The Earthquakes

A series of several major earthquakes rocked the Chuetsu region of Niigata along the Sea-of-Japan coast from 17:56 on 23 October 2004. Some basic figures are given in Figure 1. Figure 2 shows the JR East track that suffered damage and the time it took before services were resumed. Fairly long sections of the shinkansen track between Echigo Yuzawa and Niigata were damaged, as well as sections of narrow-gauge track on the Shin'etsu, Echigo and other lines.

**Figure 1 Chuetsu Earthquake Seismic Activity**

<table>
<thead>
<tr>
<th>Date and time of main earthquake:</th>
<th>23 October 2004 at 17:56</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epicentre:</td>
<td>Chuetsu district of Niigata Prefecture (37°37'N, 136°39'E)</td>
</tr>
<tr>
<td>Richter Magnitude:</td>
<td>6.8 (Maximum seismic intensity (SI) of 7, registered in Kawaguchi-machi)</td>
</tr>
<tr>
<td>Number of aftershocks:</td>
<td>Four around 9:00,Eighteen around 15:35,677 large enough to be felt (until 28 December)</td>
</tr>
<tr>
<td>Peak ground acceleration:</td>
<td>Non-JR East seismometer: 2515 gal (in Kawaguchi-machi), JR East seismometer: 846 gal (at Shin Kawaguchi transformer substation, Joetsu Shinkansen)</td>
</tr>
</tbody>
</table>

**Figure 2 Emergency Stops after Chuetsu Earthquake**

**Figure 3 Response Timeline**

<table>
<thead>
<tr>
<th>Emergency Response Meetings</th>
<th>Press Conferences</th>
<th>Other Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>18:00 Response Headquarters established within JR East Head Office</td>
<td>17:56 Began gathering information on possible injuries and damage (Director sent from Headquarters)</td>
<td>21:50 M. Otsuka, JR East President, prepares to return to Japan from London, UK, where on investor relations business.</td>
</tr>
<tr>
<td>19:40 First Emergency Response Meeting</td>
<td>18:19 First report indicates Toki 325 derailed between Urasa and Nagaoka</td>
<td></td>
</tr>
<tr>
<td>• Ascertain condition of damaged equipment</td>
<td>20:25 Press conference</td>
<td></td>
</tr>
<tr>
<td>• Ascertain derailment situation</td>
<td>• Overall situation</td>
<td></td>
</tr>
<tr>
<td>• Ascertain how many people on board</td>
<td>• Toki 325 derailed</td>
<td></td>
</tr>
<tr>
<td>• Ascertain positions of halted trains</td>
<td>• No deaths or injuries</td>
<td></td>
</tr>
<tr>
<td>22:00 Emergency Response Meeting</td>
<td>22:45 Press conference</td>
<td></td>
</tr>
<tr>
<td>• Planned passenger relief</td>
<td>• Eight carriages derailed</td>
<td></td>
</tr>
<tr>
<td>• Ascertain condition of damaged equipment</td>
<td>• Situation of trains halted between stations</td>
<td></td>
</tr>
<tr>
<td>• Ascertain derailment situation</td>
<td>• Relief effort plans, etc.</td>
<td></td>
</tr>
<tr>
<td>• Decided to send Executive Director to derailment site</td>
<td>00:27 Press conference</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Relief efforts</td>
<td></td>
</tr>
<tr>
<td>03:30 Emergency Response Meeting</td>
<td>09:03 Press conference</td>
<td></td>
</tr>
<tr>
<td>• Report on derailment</td>
<td>• Derailment situation</td>
<td></td>
</tr>
<tr>
<td>• Passenger relief efforts</td>
<td>• Equipment damage</td>
<td></td>
</tr>
<tr>
<td>08:00 Emergency Response Meeting</td>
<td>• Relief efforts</td>
<td></td>
</tr>
<tr>
<td>• Report on derailment</td>
<td>09:30 Press conference</td>
<td></td>
</tr>
<tr>
<td>• Report on equipment damage</td>
<td>• Derailment situation</td>
<td></td>
</tr>
<tr>
<td>• Planning 24 October passenger services</td>
<td>• Equipment damage</td>
<td></td>
</tr>
<tr>
<td>• Methods to get derailed cars back on track (proposals)</td>
<td>• Relief efforts</td>
<td></td>
</tr>
<tr>
<td>11:30 Emergency Response Meeting</td>
<td>17:05 Press conference</td>
<td></td>
</tr>
<tr>
<td>• Report on equipment damage</td>
<td>• Damaged equipment</td>
<td></td>
</tr>
<tr>
<td>• Plans for getting derailed cars back on track</td>
<td>• Current passenger operations situation</td>
<td></td>
</tr>
<tr>
<td>• Methods to get derailed cars back on track</td>
<td>• User situation</td>
<td></td>
</tr>
<tr>
<td>• Situation of staff sent to site for recovery efforts</td>
<td>17:05 Press conference</td>
<td></td>
</tr>
<tr>
<td>• Current passenger operations situation</td>
<td>• Damaged equipment</td>
<td></td>
</tr>
<tr>
<td>16:00 Emergency Response Meeting</td>
<td>• Current passenger operations situation</td>
<td></td>
</tr>
<tr>
<td>• Report on equipment damage</td>
<td>• User situation</td>
<td></td>
</tr>
<tr>
<td>• User situation</td>
<td>17:05 Press conference</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4**

- Main epicentre
- Aftershock epicentres (≥M6)
- Niigata
- Niitsu
- Tsubame Sanjo
- Nagaoka
- Echigo
- Yuzawa
- Joetsu
- Shinkansen
- Shin'etsu Line
- Miyauchi
- Iiyama Line
- Tohoku Line
- Shinkansen
- JR East narrow-gauge lines

**Figure 6**

- Main epicentre
- Aftershock epicentres (≥M6)
- Niigata
- Niitsu
- Tsubame Sanjo
- Nagaoka
- Echigo
- Yuzawa
- Joetsu
- Shinkansen
- Shin'etsu Line
- Miyauchi
- Iiyama Line
- Tohoku Line
- Shinkansen
- JR East narrow-gauge lines

**Figure 7**

- Main epicentre
- Aftershock epicentres (≥M6)
- Niigata
- Niitsu
- Tsubame Sanjo
- Nagaoka
- Echigo
- Yuzawa
- Joetsu
- Shinkansen
- Shin'etsu Line
- Miyauchi
- Iiyama Line
- Tohoku Line
- Shinkansen
- JR East narrow-gauge lines
As soon as his wife told him a JR East shinkansen had derailed, I was in Tokyo at the time and as soon as we heard that a shinkansen had derailed, JR East executive officers including myself rushed to headquarters, with nearly everyone arriving by 19:00.

By this time, we had confirmed that a train had derailed, but fortunately with no injuries, so the meeting did not have the tension it would otherwise have had.

The centre column shows our press conferences after the meeting at 20:25, 22:45, and at 00:27 in the small hours of the next day. At the time, we had no clear idea of circumstances in the disaster area. An Executive Director who joined the company at the same time as myself and now in charge of operations and marketing made it clear that we had to be frank and open about everything that we knew and didn’t know. This was the right approach, and set the stage for the excellent rapport we maintained with the media over the next 60 days.

The column on the right highlights the activities of our company President, Mr Mutsutake Otsuka. He was in London on JR business when the quakes struck, and luckily phoned his wife in Japan that evening not knowing about the accident. As soon as his wife told him a JR East shinkansen had derailed, he began preparing to return to Japan immediately, and arrived at headquarters in Japan at 10:30 on 24 October, proving just how small the world has become! He proved our faith in him as a President who is always ready to go where he is needed and point us in the right direction. His quick return has become something of a legend at JR East.

He put me in charge of the Field Response Headquarters and I flew by helicopter next morning to the derailment site. We arrived there at about noon and made a number of arrangements. I was trackside by 13:00 serving as Chief of Field Response Headquarters. I must confess now that I had no idea how our recovery efforts would go, but thankfully, as I will explain later, reconstruction has gone almost entirely according to plan.

Figure 4 shows the shinkansen stations from Jomo Kogen to the Niigata terminus and the position of trains stopped on the line after the earthquakes.

The Toki 325 shinkansen carrying 151 passengers derailed close to Nagaoka Station and five other trains carrying...
passengers had stopped without derailing between stations. Two other trains had also stopped temporarily but could proceed almost immediately thereafter.

**Passenger Safety First**

The first shock halted trains carrying from 151 to 410 passengers and every passenger had to be guided to safety by the train crews and our employees who rushed from stations and depots. The evacuation routes were varied, with some passengers climbing a shaft from a tunnel and others descending from a viaduct. Our employees had undergone rigorous disaster-response training and I was confident of their professionalism. One might have expected passengers to panic, but our crews remained calm during the evacuation and kept the passengers calm too. No one was injured before or during the evacuation, giving everyone at Field Response Headquarters a strong sense of pride and encouraging us in our work.

Figure 5 shows photographs and a diagram of the derailed train to Niigata (left to right in the picture). The first carriage is at the extreme left and 22 of 40 axles derailed. Car No. 1 slipped into water drainage channel and came to rest at 30° angle.

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**Figure 5 Situation after Derailment**

- Train travelling to Niigata
- Tokyo-bound (up) track
- Niigata-bound (down) track
- Car No. 1 (tail car)
- Car No. 10 (lead car)

22 of 40 axles derailed. Car No. 1 slipped into water drainage channel and came to rest at 30° angle.

**Figure 6 Positioning Cars Back on Track—Plans and Implementation**

- Initial plan: Use jacks and cranes to position cars on tracks
  - Cars to be jacked: No. 10, No. 9, No. 8, No. 5
  - Cars to be lifted: No. 1, No. 2, No. 3, No. 4
- Revised plan: Cars to be positioned on track by crane
  - Site to be open to media
  - Cars to be moved from site to depot

- Revised plan: *New plan calls for positioning of all derailed cars on track by crane.*

- M6 Aftershock causes JR to abandon initial jacking plan.

- [Media invited to recovery site]
  - Media given illustrated documentation on proposed work

- [Media invited to recovery site]
  - New plan calls for positioning of all derailed cars on track by crane.

- [Press release]
  - 22 of 40 axles derailed
  - Car No. 1: 30° tilt
  - Car No. 4: 5° tilt
  - Proposed repatriation methods
  - Jacking and cranes

- 27 October M6 aftershock

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**Press release**

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**Press release**

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**Press release**

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27 October M6 aftershock

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**Press release**

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**Press release**

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the 40 axles had derailed either left or right of the track.
As I explain in greater detail later, cars 5, 8, 9 and 10 were slightly affected, cars 6 and 7 were unaffected, and cars 1 through 4 were badly derailed with car 1 shifting a long way towards the Tokyo-bound track and coming to rest at an alarming angle.

Aftershocks Caused Cold Sweats

Soon after I arrived at the site I realized that our first task would be to get the cars back on the tracks. Figure 6 is a timeline of our efforts to achieve this. On day 4, we began raising some cars. Our initial plan was to use jacks for slightly derailed cars and cranes for cars further off the track. What happened next was widely reported with headlines like ‘JR Workers Run for Their Lives.’ Just as we were about to start jacking, a violent aftershock of almost magnitude 6 rocked the area. During the jacking preparations, I was on the viaduct giving instructions. There had already been a small aftershock, so I decided to suspend the jacking operation. The site was open to the media and many media people had been on the viaduct, but nearly everyone had gone down to ground level after I suspended work. About the only people left on the viaduct were reporters from two media organizations. They were milling around, some with their cameras at the ready, so we shouted to them that the situation was dangerous and that they should get down because the work was suspended. They were slow and were still near the train as the major aftershock struck, explaining why they could take the pictures used as a media scoop. I guess it goes to show that being a slowpoke pays off sometimes.

The danger was obvious and it sent a chill down our backs. Without the small warning aftershock, if the violent shock had struck 30 minutes later, many workers would have been close to jacks supporting the carriage and some would probably have been injured.

Scenes of the violent aftershock and scrambling workers were shown on TV throughout Japan, which was a blessing for us because until then the media had been very critical, making comments like ‘The nearby expressway is back in operation, but 5 days have passed since the earthquake and JR East still hasn’t moved its derailed cars.’ After TV shots of the shinkansen cars rocking to and fro were broadcast, the media quieted and their stance changed to respect for the difficult job we faced.

We learned that the job was more dangerous than we had assumed, which led to a change in our strategy. Keeping safety in mind, we decided to lift all the derailed cars with cranes and started on 10 November. Figure 7 shows the main tasks. The area around the derailment site is all rice paddy, and we had to bring three 360- to 450-tonne cranes across the paddy from a company in Niigata. Basically, the job involved using two cranes to hoist one car, and the third crane to steady the adjacent car to prevent it shifting. Each derailed car was positioned back on track in order, one after the other. The whole operation was quite a sight!

The bottom right photo shows how we positioned the cranes close to the viaduct, which was difficult in itself. First, we needed permission to access the land (luckily the rice had just been harvested). Next, we had to lay down metal sheets and drive piles to create a firm base for the cranes. This took some time.

The local people must have wondered what we were up to. Some thought we were going to lower the whole shinkansen train set to the ground. What we did was simpler—we used the cranes to hoist each car from the Niigata-bound track to the Tokyo-bound track. This work was finished by November 17.

Figure 8 shows the track in the general area of the derailment. I will explain the general mechanism of the derailment without getting too technical. Figure 8 has five parts, the top left shows the track closest to Tokyo, the bottom right closest to Niigata. The figure 206 km 191 m (meaning distance from Omiya base) near...
the middle of the second section from the top was where we found marks indicating that wheels had mounted the right rail. The rails were badly deformed from the area shown on the left of the fourth section. Because the construction is a slab track, it was obvious that the rail fasteners here had been ridden over by the wheels. The rail was broken in three places as shown in the bottom of the figure. The train ran about 1.6 km from where the wheels first mounted the rail to where it finally came to a stop.

**Many Contradicted Assumptions**

Next, I went to inspect the track where the derailment began. My first impression was that although the rails were badly twisted and had been severely thrown out of alignment in places, the concrete slab track itself was in good condition. The train had run on the slab, causing some damage, but the slab remained almost unbroken. Basing my judgment on past experience, I assumed that if we simply replaced the rails and repaired the area where the metal fasteners hold the rails to the slab, we could have the shinkansen fully operational in about 2 weeks. As far as the track condition was concerned this may have been on target, but other problems—including a need to change our system for hoisting the cars—slowed progress considerably. In addition, although I was on site, we discovered only later that the tunnels between the derailment and Urasa Station were

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**Figure 8 Damage to Railway Infrastructure near Shinkansen Derailment Site**
badly damaged. This was certainly a rude awakening!
Figure 9 shows the track between Echigo Yuzawa, Urasa, Nagaoka and Tsubame Sanjo stations, with Niigata Station off to the right. The most damaged section was between Urasa and Nagaoka stations, near the epicentre.

There are five tunnels between Urasa and the derailment site. Proceeding from the station we have the Urasa and Horinouchi tunnels, about 800 m of aboveground

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**Figure 9 Major Damage to Aboveground Structures—Joetsu Shinkansen**

- Slab track deformed
- Fallen concrete
- Cracks in central passageway
- Subsidence in two places, on Jodogawa Bridge and Toka-machi Viaduct
- Slab and rail fasteners damaged
- Rails thrown off track
- Near 206 km 220 m to 207 km 820 m
- Subsidence at one place on Kamishima Viaduct
- 14 catenary poles tilted
- 5 snow-melting stations damaged
- Between Nagaoka and Tsubame Sanjo stations
- 1 snow-melting station damaged
- Between Tsubame Sanjo and Niigata stations
- 1 snow-melting station damaged
- Near 206 km 600 m to 207 km 500 m
- Snail pole tilted
- 70 catenary poles tilted
- 2 snow-melting stations damaged
- Between Urasa and Nagaoka stations
- 44 catenary poles tilted
- 2 snow-melting stations damaged
- Uonuma Tunnel
- 1 column damaged
- 1 column damaged
- 1 column damaged
- 1 column damaged
- 1 snow-melting station damaged
- Uono-gawa Bridge
- Slab track deformed
- Fallen pieces from arch and side walls
- Side wall of central passageway damaged
Earthquake Disaster Countermeasures

Figure 10  Operation Restart Timeline—Joetsu Shinkansen

23 October 2004:  Earthquake strikes and services suspended on entire Joetsu Shinkansen
Shin Yuzawa transformer station 125 gal
Shin Muika-machi feeder station 270 gal
Shin-Kawaguchi transformer station 846 gal
Shin Nagaoka supplementary feeder station 466 gal
Shin Oshikiri feeder station 203 gal
Shin Nakanokuchi transformer station 116 gal
Shin Oshikiri secondary feeder station 87 gal

Echigo Yuzawa  Urasa  Nagaoka  Tsubame Sanjo  Niigata

24 October 2004:  Passenger services resume between Tokyo and Echigo Yuzawa stations

30 October 2004:  Passenger services resume between Tsubame Sanjo and Niigata stations

4 November 2004:  Passenger services resume between Nagaoka and Tsubame Sanjo stations

28 December 2004:  Passenger services return to full operation

We continued inspecting each area and repairing the viaducts, making it possible to resume passenger services in one section after another. The Tsubame Sanjo–Niigata section was reopened on 30 October followed by the Nagaoka–Tsubame Sanjo section on 4 November. Excluding the track between Echigo Yuzawa and Nagaoka, we were back in operation just 12 days after the earthquakes. Buses were used to carry passengers between Echigo Yuzawa and Nagaoka until the entire line was made fully operational again on 28 December. Figure 11 shows Uonuma Tunnel with damage in three places. The damage in the middle looks serious, but actually only some 5 to 10 m was badly damaged with about 100 m of the concrete substructure damaged by heaving. Even so, this was unusually serious for a tunnel bored through a mountain and we decided that we would not resume services until we
had made the tunnel stronger than it was before. Figure 11 shows how we inserted rock bolts into the bedrock to reinforce the tunnel structure and prevent lining collapse. We also installed fibre-reinforced concrete plates from the inside. In some cases we also inserted rock bolts through the tunnel flooring into the bedrock, making tunnel stronger than it had ever been.

**Announcing Resumption of Full Service**

We hesitated over announcing a date for resuming services over the entire line and waited until 19 November before doing so. Prior to this date, we were extremely busy determining how badly the tunnels were damaged.

The illustration in the top right of Figure 11 gives an idea of the complex structure of a tunnel. Concrete inverts are installed for the arch, tunnel walls and substructure. Next, the roadbed concrete is poured, and then 5-m slabs are installed on that. All these components make for quite a complicated structure.

We were most worried about fissures or gaps between the concrete inverts, roadbed concrete and bedrock, but there was no way of knowing without peeling back the concrete facing. There was no time to peel back the facing throughout the entire tunnel, so we drilled holes every 20 m to obtain samples. This was long and frustrating work, but it helped us to eventually decide to tell the public on 19 November when we hoped to resume services.

The top left photograph in Figure 12 shows some of the damage to Uonogawa Bridge. Damage to the mid-level of the piers looks extensive, but from a civil engineering viewpoint they were not difficult to repair. The rough drawings show how we plugged the fissures with shotcrete, applied reinforced concrete jackets around the piers above the water line and steel jackets below it. This made the structure more quake-resistant. The work was a little more difficult than I describe, but you can see the repaired structure in the bottom photograph.

In the derailment area, the slabs were basically in good condition, so remedial work consisted mainly of replacing the metal fasteners. This job went according to plan.

Repairing the slab track in the tunnel was more complicated. The photographs in Figure 13 do not show the structural components or remedial process clearly,
so I will explain. After the concrete base is poured during the original construction, concrete slabs, each measuring about 2.34 x 5 m and weighing about 5 tonnes are laid one-by-one on top of the base. We had to lift about 300 of these slabs, remove them from the tunnel, repair the concrete base and slabs, then bring the slabs back in four or five at a time and realign them. This was hard and long work, but we finished it on schedule.

Figure 14 shows the final running tests in late December after most of the construction and remedial work was finished. We began the speed tests on 24 December, starting at about 30 km/h and increasing in increments. The photograph on the right shows an East-i track inspection car that used to be nicknamed Dr Yellow. On day 1, we began return runs at 30 km/h, then increasing sequentially to 70, 110, and 160 km/h. Most of our attention was focussed on the most damaged track section between Urasa and Nagaoka. Although our test runs went as high as 160 km/h, the first resumed passenger services ran at a reduced speed of 110 km/h over this section. All safety verification tests are generally conducted in this fashion, but we were restricted in this case because of the fast-approaching service resumption date. We managed to finish the running tests in 2.5 days, running back and forth on 26 and 27 December. Then, the first day of full services came on 28 December.

The first passenger-carrying train to pass through Uonuma Tunnel leaves Niigata Station at 05:40 each day. Company President Mr Otsuka was determined to ride this train. I am sure he didn’t intend to become a human sacrifice, but he said he wanted to ride in the lead car of the first passenger train to use the track his company had repaired. He boarded in good spirits and I joined him in the lead car.

The driver was quite young. Many of our drivers had been at the controls during
the more than 2 days of running tests through Uonuma Tunnel, although some had driven only at lower speeds. But our driver had not. I didn’t know this and asked, ‘You must have been on the test runs, eh?’ but he replied, ‘No, today’s the first time.’ President Otsuka then asked him, ‘Are you nervous?’ He said nothing. On this first commercial run through the tunnel since the earthquake, I thought he might say, ‘No, not nervous at all!’ at least if that was the case. Of course, he could hardly say ‘Yes, I’m nervous’ to the President—so he remained silent.

Mr Otsuka rose to the occasion. ‘Mr Ogura here, his staff and many workers did what was necessary to repair the tunnel and make it stronger than before, so there’s no need to worry. Just relax and take us to Tokyo!’ The driver listened, obviously only half believing him, but I was very glad to hear Mr Otsuka express his confidence in our workers and me. During the 3 days of running tests a number of interesting things happened, but I will save discussion of those events for another time.

### Damage to Narrow-gauge Tracks

So far, I have discussed only damage to our shinkansen, but our narrow-gauge lines were also badly affected as you can see in Figure 16. Damage to the shinkansen stole much of the limelight from our conventional lines, explaining why not much was reported about them. The top right photograph in Figure 16 shows a line along the Shinano River where the track paralleling the river suffered dramatic damage at cliffs and slopes. Altogether, our narrow-gauge track was damaged at 86 locations. As shown, the tracks were washed out, leaving what appears to be a rope ladder instead of a railway. Quite a few trains were on the affected tracks, but all stopped before or after damaged track, so luckily not one train derailed and no passengers were injured.

The bottom of Figure 17 shows dates and places of service resumption after remedial work was completed. The columns from left to right show the dates and affected sections of the Shin’etsu, Joetsu, Iiyama, Tadami and Echigo lines. The top bar shows that sections on all five lines shut on 23 October. Services on the affected sections resumed gradually—the Echigo Line on 26 October, part of the Joetsu Line on 2 November, the Joetsu Line as far as Koide on 13 November, the Tadami Line on 20 November, and the Shin’etsu Line on 29 November.

Finally, on 27 December, 1 day before full Joetsu Shinkansen services resumed, trains began running again on affected sections of the Joetsu and Iiyama lines. Somehow we found a way to get all our narrow-gauge lines back in operation.

The photographs on the left of Figure 15 show the slope failure and roadbed collapse on the Joetsu Line next to the Shinano River. The scene of track suspended in mid-air like a rope ladder is typical. The photographs in the centre were taken after the remedial work. The two diagrams on the right show new retaining walls with earth laid behind them, using the popular Reinforced Railroad with Rigid facing (RRR) construction method, taking into account soil drainage. Thanks to these solid embankments, passenger services are once again operating smoothly.

The Uonogawa Bridge on the Iiyama Line (Fig. 18) is quite old and was severely damaged, as the photograph shows. The bridge dates from another era before reinforcing; pier 13P in the foreground experienced considerable failure in its upper section and the next pier (14P) was severed in the middle, because the top section shifted laterally by about 50 cm. This is a textbook failure.

The diagrams at the bottom right show the application of a layer of concrete around the pier, followed by a grid of reinforcing bars around the pier, covered by a concrete jacket. The resulting structure is now stronger than ever. The photograph at the bottom left was taken after completion of the remedial work.
Earthquake Disaster Countermeasures

Figure 17 Service Resumption on Narrow-gauge JR Lines

<table>
<thead>
<tr>
<th>Date</th>
<th>Shin’etsu Line</th>
<th>Joetsu Line</th>
<th>Iiyama Line</th>
<th>Tadami Line</th>
<th>Echigo Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 October 2004</td>
<td>Earthquake strikes; services suspended</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kashiwazaki</td>
<td>Nagaoka</td>
<td>Higashi Sanjo</td>
<td>Minakami</td>
<td>Mukamachi</td>
</tr>
<tr>
<td>26 October 2004</td>
<td>Services resume on Shin’etsu Line between Nagaoka and Higashi Sanjo, and on Joetsu Line between Kashiwazaki and Yoshida</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kashiwazaki</td>
<td>Nagaoka</td>
<td>Higashi Sanjo</td>
<td>Minakami</td>
<td>Mukamachi</td>
</tr>
<tr>
<td>2 November 2004</td>
<td>Services resume on Joetsu Line between Minakami and Mukamachi</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minakami</td>
<td>Mukamachi</td>
<td>Kode</td>
<td>Miyazuchi</td>
<td></td>
</tr>
<tr>
<td>13 November 2004</td>
<td>Services resume on Joetsu Line between Mukamachi and Koide</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minakami</td>
<td>Mukamachi</td>
<td>Koide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 November 2004</td>
<td>Services resume on Tadami Line between Koide and Tadami</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kode</td>
<td>Tadami</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29 November 2004</td>
<td>Services resume on Shin’etsu Line between Kashiwazaki and Nagaoka</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kashiwazaki</td>
<td>Nagaoka</td>
<td>Higashi Sanjo</td>
<td>Minakami</td>
<td>Mukamachi</td>
</tr>
<tr>
<td>7 December 2004</td>
<td>Services resume on Joetsu Line between Koide and Miyazuchi, and on Iiyama Line between Echigo Kawaguchi and Tokamachi</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minakami</td>
<td>Mukamachi</td>
<td>Koide</td>
<td>Miyazuchi</td>
<td>Echigo Kawaguchi</td>
</tr>
</tbody>
</table>

- Services suspended
- Services resumed

*Services between Echigo Kawaguchi and Echigo Takiya resume on single track
Only Single Track on Joetsu Line

The last section of our narrow-gauge lines to resume services was between Echigo Kawaguchi and Echigo Takiya stations on the Joetsu Line (Fig. 19) and this section still has only single-track operations. We hope to have both tracks operating by the end of March 2006. The top right aerial shot shows Enoki Pass where a car was buried by a landslide and only a small boy was rescued alive. The photograph shows our two tracks to the right of that road. The tunnel entrance for the down track on the left remains completely blocked by landslide debris. Luckily, the up track to the right of it is free of debris and we are now using it for both up and down services.

Figure 18 Infrastructure Damage on Uonogawa Bridge, Iiyama Line

Figure 19 Services Reduced to Single Track Only on Joetsu Line

Aiming for quick resumption of double-track services

Modifications required for single-track operations
- Tablet/block system for up track
- Turnout and signalling devices newly installed at Echigo Takiya Station
- Level crossings modified at 9 locations to accommodate single-track operations
- Level crossings at 2 of 11 locations in single-track section closed to road traffic for winter—these modifications coordinated with road authorities
Of all transportation corridors blocked by landslides, this JR East line is the only one still being cleared of debris despite the heavy winter snows. We couldn’t wait for the roads department to get round to clearing winter snow, so we are going all out to keep access open with the aim of getting both tracks running again.

**Restoring Shinanogawa Power Plant**

Moving away from rail services for a moment, I’d like to discuss the major damage sustained by our Shinanogawa Power Plant (Fig. 20). This hydropower plant has three large storage reservoirs that draw water from the River Shinano to power three generators making the electricity that we need for morning peak operations. Nearly all these facilities were severely damaged. We have drained the reservoirs and are now examining how best to repair the infrastructure. Unfortunately, the area is now under deep snow and we probably cannot get everything back into full operation before late 2006. However, we need the power and can’t wait until then, so from last February we started drawing water directly from the river into the races to generate some power without filling the reservoirs. This is providing about 35% of the plant’s normal capacity.

**Dealing with Crisis**

Figure 21 summarizes bus services that replaced the lost rail section. From 31 October, buses ran between the Echigo Yuzawa and Tsubame Sanjo shinkansen stations, as well as over the shorter gap between Echigo Yuzawa and Nagaoka stations. Two JR companies, Kanto Bus and Tohoku Bus, did everything they could as did many other companies. We adjusted fares so that the combination of train and bus would not exceed what passengers would have paid if going by shinkansen only. But passengers could not enjoy the speed and convenience of shinkansen services only and we greatly regretted this inconvenience.
Table 1 shows the losses to JR East caused by the earthquakes. Lost fares amounted to about ¥13 billion (¥115 = US$1), which is not surprising. Remedial work has cost about ¥20 billion so far and the Shinanogawa Power Plant will require considerable investment of a so-far unknown amount. Another problem is that since we cannot generate sufficient power, we are depending on electricity from many thermal plants and are buying power from Tokyo Electric Power. This will cost another ¥5 billion. These costs total about ¥40 billion and we expect the entire bill to come in at under ¥100 billion, including the cost of repairing the Shinanogawa Power Plant. In any event, the financial burden is very heavy. We intend to minimize it in several ways, including drawing on reserve funds, so we expect to start next fiscal year in a relatively healthy financial state.

**Rights and Wrongs**

After everything settled down, we drew up lists of things that went right, and others that went wrong. The first list (Table 2) relates to emergency information given to passengers and passenger evacuation. As I mentioned before, our employees on site, our train crews and our station personnel all showed true professionalism in handling the situation. As the first item on the list shows, one thing that went well was our use of radio and TV to give passengers information on the situation as it developed. The pocket body warmers and blankets were a success because we had set aside many in case of an emergency in winter. Food supplies ran low in Niigata Prefecture because of the earthquake, but Nagano, Takasaki and other places sent enough to make up the difference. On a personal note, the day after the quake, I went to the derailment site and quickly realized that the area had no electricity and little food. I saw convenience stores but most were closed. I had a cell phone but the battery soon died. Although I wanted to buy batteries, the local people had rightly snapped them all up. In Nagaoka and neighbouring communities, it was impossible to buy a ready-made box lunch.
for a few days. Luckily, the local JR branch office sent us meals.
The last item in the ‘Things that went right’ column reads: ‘Staff had previously undergone training in passenger evacuation using inclined passageways, so evacuations went smoothly.’ By great good luck, just 2 days before the quake, our Niigata office had run a training session on evacuating passengers from a shinkansen train and giving on-board emergency announcements. Quite a few employees who were caught up in the emergency had participated in that session and were able to put what they had learned into practice. The column on the right lists things that went wrong, including cell phones losing power.
The left side of Table 3 lists things that went well during remedial work. One successful strategy was the numerous helicopter flights to examine the effects of the earthquake.

<table>
<thead>
<tr>
<th>Things that went right</th>
<th>Things that went wrong</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Helicopter flights made it possible to take aerial photos and videos used to rapidly assess damage over wide areas.</td>
<td>• The extensive damage and series of aftershocks made it difficult to obtain a clear understanding of the damage.</td>
</tr>
<tr>
<td>• A civil engineering project team was set up in the stricken area immediately after the quake, making it possible to provide humanitarian aid in an organized fashion.</td>
<td>• After repairing tunnel roadbeds, we discovered it was necessary to rectify long-wave track irregularities in many locations.</td>
</tr>
<tr>
<td>• Other companies quickly arranged supplies for us and leased us heavy-duty maintenance machinery.</td>
<td>• We did not fully realize the importance of investigating the derailment, so we were slow in establishing investigation mechanisms. Also, we found it difficult to find staff with sufficient expertise to conduct such an investigation.</td>
</tr>
<tr>
<td>- Keihin Electric Express Railway leased us their EM30 track inspection vehicle, greatly improving our inspection efficiency.</td>
<td>• We had difficulty establishing contractual agreements with electric power utilities for emergency supply of electricity.</td>
</tr>
<tr>
<td>- The Japan Railway Construction, Transport and Technology Agency leased us a shinkansen track inspection vehicle for clearance inspections, greatly improving our infrastructure inspection efficiency.</td>
<td>• We had difficulty buying gasoline and other supplies in the stricken area.</td>
</tr>
<tr>
<td>• Our ‘Aluminium Cart’ (a bicycle built to run on track) was most useful for infrastructure inspections.</td>
<td>- We decided to use only cranes to reposition all cars.</td>
</tr>
<tr>
<td>• Communications and cooperative efforts with police were excellent. During the emergency, patrol cars provided us with road information and greatly helped with evacuations.</td>
<td>• We used a maintenance vehicle to tow the repositioned carriages away, but structural differences made coupling difficult.</td>
</tr>
<tr>
<td>• JR East’s Structural Engineering Center formed an emergency technical team that quickly established a reconstruction plan based on the damage, making it possible to take on-site decisions rapidly.</td>
<td>• We had difficulty establishing contractual agreements with electric power utilities for emergency supply of electricity.</td>
</tr>
<tr>
<td>• Giving on-site personnel greater authority over and responsibility for remedial work made it possible to base remedial work decisions on the actual situation, helping reconstruction proceed faster.</td>
<td>• We had difficulty buying gasoline and other supplies in the stricken area.</td>
</tr>
<tr>
<td>• We used technical know-how gained from experience after the 2003 Sanriku-Minami earthquakes (north-east Honshu) and elsewhere, making remedial work proceed faster.</td>
<td>- We decided to use only cranes to reposition all cars.</td>
</tr>
<tr>
<td>• There was little snow even in December—unusual for Niigata Prefecture—so weather did not slow reconstruction work very much.</td>
<td>• We used a maintenance vehicle to tow the repositioned carriages away, but structural differences made coupling difficult.</td>
</tr>
</tbody>
</table>

The Joetsu Shinkansen was not the only part of our operations to receive a crippling blow. As I mentioned, our narrow-gauge track sustained damage in more than 80 locations. Some probably would not have been discovered as quickly if we had not taken aerial photographs and video. Our head and branch offices were able to make an overall assessment of the damage before local authorities on the ground had similar information.

### Tremendous Help from Other Companies

The third item that ‘went right’ is that other companies were quick to lend a hand. For example, Keihin Electric Express Railway, which operates mainly in the Yokohama-Tokyo area, kindly loaned us their EM30 track inspection car. I have already mentioned our East-i that

we used to test the ability of infrastructure to support higher speeds. But until we repaired Uonuma Tunnel, we could not get it onto track on the Niigata side of the tunnel, the section where we needed speed tests. Keihin Electric’s trains run on the same gauge as shinkansen, and their EM30 track inspection car runs at speeds up to 30 km/h. We made good use of it until services resumed over the entire line. Without it we would have had to use far simpler inspection devices and probably could not have resumed full services on 28 December.

The Japan Railway Construction, Transport and Technology Agency (formerly Japan Railway Construction Public Corporation—JRCC) loaned us their Oiran inspection car for checking structural clearance. Actually, we do not have such an inspection vehicle for shinkansen track, because we normally don’t need one.

The predecessor JRCC built the Joetsu Shinkansen, explaining why its successor could lend us Oiran, without which we probably couldn’t have resumed services as early as 28 December. In addition to the tremendous help from other companies, we could also draw on our past experiences coping with disasters.

### Challenges at Derailment Site

The right column in Table 3 lists our main difficulties during the remedial work. As one example, the last item on the list deals with removal of the shinkansen rolling stock. As I mentioned before, we eventually repositioned it on the opposite track and then had to remove it from the scene. A maintenance vehicle arrived to do this but it was immediately apparent that the couplers were different, so we had to make a special device to link the two. The second item in the column, long-wave track irregularities, did not stop us from resuming services on 28 December.
but there are still some small irregularities in the slab track. Although we could run trains at 240 km/h over the track without compromising safety, ride comfort would suffer so we are still operating at slightly lower speeds. This shows that a slab track requires more careful final adjustments than ballasted track.

Table 4 examines the emergency response taken at the organizational level. One thing listed as going well is ‘A Field Response Headquarters was established and JR East’s Executive Director was sent there as Headquarters Chief.’ I was the Headquarters Chief, so I should be pleased with this comment. The same item continues: ‘This organizational measure created a responsible position for directing recovery efforts and working with the media on site.’ In truth, I did not have to do much after arriving—I probably would have been busier at JR East Headquarters in Tokyo. As it was, many qualified, experienced personnel came to the derailment site where they worked admirably, greatly simplifying my task of overseeing the recovery.

One function that I could fulfil as executive officer with on-site responsibility was to grant or refuse admittance to the many people who wanted to get close to the derailed train. The scene was unique and dramatic—a derailed shinkansen—and the site could be easily seen from a nearby road, so we naturally attracted a lot of attention. People wanting a close-up view included Cabinet Ministers on two occasions, more than 30 politicians, the media, bureaucrats, experts, non-profit organizations—and of course I can’t forget the curious bystanders. Everyone wanted to get up on the viaduct to ‘take a look,’ and it was my job to say who could and couldn’t. Anyone other than an executive officer would have had a hard time saying ‘No’ to some of those people!

But when it came to directing the actual recovery work, we had specialists who were highly qualified in their respective fields and it was they who did what was required. I was representing Headquarters, and my presence indicated to everyone working on site that JR East was naturally anxious that the recovery and reconstruction proceed smoothly.

Table 4 Organizational Response: Sharing Information

<table>
<thead>
<tr>
<th>Things that went right</th>
<th>Things that went wrong</th>
</tr>
</thead>
<tbody>
<tr>
<td>• A Field Response Headquarters was established immediately after the quake, and JR East’s Executive Director was sent there as Headquarters Chief. This organizational measure created a responsible position for directing recovery efforts and working with media on-site.</td>
<td>• Train crew used wireless devices to ask superiors for directions, leading to overloaded telecommunications circuits making it difficult to give passengers required emergency information.</td>
</tr>
<tr>
<td>• The company intranet (Joi-Net) was quickly connected to the Field Response Headquarters at the derailment site, permitting efficient information sharing.</td>
<td>• Cell phones often could not be used for voice communications, and in many cases batteries went dead quickly.</td>
</tr>
<tr>
<td>• Coordination made train crew announcements more effective.</td>
<td>• Since telephone lines were often busy, we could not quickly learn whether employees were safe. (Employees did not contact us to report their own situation.)</td>
</tr>
<tr>
<td>• Trackside telephones were used to gather information at the derailment site.</td>
<td>•</td>
</tr>
</tbody>
</table>
Figure 23  Early Earthquake Detection System Improvements for Shinkansen

System improvement objective: Shorten time required to detect seismic activity, thereby permitting faster power transmission cut-off and train braking.

<table>
<thead>
<tr>
<th>Seismometer location</th>
<th>Track section</th>
<th>Existing</th>
<th>New</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trackside</td>
<td>Tohoku Shinkansen</td>
<td>13</td>
<td>9</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Joetsu Shinkansen</td>
<td>8</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Nagano Shinkansen</td>
<td>6</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Coast</td>
<td>Pacific-Ocean side</td>
<td>9</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Sea-of-Japan side</td>
<td>6</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>28</td>
<td>56</td>
<td></td>
</tr>
</tbody>
</table>

(1) Earlier warning using P-wave detection, which arrive before S-waves, permits earlier warning.

(2) Use of coastal seismometers in earlier earthquake detection. Warning triggered by coastal seismometers located closer to epicentre of undersea earthquake.

Operation control method: Trackside seismometers indicate the earthquake magnitude, forming the basis for a decision to stop operations.

- In FY2005, JR East changed its seismic activity index from gal to kine (SI). And, without sacrificing safety, changed its Operating Rule Criteria to more accurately predict possible damage to track infrastructure.
- Operation restarts: <80 gal
- Speed restrictions: 80 to <120 gal
- Operation stops: 120 gal
- Operation restarts: <9 kine
- Speed restrictions: 9 to <18 kine
- Operation stops: 18 kine +

Figure 24  Niigata Tourism Campaign—We’re Getting It Done!

Joetsu Shinkansen trains are once more running between Tokyo and Niigata, but things will return to normal only when the same number of tourists are riding the rails again. JR East and local governments in Niigata Prefecture are working together to promote tourism in the prefecture. The campaign lasted until the end of March 2005.

- The Niigata prefectural government, local municipal governments and tourist agencies are organizing events and offering special attractions.
- 70,000 passengers
- 180,000 passengers
- 110,000 passengers
- More travel promotion specials, discount fares, across-the-board discounts of ¥2,000.
- ‘Come to Niigata’ tickets with some unrestricted boarding/disembarking privileges.
- Campaign logo displayed on MAX Joetsu Shinkansen rolling stock.
- Campaign prizes.
- Campaign kick-off attended by representatives of promoting organizations.

By February 2005, our Joetsu Shinkansen ridership returned to similar levels as the previous year. This is a great turnaround after the recent slump.
infrastructural failure, and developing countermeasures. We have documentation covering these issues, but I am not going to describe it here. The Ministry of Land, Infrastructure and Transport is involved in ongoing safety-related discussions, so some matters cannot be made public yet. Future investigations will focus mainly on how to prevent a derailment, how to prevent carriages from causing harm if they do derail, and how to prevent major damage in so many tunnels. The Joetsu Shinkansen has resumed operations, but we expect that the hardest part of our job is still ahead.

Acknowledgments
The article is based on a lecture given at a Transportation Research Committee seminar on 15 February 2005 organized by Japan Transportation Association.

Masahiko Ogura
Mr Ogura is a JR East Executive Director. After graduating in civil engineering from the University of Tokyo in 1974, he joined Japanese National Railways where he later served as Head of the Track Maintenance Division at the South Tokyo Railway Operating Division. After transferring to JR East, he served in various capacities, including Head of the Engineering Works Department at JR East’s Morioka Branch Office. He was appointed Director of the Yokohama Branch Office in 2002 and has been an Executive Director, and Deputy Director of Railway Operations Headquarters since 2004.