Feature

The Niigata Chuetsu Earthquake —Railway Response and Reconstruction

Masahiko Ogura

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

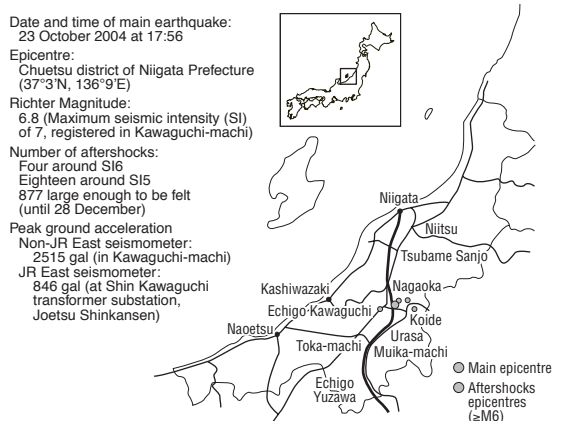


Figure 2 Emergency Stops after Chuetsu Earthquake

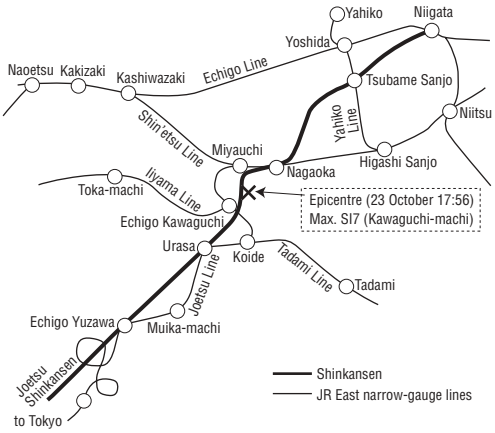


Figure 3 Response Timeline

	Emergency Response Meetings	Press Conferences	Other Events
23 October	18:00 Response Headquarters established within JR East Head Office 19:40 First Emergency Response Meeting • Ascertained *Toki* 325 derailment • Ascertained injuries to passengers • Ascertained how many people on board • Ascertained positions of halted trains 22:00 Emergency Response Meeting • Planned passenger relief • Ascertained condition of damaged equipment • Ascertained derailment situation • Decided to send Executive Director to derailment site	17:56 Began gathering information on possible injuries and damage (Director sent from Headquarters) 18:19 First report indicates *Toki* 325 derailed between Urasa and Nagaoka 20:25 Press conference • Overall situation • *Toki* 325 derailed • No deaths or injuries 22:45 Press conference • Eight carriages derailed • Situation of trains halted between stations • Relief effort plans, etc.	21:50 M. Otsuka, JR East President, prepares to return to Japan from London, UK, where on investor relations business.
24 October	03:30 Emergency Response Meeting • Report on derailment • Passenger relief efforts 08:00 Emergency Response Meeting • Report on derailment • Report on equipment damage • Planning 24 October passenger services • Methods to get derailed cars back on track (proposals) 11:30 Emergency Response Meeting • Report on equipment damage • Plans for getting derailed cars back on track • Situation of staff sent to site for recovery efforts 16:00 Emergency Response Meeting • Report on equipment damage • Current passenger operations situation • User situation	00:27 Press conference • Relief efforts 09:03 Press conference • Derailment situation • Equipment damage • Relief efforts • Plans for 24 October passenger services • Methods to get derailed cars back on track (proposal) 17:05 Press conference • Damaged equipment • Current passenger operations situation • User situation	05:00 Derailment Investigation Committee start on-site investigation 10:30 M. Otsuka, JR East President, arrives at Headquarters (visits site on 25 October) 13:00 Field Response Headquarters established, with Executive Director M. Ogura in charge

Response on Day 1

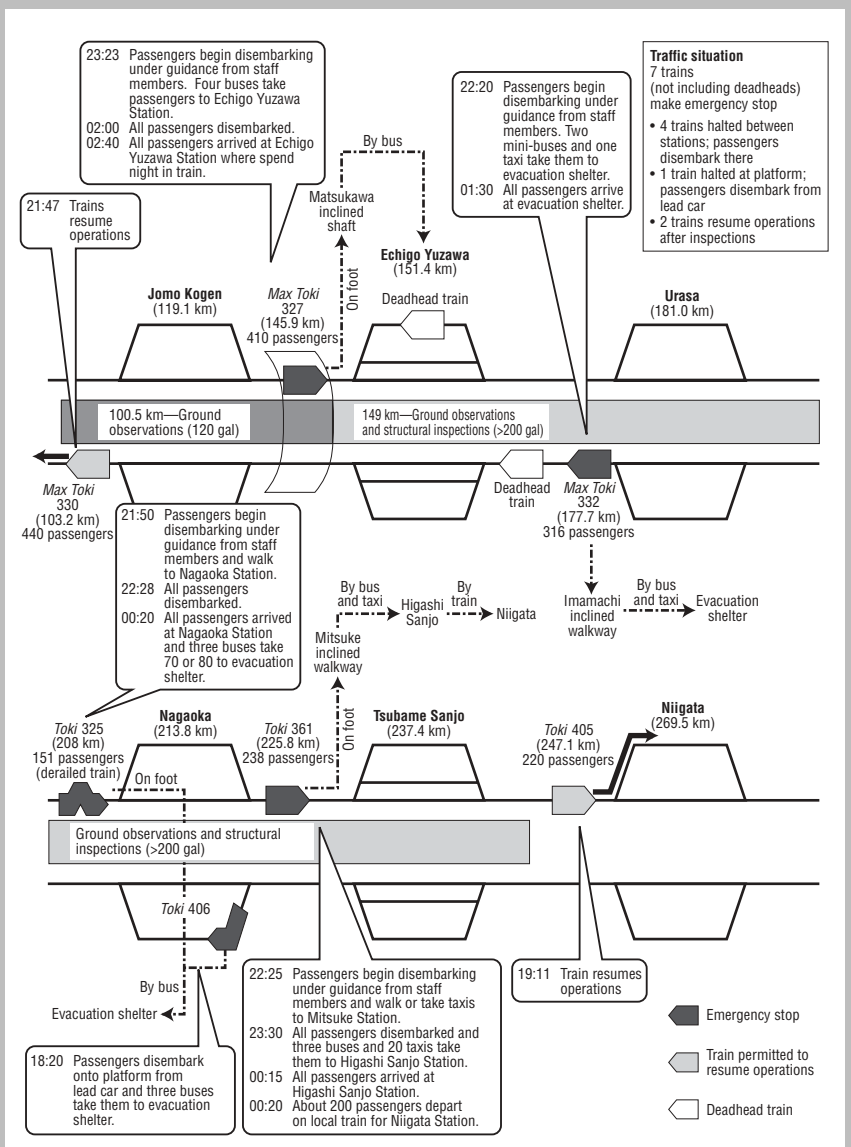
Figure 3 is a timeline of events on 23 and 24 October. I was in Tokyo at the time and as soon as we heard that a shinkansen had derailed, JR East executive officers including myself rushed to headquarters, with nearly everyone arriving by 19:00.

As the left column shows, our first Emergency Response Meeting began at 19:40 attended by all executive officers who had arrived at headquarters by then. 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.

Figure 4 Passenger Movement and Evacuation after First Earthquake



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, not even on the derailed train, 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

Figure 5 Situation after Derailment

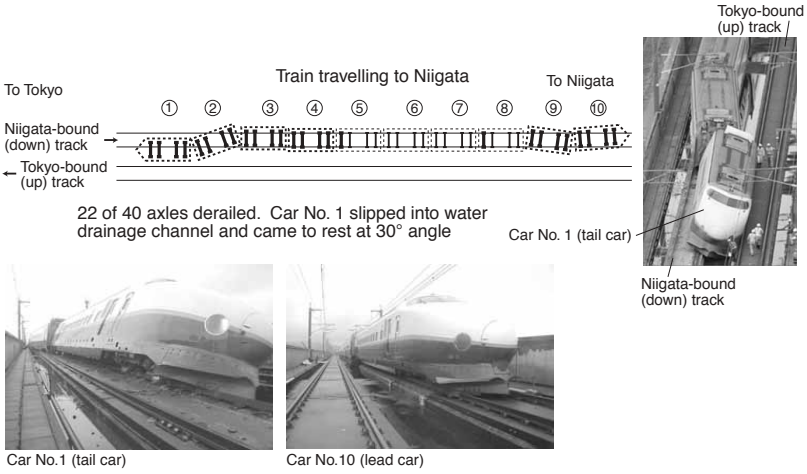
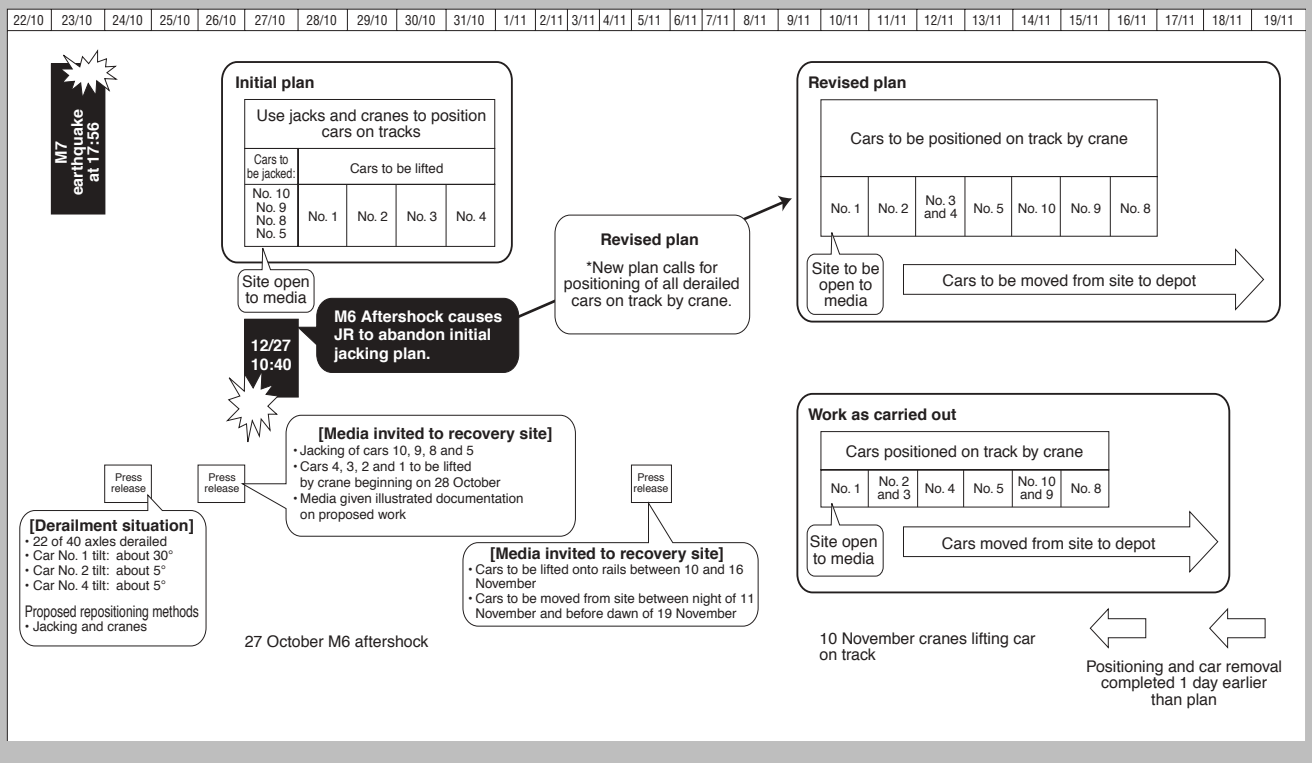


Figure 6 Positioning Cars Back on Track—Plans and Implementation



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 near the front cars and they 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.

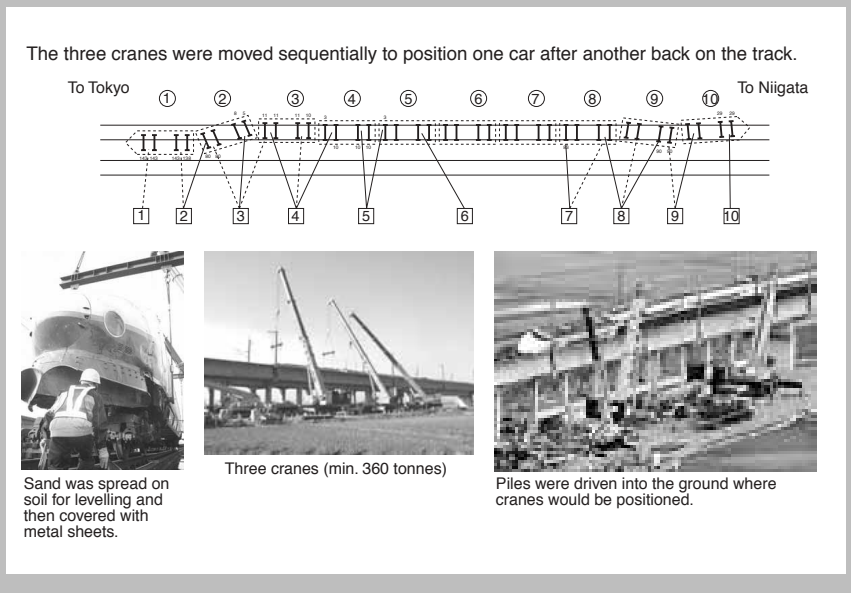
Figure 7 shows the main tasks. The area around the derailment site is all rice paddy, and we had to bring three 360- to 450-tonne cranes across the paddy from a company in Niigata. Basically, the job involved using two cranes to hoist one car, and the third crane to steady the adjacent car to prevent 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

Figure 7 Lifting Cars on Track



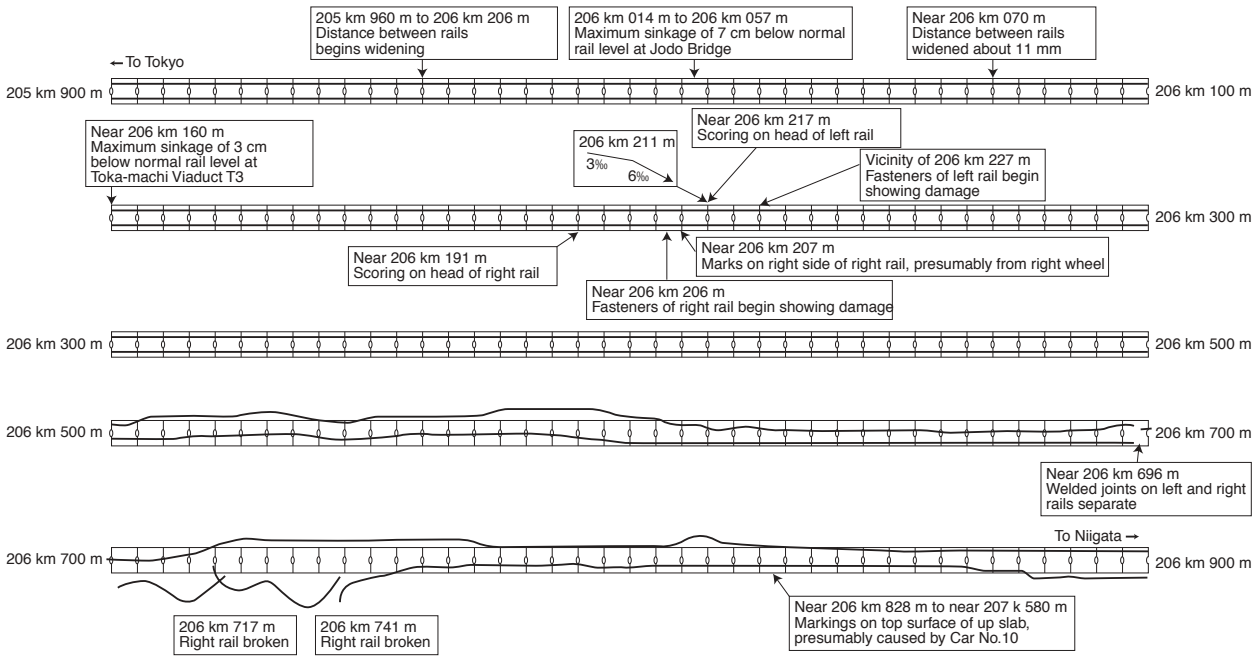
the middle of the second section from the top was where we found marks indicating that wheels had mounted the right rail. The rails were badly deformed from the area shown on the left of the fourth section. Because the construction is a slab track, it was obvious that the rail fasteners here had been 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

Figure 8 Damage to Railway Infrastructure near Shinkansen Derailment Site

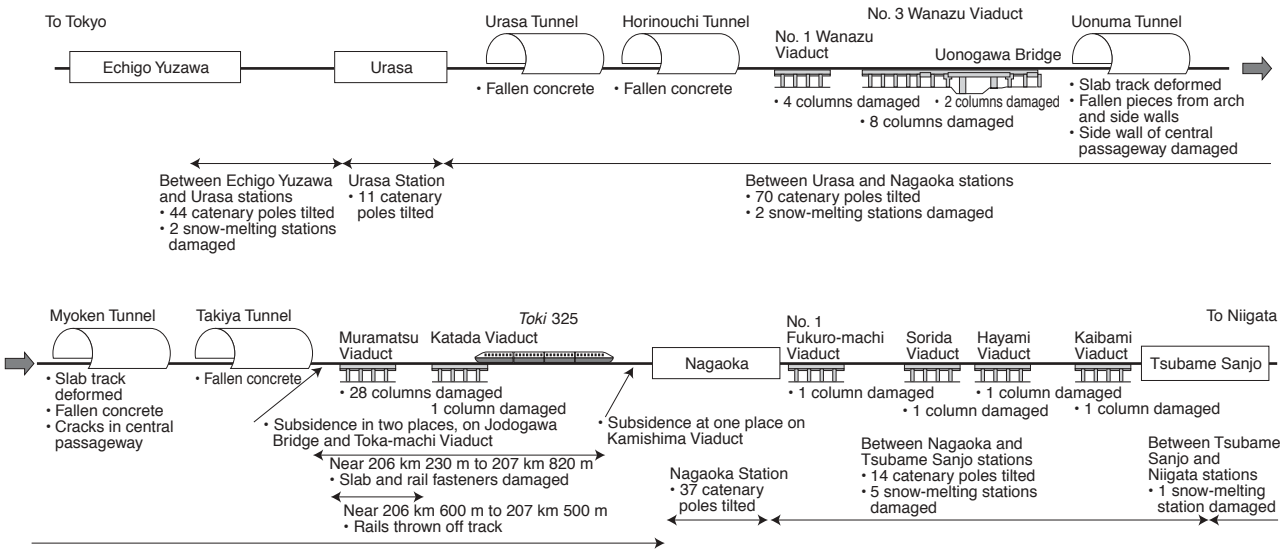


badly damaged. This was certainly a rude awakening!

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

Figure 9 Major Damage to Aboveground Structures—Joetsu Shinkansen




Damage to track caused by passage of derailed *Toki* 325


Uonuma Tunnel


Myoken Tunnel


No. 1 Wanazu Viaduct


No. 3 Wanazu Viaduct


Uonogawa Bridge

track, then the Uonuma, Myoken and Takiya tunnels, and then the derailment site. From the last tunnel to the derailed train and on to Nagaoka Station is all above ground.

The worst hit areas were the Uonuma, Myoken and Takiya tunnels, with the former two in especially bad shape. What the figure does not show is that there are snow shelters over the track between the Uonuma and Myoken tunnels, and between the Myoken and Takiya tunnels, so this whole section is really one long tunnel. This made the remedial work difficult, because we could only use the entrances at the two extremities to enter the tunnels with equipment. The No. 1 Wanazu Viaduct, No. 3 Wanazu Viaduct, and Uonogawa Bridge beyond the Uonuma Tunnel on an aboveground section of only about 800 m between the two tunnels were all quite damaged too. The Uonuma Tunnel, which is slightly more than 8-km long, was badly damaged in three places, with cracks in the tunnel arch and upheaval in the slab. The Myoken Tunnel was quite seriously damaged in two places.

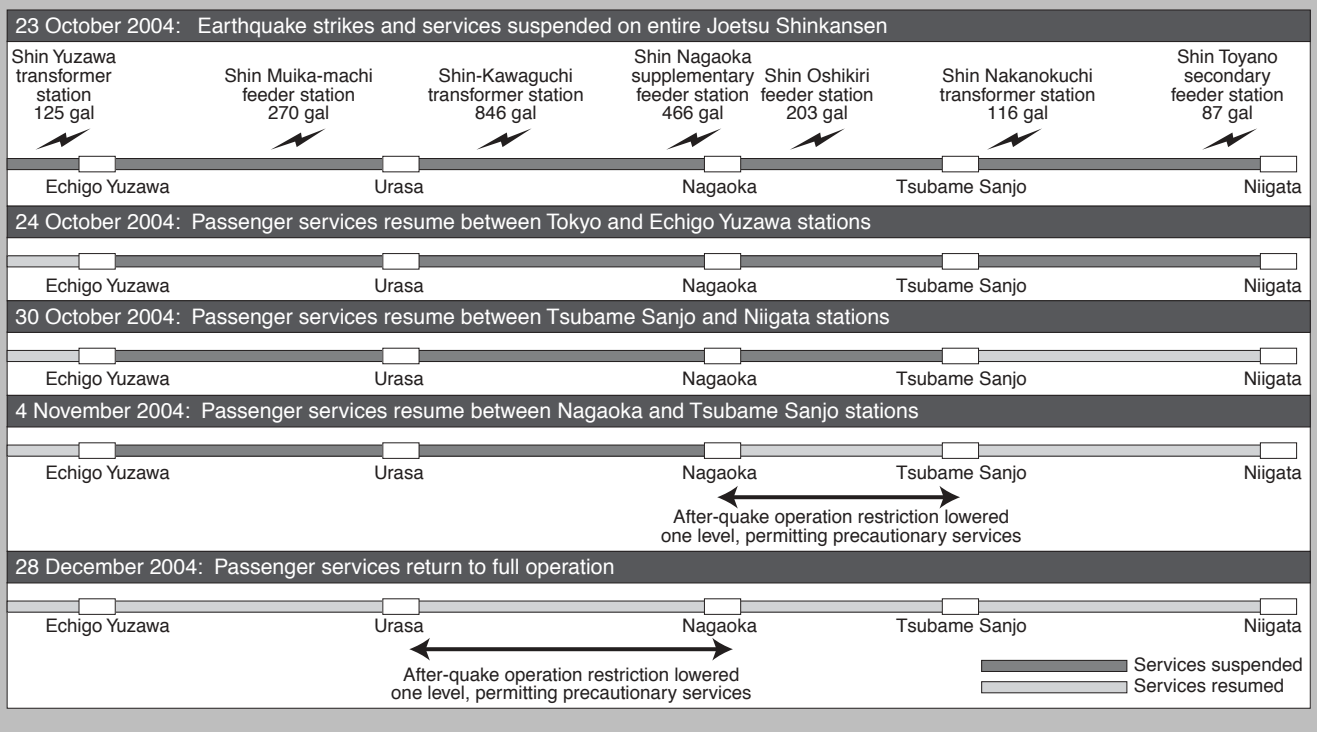
Some viaduct columns suffered shear-induced damage, with concrete falling away to expose the reinforcing bars. The Uonogawa Bridge (Fig. 9, bottom right) looked awful with exposed reinforcing bars after concrete broke off about halfway up the columns.

We repaired the structures in methodical order. The solid black lines in Figure 10 show track sections where there were no passenger services, while the shaded lines indicate sections with resumed services. Immediately after the earthquake, we suspended services on all sections from before Echigo Yuzawa Station to Niigata Station. The day after the earthquake, trains were running from Echigo Yuzawa from Tokyo.

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

Figure 10 Operation Restart Timeline—Joetsu Shinkansen



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,

Figure 11 Damage at Uonuma Tunnel

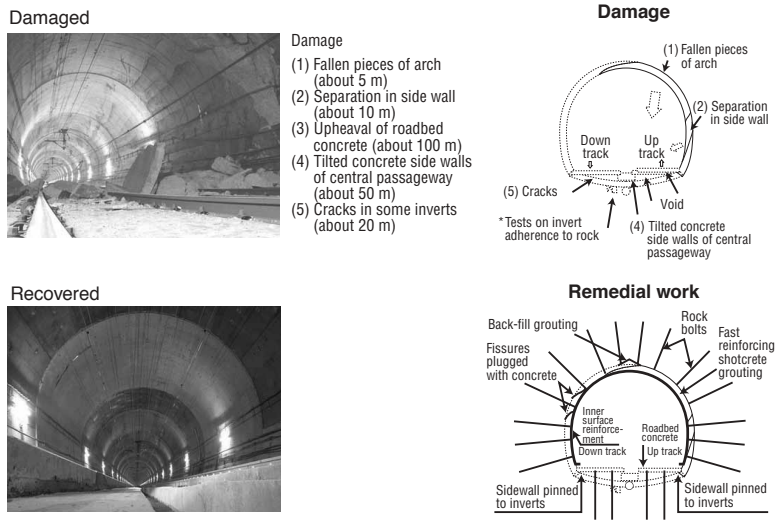


Figure 12 Damage at Uonogawa Bridge

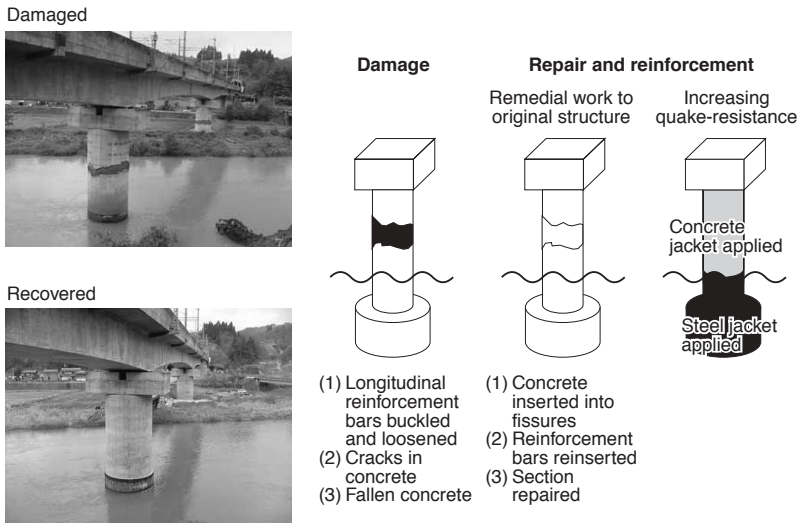


Figure 13 Repairs at Derailment Area and Tunnel Track

Remedial work to derailment track

Remedial work to slabs and roadbed

Slab T-bolt repairs, rail replacement, rail surface adjustments

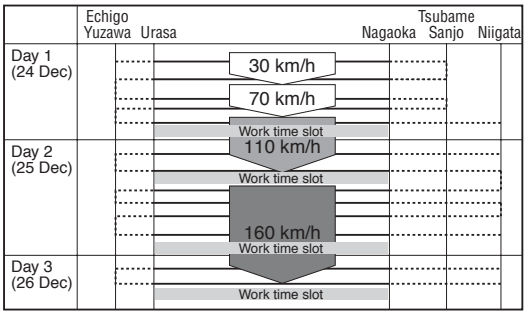
Track remedial work in Uonuma Tunnel

- Slab T-bolt repairs
- Roadbed repairs
- Rail surface adjustments

Breaking up concrete base

Figure 14 Running Tests on Joetsu Shinkansen between Urasa and Nagaoka

Test runs



Test running by *East-i*

Decision-making factors permitting higher speed trial runs

Speed increase	Track	Infrastructure	Electric supply system	Signalling system
30 km/h→70 km/h	(1) Car vibration • Vertical and horizontal vibrations (2) Track displacement • Distance between rails, level, unevenness, ease of passage, smoothness	Measurement of extent of subsidence on No. 1 Wanazu Viaduct, No. 3 Wanazu Viaduct, Uonuma Tunnel and elsewhere	(1) Catenary height (2) Catenary tilt (3) Catenary gradient	(1) ATC Signal transmission verification (2) Verification of train wireless system field strength
70 km/h→110 km/h				
110 km/h→160 km/h				

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.

Back to Full Passenger Services

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.

Figure 15 Embankment Failure on Joetsu Line

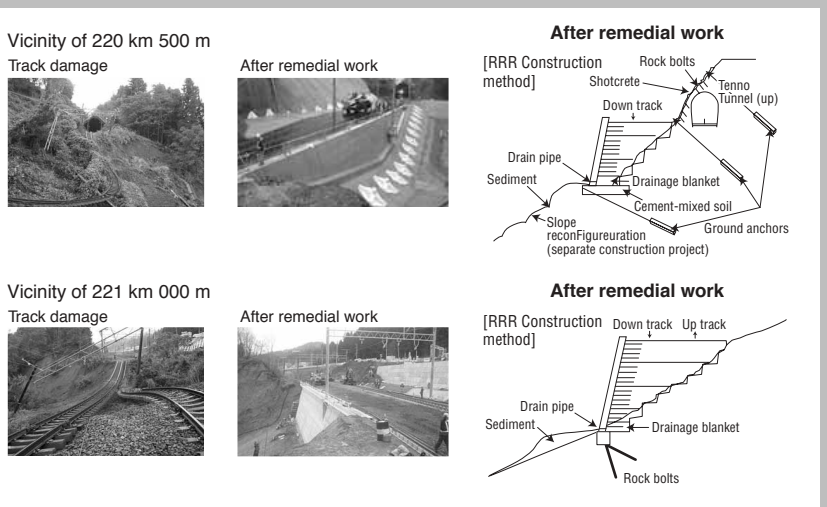
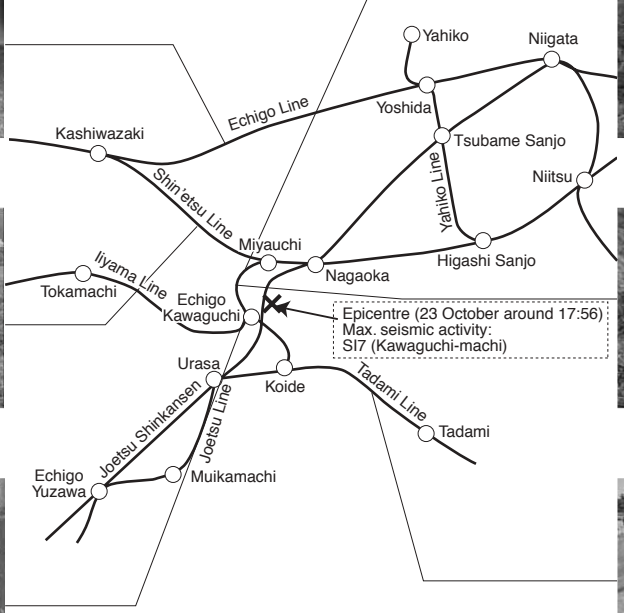


Figure 16 Major Damage to Narrow-gauge Infrastructure

Echigo Line: Some damage at Izumozaki Station

Shin'etsu Line: Collapsed embankment near 54 km 800 m

Iiyama Line: Deformed columns, Uonogawa Bridge

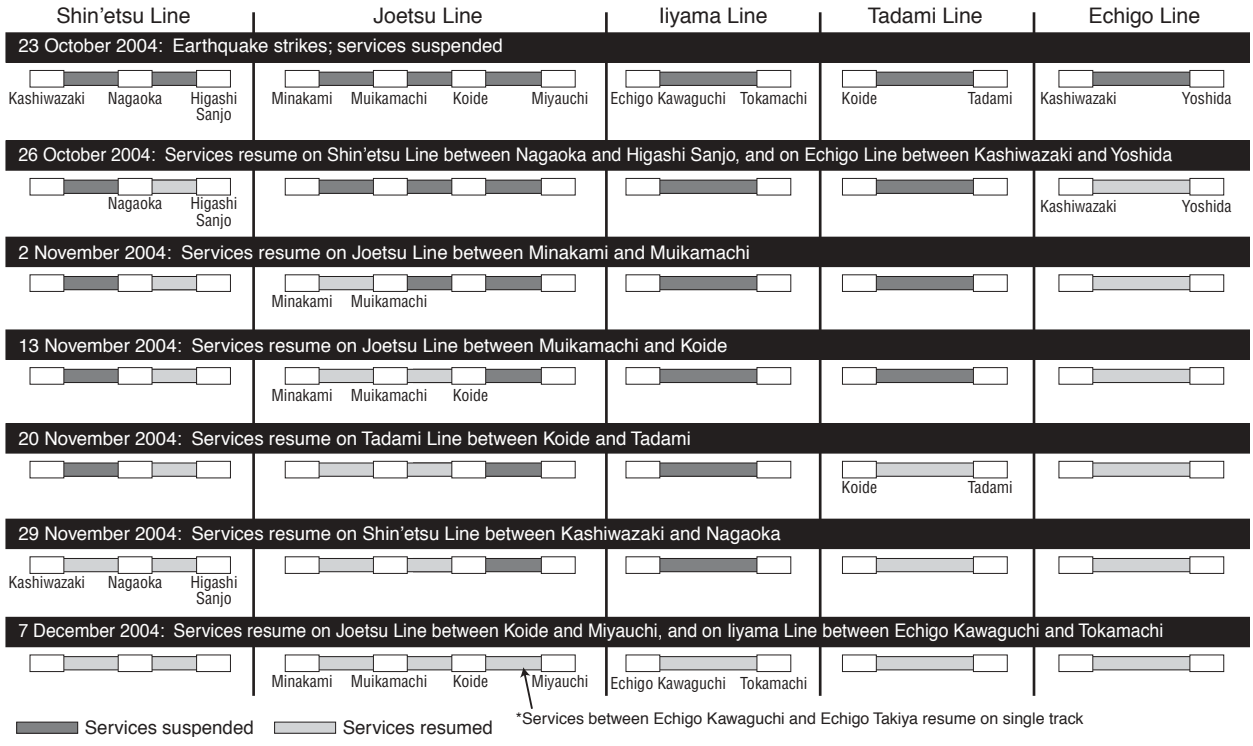


Joetsu Line: Collapsed embankment near 221 km 000 m

Joetsu Line: Collapsed embankment near 220 km 500 m

Tadami Line: Some damage at Echigo Suhara Station

Figure 17 Service Resumption on Narrow-gauge JR Lines



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

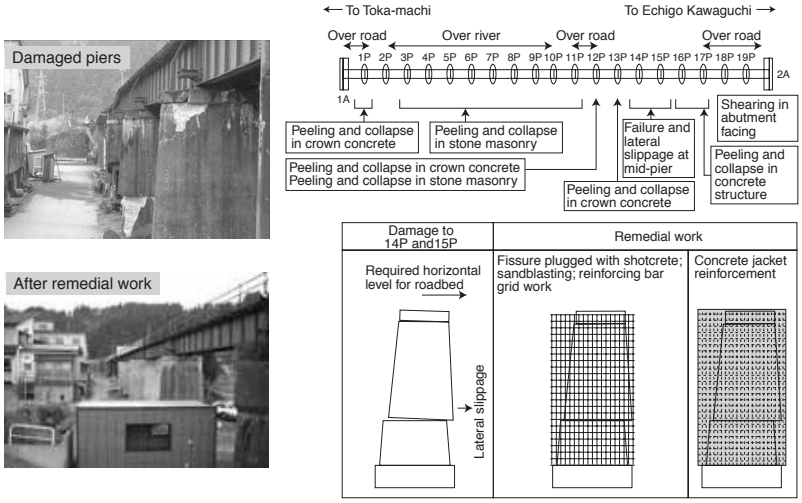
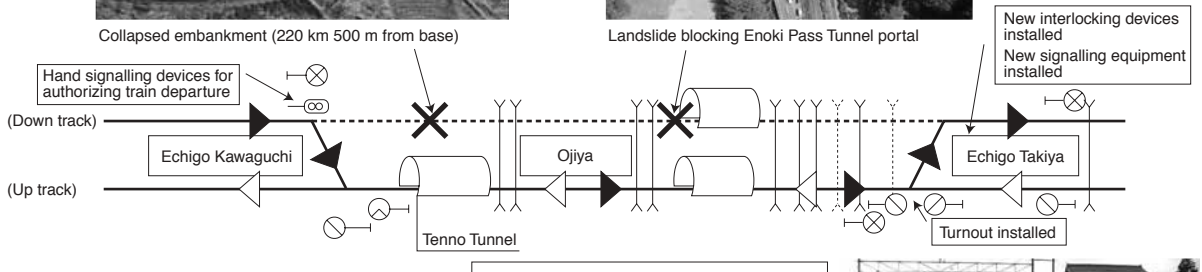


Figure 19 Services Reduced to Single Track Only on Joetsu Line

Aiming for quick resumption of double-track services

Collapsed embankment (220 km 500 m from base)

Landslide blocking Enoki Pass Tunnel portal



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

Installed turnout (Echigo Takiya Station)

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.

Figure 20 Damage to Shinanogawa Power Plant

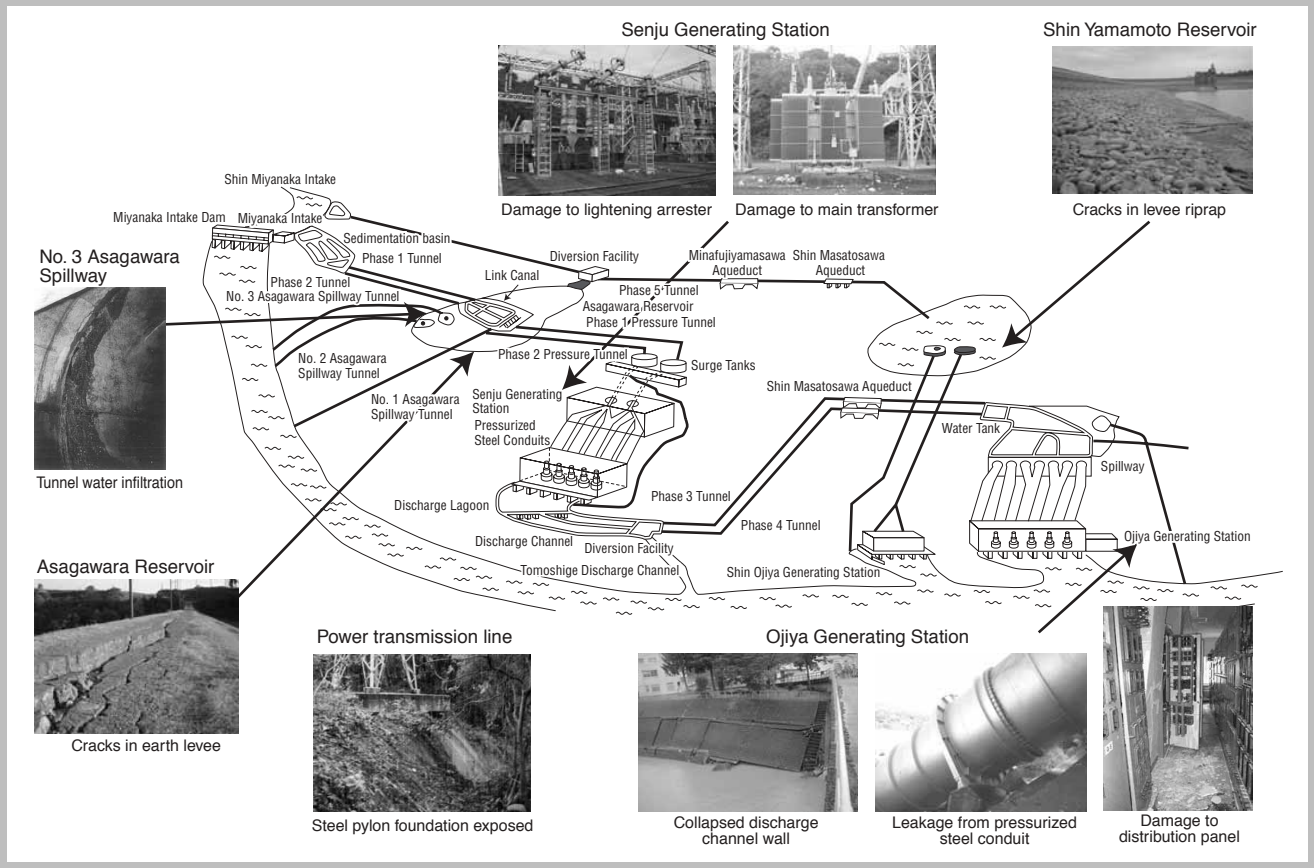


Table 1 shows the losses to JR East caused by the earthquakes. Lost fares amounted to about ¥13 billion (¥115 = US$1), which is not surprising. Remedial work has cost about ¥20 billion so far and the Shinanogawa Power Plant will require considerable investment of a so-far unknown amount. Another problem 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

Figure 21 Bus Transport Replacing Suspended Joetsu Shinkansen Services

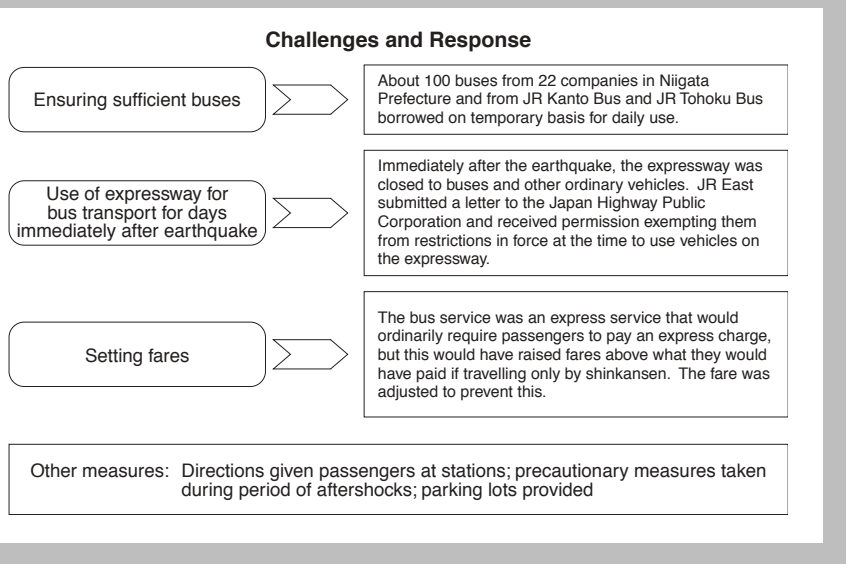


Table 1 Financial Burden of Chuetsu Niigata Earthquakes (FY2005)

• Lost fare revenues	Approx. ¥13 billion
• Cost of remedial work for railway infrastructure (cost of replacement bus services not included)	Approx. ¥20 billion
• Cost of remedial work for Shinanogawa Power Plant	Still unknown
Purchase of electricity, etc.	Approx. ¥5 billion
• Lost revenues from station kiosks, etc.	Approx. ¥1 billion

Table 2 Emergency Information for Passengers and Their Evacuation

Things that went right	Things that went wrong
• Radios, and TVs powered by emergency power supply were useful in explaining the overall emergency situation to passengers. This helped relieve their anxiety somewhat. • We had established emergency reserves of disposable body warmers and blankets for any emergency winter service suspension. These supplies were most useful. • A nearby JR branch office quickly responded by delivering food, disposable body warmers and other relief supplies early next morning after the quake. • Cell phone reception was extremely poor, so Personal Handyphone System (PHS) phones communication were most useful. • Staff had previously undergone training in passenger evacuation using inclined passageways, so evacuations went smoothly.	• Flashlights used during evacuation from trains halted between stations were not bright enough. • We should have sent staff from stations to Disaster Response Headquarters to request the help of local municipal governments in establishing evacuation shelters, etc. • The cell phones of many employees and passengers ran out of battery power. • We saw a need for more emergency reserves of blankets, pharmaceuticals, batteries, etc.

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 3 Remedial Work

Things that went right	Things that went wrong
• Helicopter flights made it possible to take aerial photos and videos used to rapidly assess damage over wide areas. • 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. • Other companies quickly arranged supplies for us and leased us heavy-duty maintenance machinery. - Keihin Electric Express Railway leased us their EM30 track inspection vehicle, greatly improving our inspection efficiency. - The Japan Railway Construction, Transport and Technology Agency leased us a shinkansen track inspection vehicle for clearance inspections, greatly improving our infrastructure inspection efficiency. • Our 'Aluminium Cart' (a bicycle built to run on track) was most useful for infrastructure inspections. • Communications and cooperative efforts with police were excellent. During the emergency, patrol cars provided us with road information and greatly helped with evacuations. • 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. • 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. • We used technical know-how gained from experience after the 2003 Sanriku-Minami earthquakes (north-east Honshu) and elsewhere, making remedial work proceed faster. • There was little snow even in December—unusual for Niigata Prefecture—so weather did not slow reconstruction work very much.	• The extensive damage and series of aftershocks made it difficult to obtain a clear understanding of the damage. • After repairing tunnel roadbeds, we discovered it was necessary to rectify long-wave track irregularities in many locations. • 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. • We had difficulty establishing contractual agreements with electric power utilities for emergency supply of electricity. • We had difficulty buying gasoline and other supplies in the stricken area. (Gasoline stations were closed during the blackout.) • Just when we were jacking up carriages to position them back on the track, an aftershock measuring almost SI6 struck created a very dangerous situation. - We decided to use only cranes to reposition all cars. • We used a maintenance vehicle to tow the repositioned carriages away, but structural differences made coupling difficult. - We had to make a special device to couple the maintenance vehicle and shinkansen.

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.

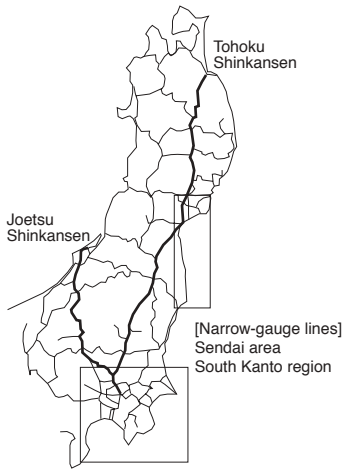
One function that I could fulfil as executive officer with on-site responsibility was to grant or refuse admittance to the many people who wanted to get close to the derailed train. The scene was unique and dramatic—a derailed shinkansen—and the site could be easily seen from a nearby road, so we naturally 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

Things that went right	Things that went wrong
• 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. • The company intranet (Joi-Net) was quickly connected to the Field Response Headquarters at the derailment site, permitting efficient information sharing. • Coordination made train crew announcements more effective. • Trackside telephones were used to gather information at the derailment site. • When cell phones could not be used for voice communications, they could still be used to send text messages, providing an effective means of communication. • The frequent Emergency Response Meetings ensured that information was shared. The meetings provided an opportunity for top executives to make rapid decisions that spurred recovery and reconstruction efforts. • Frequent press conferences gave the media much information. This established a good rapport with the media.	• Train crew used wireless devices to ask superiors for directions, leading to overloaded telecommunications circuits making it difficult to give passengers required emergency information. • Cell phones often could not be used for voice communications, and in many cases batteries went dead quickly. • 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.)

Figure 22 Countermeasures after 1995 Hanshin-Awaji Earthquake



Viaduct column reinforcement
Reinforcement efforts prioritize columns at risk of major damage through shear failure in earthquake as severe as Hanshin-Awaji or Chuetsu Niigata earthquakes.

Shinkansen
Plans call for aseismic reinforcement of about 18,500 out of approx. 82,100 columns.
- Approx. 12,300 columns (66%) to be reinforced during FY2004
- Additional 6,200 columns (approx.) to be reinforced by end of FY2007

Narrow-gauge lines
Plans call for aseismic reinforcement of about 12,600 out of approx. 42,400 columns in South Kanto and Sendai areas.
- Approx. 9,800 columns (78%) to be reinforced during FY2004
- Additional 2,800 columns (approx.) to be reinforced by end of FY2008

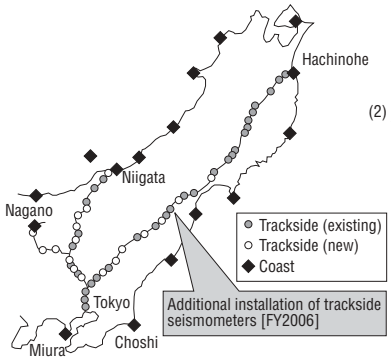
Organizational Response and Information Sharing

Another 'went well' item is 'The frequent Emergency Response Meetings ensured that information was shared. The meetings provided an opportunity for top executives to make rapid decisions that spurred recovery and reconstruction efforts.' It is commonly known that different departments in a company can squabble over decision-making powers and work for their own interests against each other. However, in our case, members of each department came together for the meetings and worked as

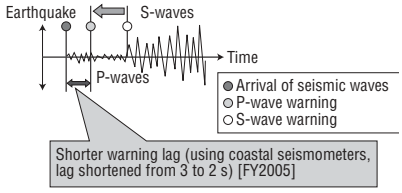
Figure 23 Early Earthquake Detection System Improvements for Shinkansen

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

Seismometer location	Track section	Existing	New	Total
Trackside	Tohoku Shinkansen	28	16	44
	Joetsu Shinkansen	13	9	22
	Nagano Shinkansen	8	3	9
Coast	Pacific-Ocean side	9	-	9
	Sea-of-Japan side	6	-	6
Total		82	28	90

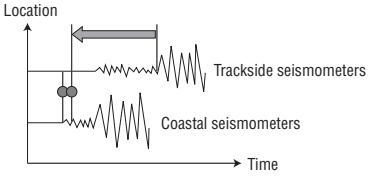


(1) Earlier warning using P-wave detection
Detection of P-waves, which arrive before S-waves, permits earlier warning.



Shorter warning lag (using coastal seismometers, lag shortened from 3 to 2 s) [FY2005]

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



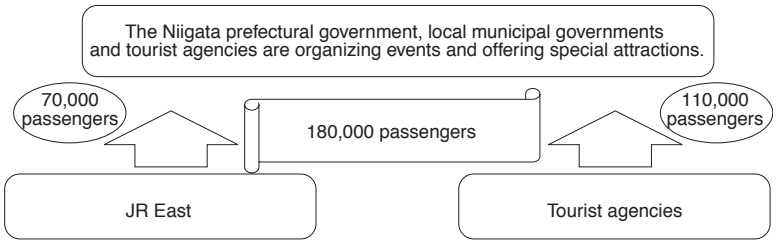
Operation control method: Trackside seismometers indicate the earthquake magnitude, forming the basis for a decision to stop operations.

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	Operation restarts: <9 kine
Speed restrictions: 80 to <120 gal	Speed restrictions: 9 to <18 kine
Operation stops: 120 gal	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.



- 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

a team for early resumption of services. I know I am blowing the JR East horn, but I must say that we took the best approach—our departments cooperated and compromised very well, placing the interests of our passengers ahead of their own interests. I said at the beginning, JR East's frequent and frank press conferences established a good rapport with the media for the benefit of all.

Safeguarding Lives Next Time

Figure 22 shows our plans to reinforce viaducts to make them more earthquake-resistant. We are making considerable investments in this endeavour and have decided to implement reinforcement plans earlier than first scheduled.

Figure 23 gives information on our installation of more seismometers in our Urgent Earthquake Detection and Alarm System (UrEDAS) and our efforts to reduce response times from 3 to 2 seconds.

The information in these two figures has been published elsewhere, so I will not go into greater detail here.

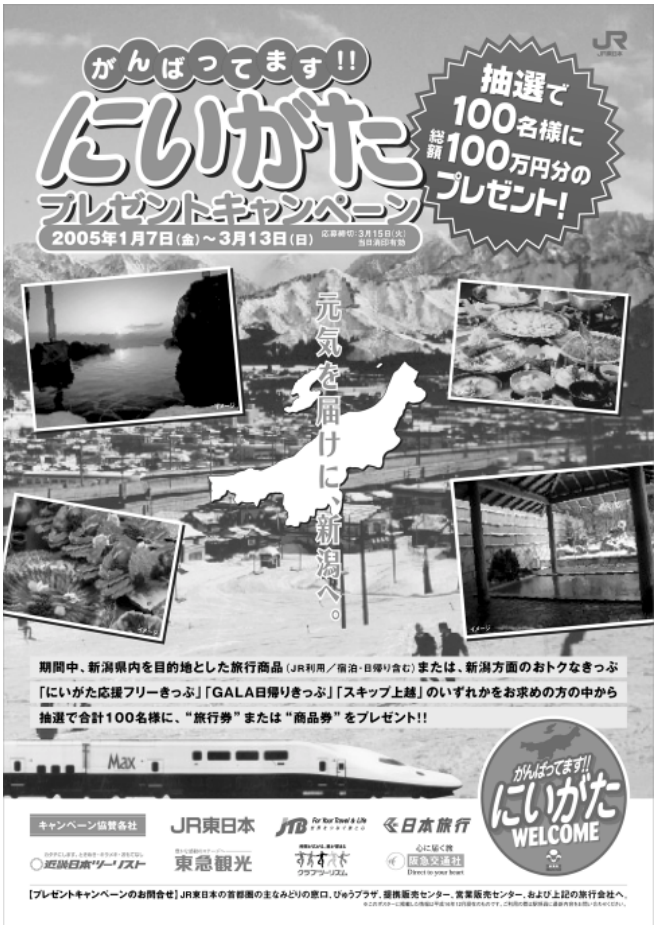
Raising Ridership to Pre-disaster Levels

Figure 24 highlights our 'Niigata Tourism Campaign—We're Getting It Done!' programme. The weeks of interrupted shinkansen services in the Niigata area greatly inconvenienced the travelling public, so we are trying to make it up to them through special offers.

By February 2005, our Joetsu Shinkansen ridership returned to similar levels as the previous year. This is a great turnaround after the recent slump.

Further Study and Countermeasures

Our remaining main tasks are examining the derailment mechanisms and



Pamphlets of 'Niigata Tourism Campaign—We're Getting It Done!' (JR East)

infrastructure 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.