear failure			Number of viaduct columns with low aseismatic adequacy susceptible to flexural failure
		Emergency aseismatic reinforcement measures in response to the Great Hanshin-Awaji Earthquake	Aseismatic reinforcement measures in response to the Sanriku-Minami Earthquake and Niigata Chuetsu Earthquake	Total	Second round of aseismatic reinforcements
Timeframe		Fiscal 1996–fiscal 2001	Fiscal 2004–fiscal 2009	—	Fiscal 2010–fiscal 2014 (scheduled)
Areas covered		Southern Kanto and Sendai area	Shinkansen: Entire lines including the southern Kanto and Sendai area Conventional lines: southern Kanto and Sendai area	—	Southern Kanto, Sendai and areas near active fault lines
Viaduct columns	Shinkansen Lines	3,100	15,400 (areas other than southern Kanto and Sendai)	18,500	6,700
	Conventional Lines	7,300	5,300 (southern Kanto and Sendai area)	12,600	5,500
Bridge piers	Shinkansen Lines	—	2,340	2,340	—
	Conventional Lines	—	540	540	—

* The number of viaduct columns is an approximation