Role of Railways in Building Resilient Against Natural Disaster-Lessons from Japan

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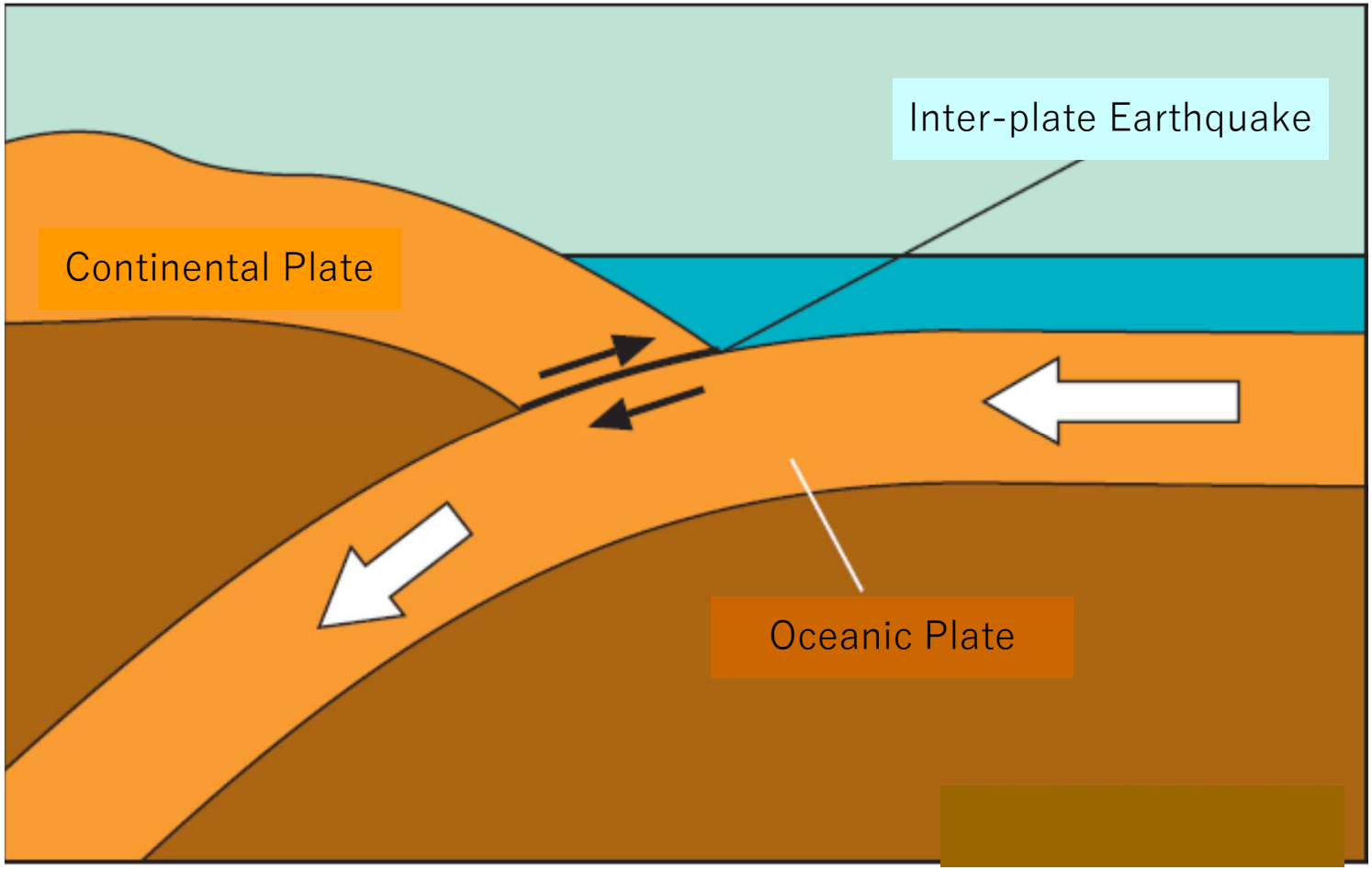
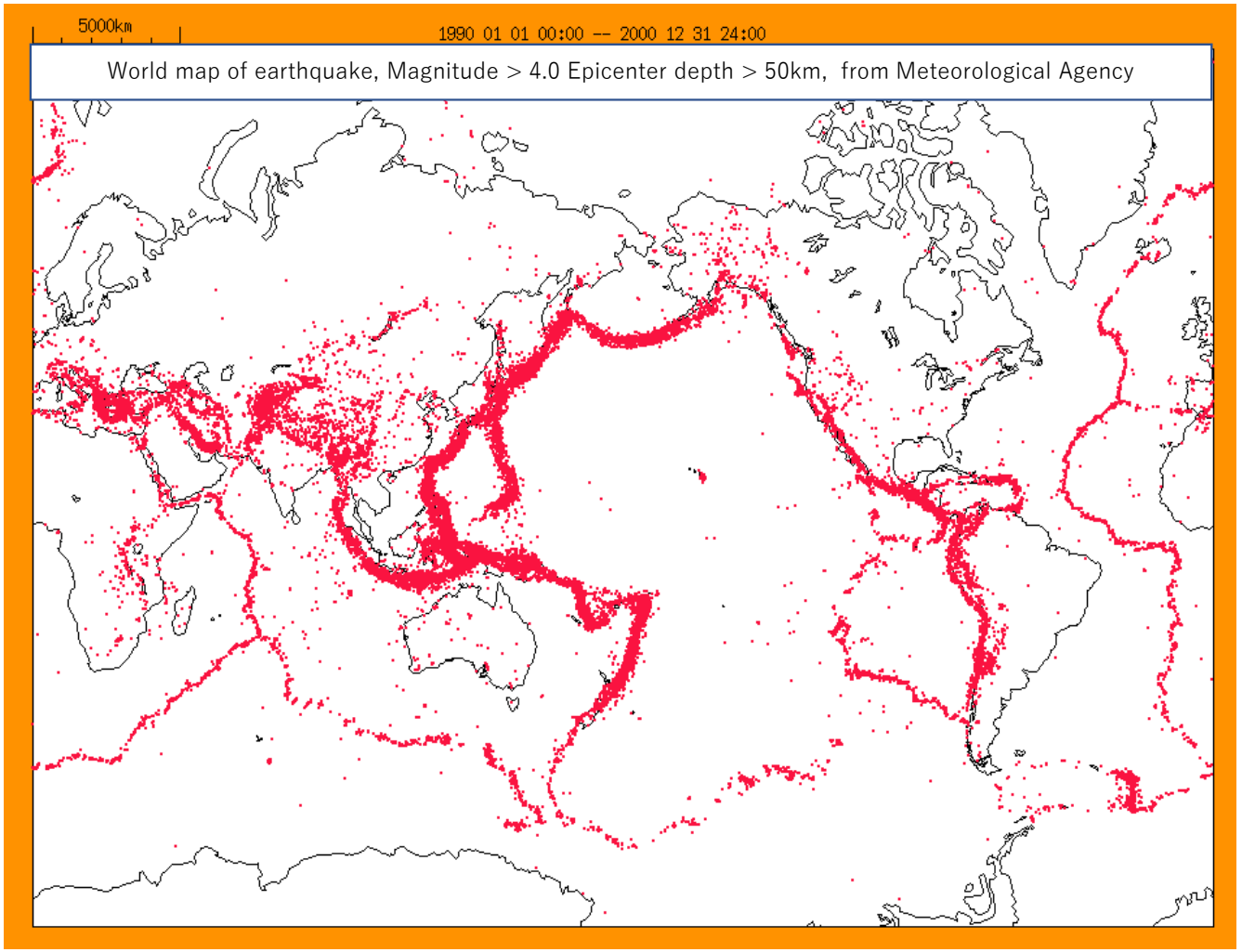
大ふまばゆひ

Mechanism of Earthquake (Inter-plate earthquake)

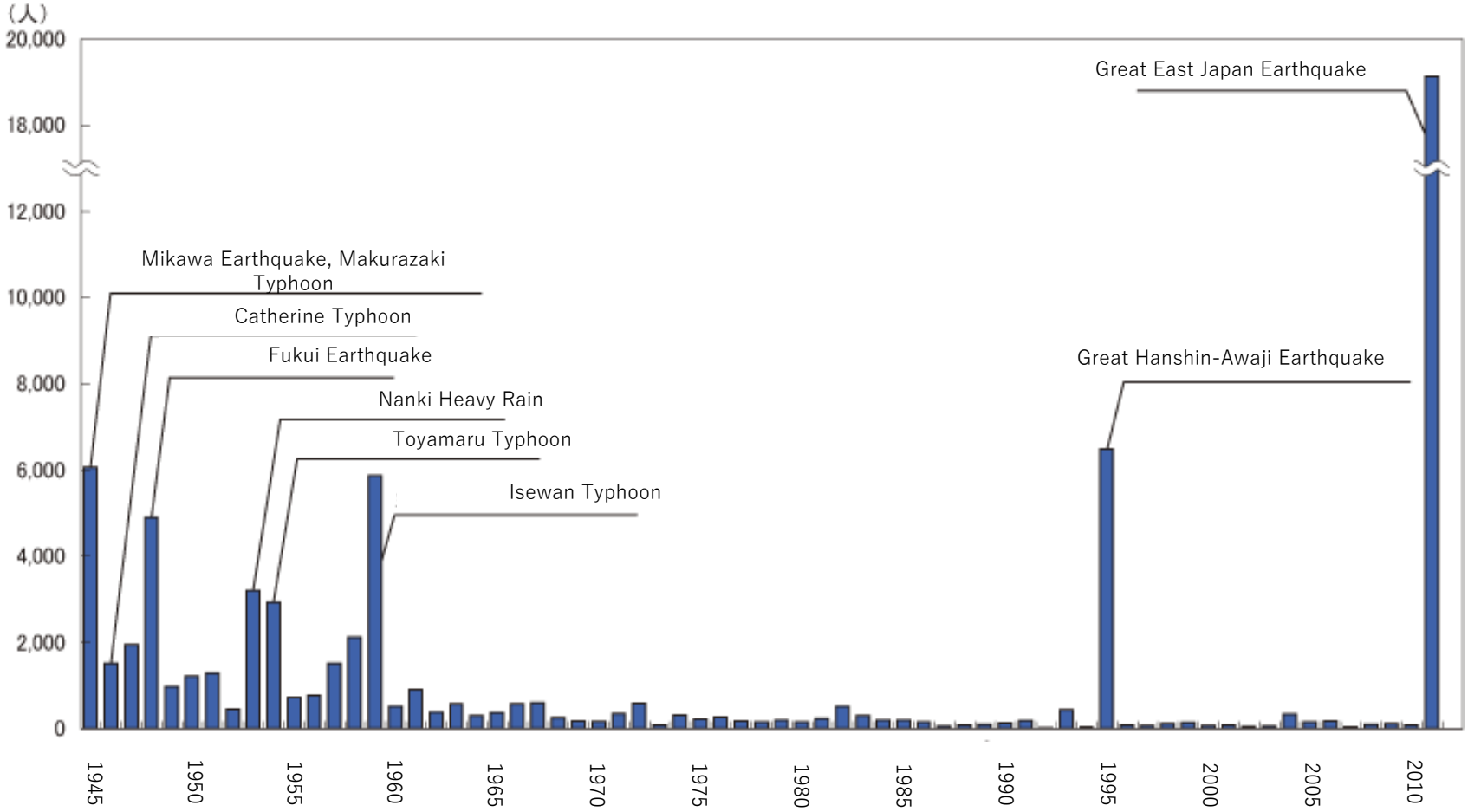


The Headquarters for Earthquake Research Promotion

Earthquake Map in the world



Trend of Fatalities and Missing by Natural Disaster in Japan(Cabinet Office)



Great East Japan Earthquake in 2011

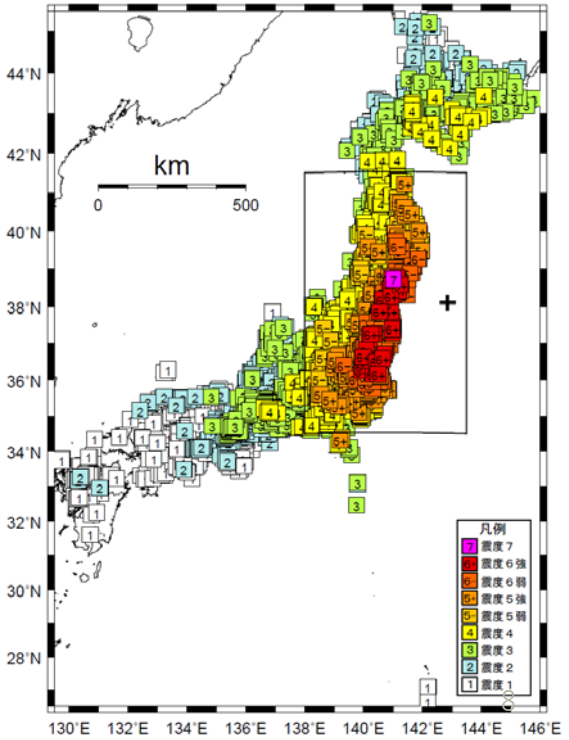
1. The earthquake in summary

(Official) name of the earthquake: Earthquake off the Pacific Coast of Tohoku Region

Time and date of occurrence: 2:46pm, March 11th JST, 2011

* The fourth greatest earthquake observed in the whole world, in and after 1900

	Time and date	Earthquake's name	Magnitude (Mw)
1	May 23, 1960	Chili Earthquake	9.5
2	March 28, 1964	Alaska Earthquake	9.2
3	December 26, 2004	Sumatra Earthquake	9.1
4	November 5, 1952	Kamchatka Earthquake	9.0
	March 11, 2011	Earthquake off the Pacific Coast of Tohoku Region	9.0



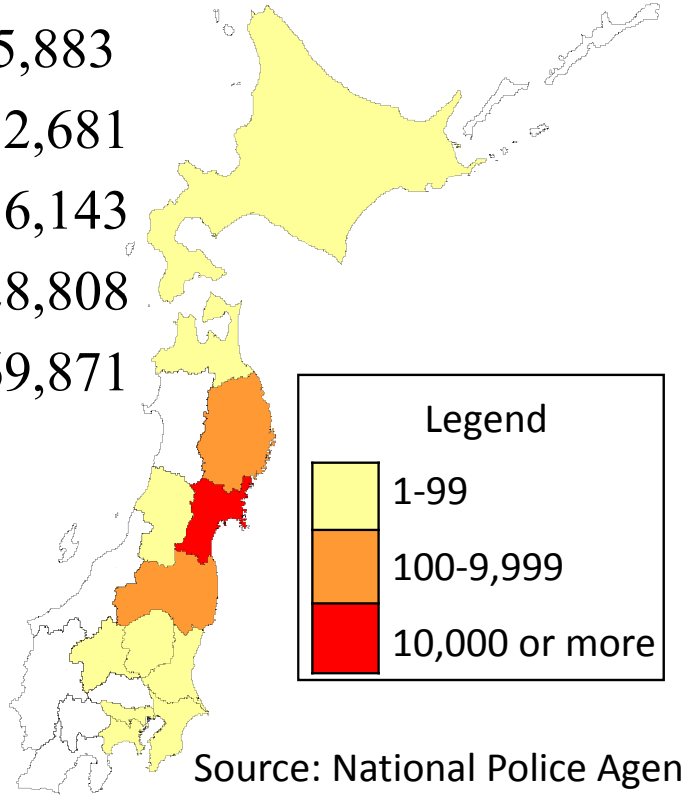
Distribution of earthquake intensities (From the website of the Japan Meteorological Agency)

Damages in summary

- Casualties : 15,883
- Missing : 2,681
- Injured : 6,143
- Fully destroyed buildings : 128,808
- Partially destroyed buildings : 269,871

(As of April 10, 2013)

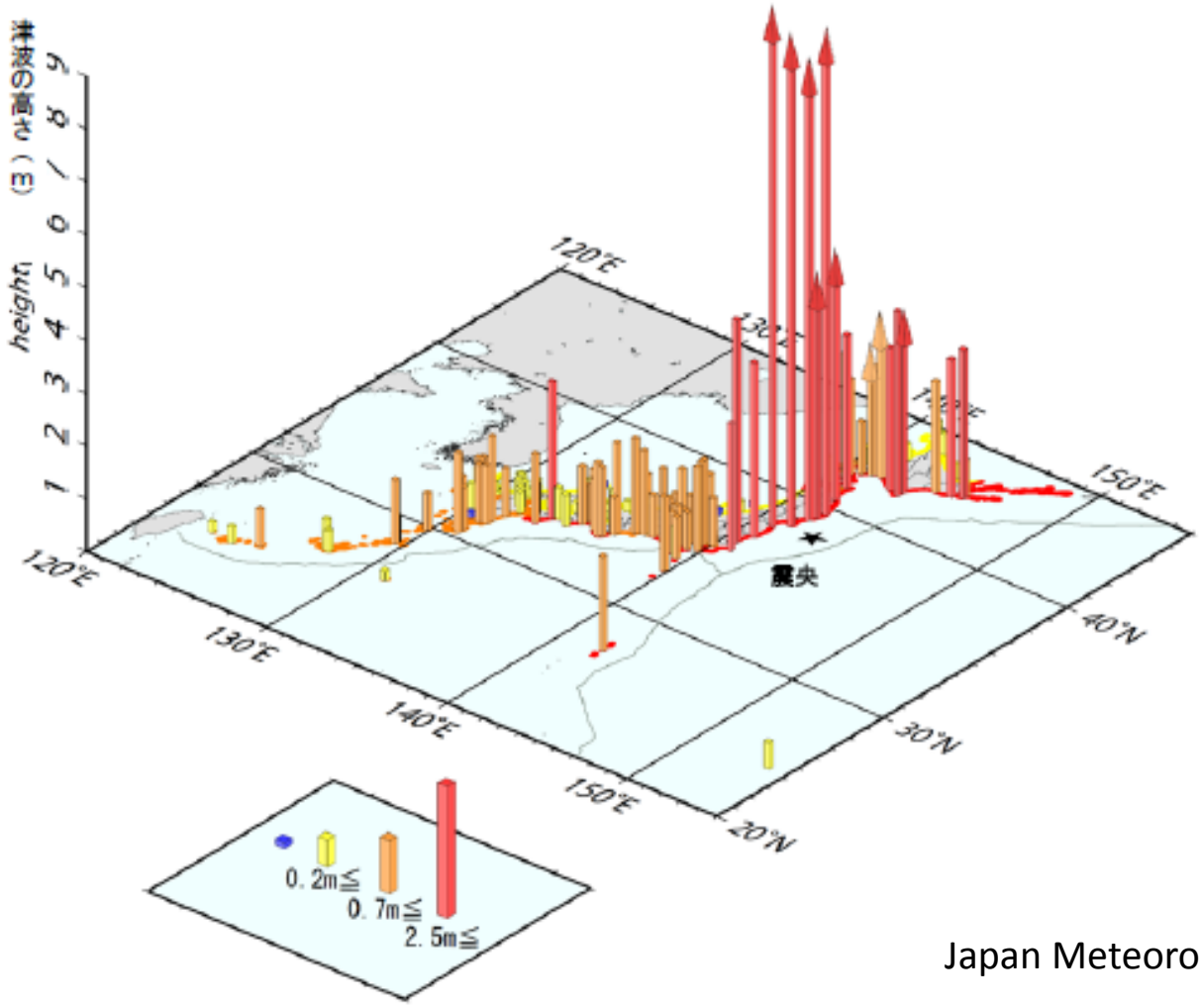
Casualties and missing people in each Prefecture affected



Source: National Police Agency

Damages by Tsunami

The massive tsunami hit



Japan Meteorological Agency

Ships hit town

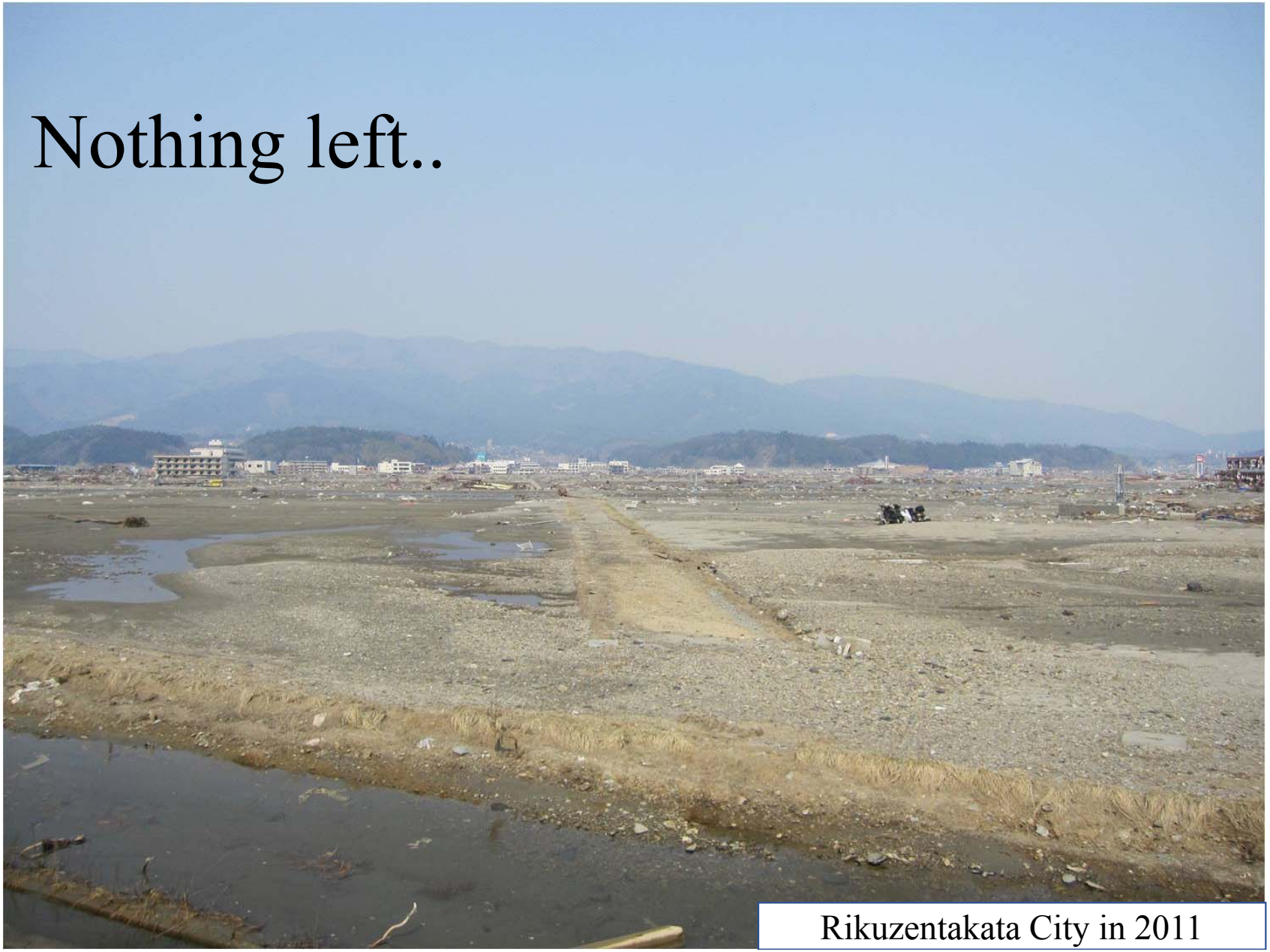
Ohtsuchi Town

Kamaishi City

Taro district in Miyako city in Iwate Prefecture in 1998

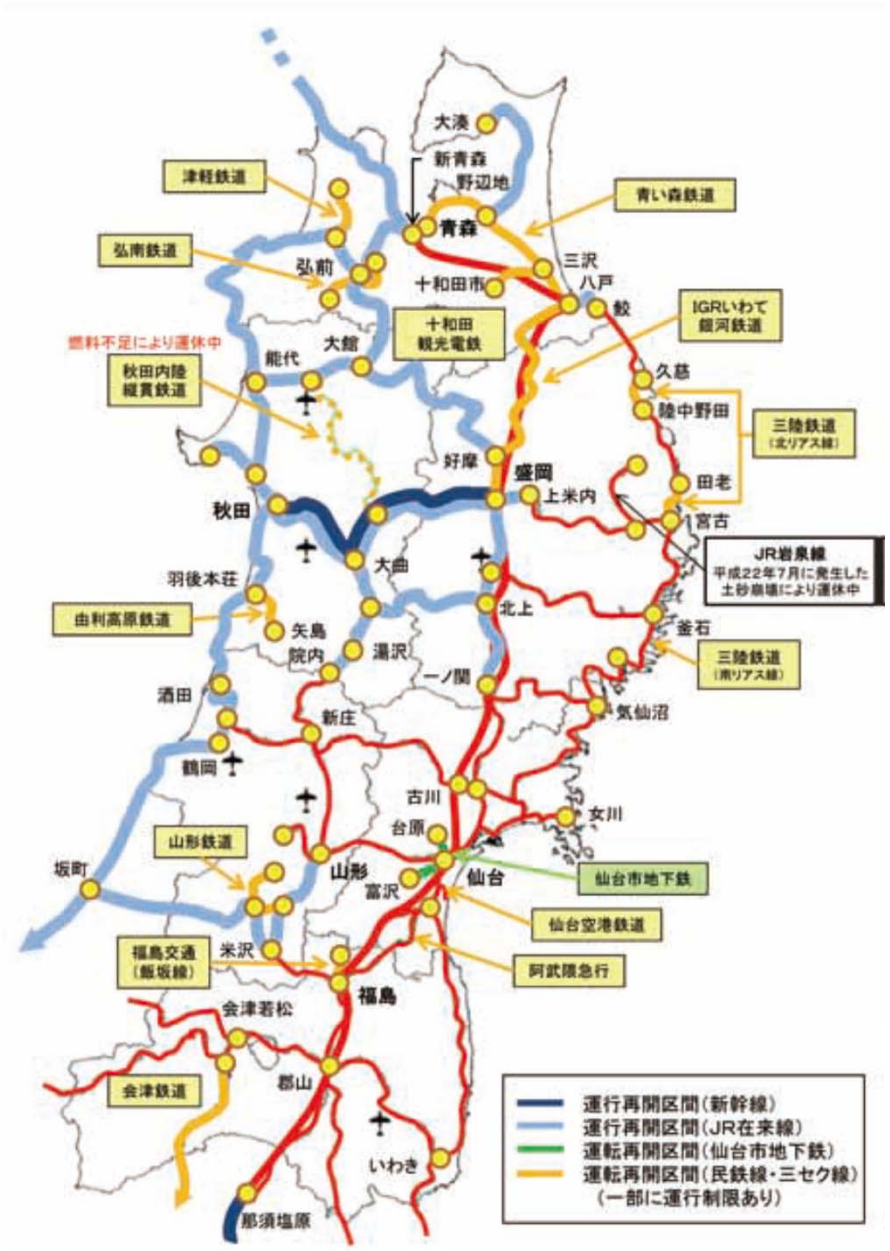
Taro district in Miyako city in Iwate Prefecture in 2011

Nothing left..



Rikuzentakata City in 2011

Damage of Railways



Not in Service
March 21, 2011

Source: Ministry of Land, Infrastructure, Transport and Tourism

Railway Damage (Restoration Cost by MLIT)

Railway Sector	Estimated Cost (JPY)	Estimated Cost (USD)
JR East Japan	58.7 billion (by Nikkei News paper)	534 million
Sanriku Railway	10.8 billion	98 million
Sendai Airport Railway	2.8 billion	25 million
Sendai City Subway	500 million	4.5 million
Abukuma Express	380 million	3.5 million
IGR Iwate Galaxy Railway	6 million	54,000
Fukushima Transport	1million	9,090
Hachinohe Seaside Railway	56 million	509,000
Iwate Development Railway	120 million	1 million
Sendai Seaside Railway	1.75 billion	16 million
Fukushima Seaside Railway	770 million	7 million
Total	75.9 billion	690 million

1 USD =110 JPY

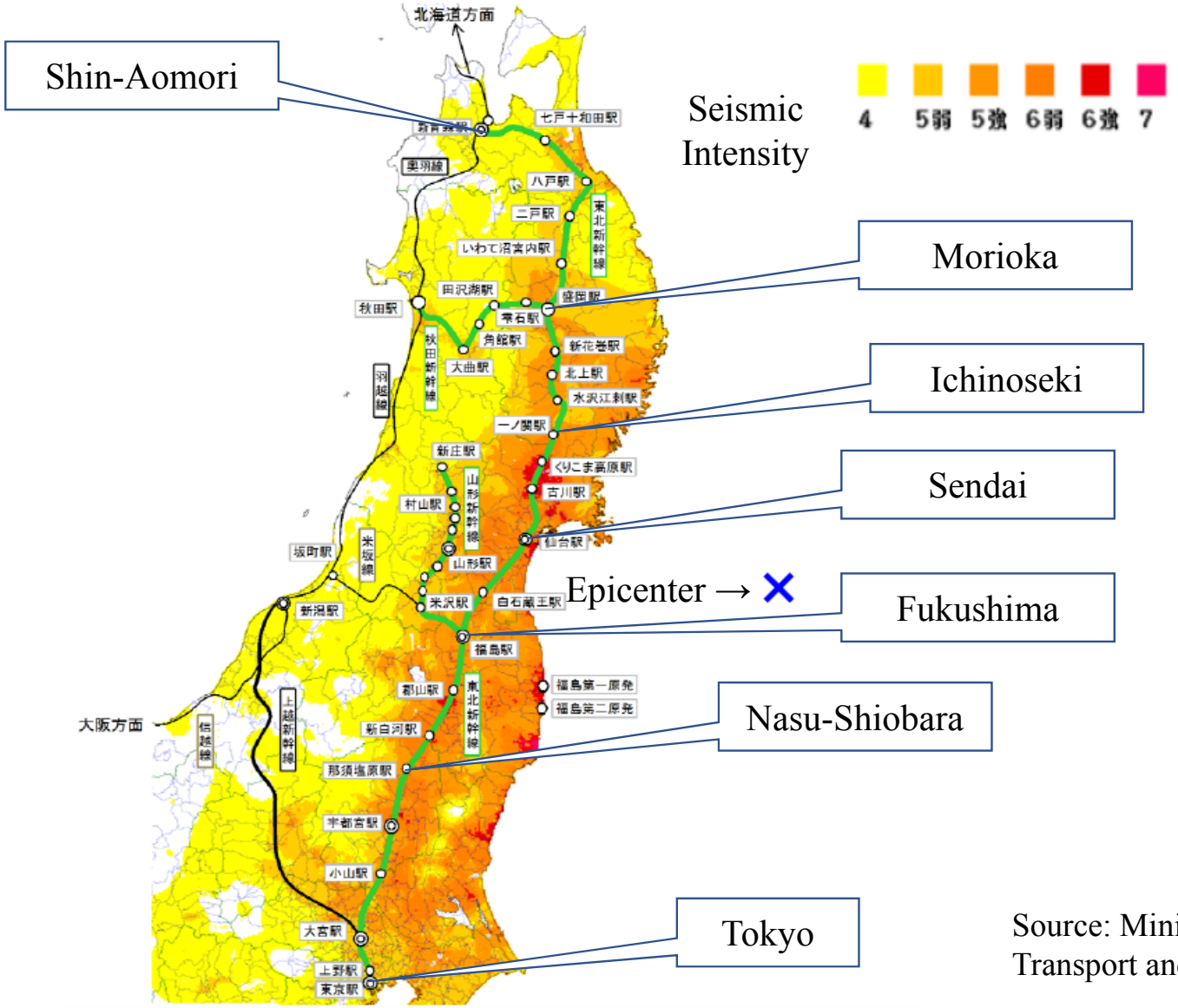
Injury, Death

- There was no fatality or injury on board train

Damage of Shinkansen (High Speed Train)

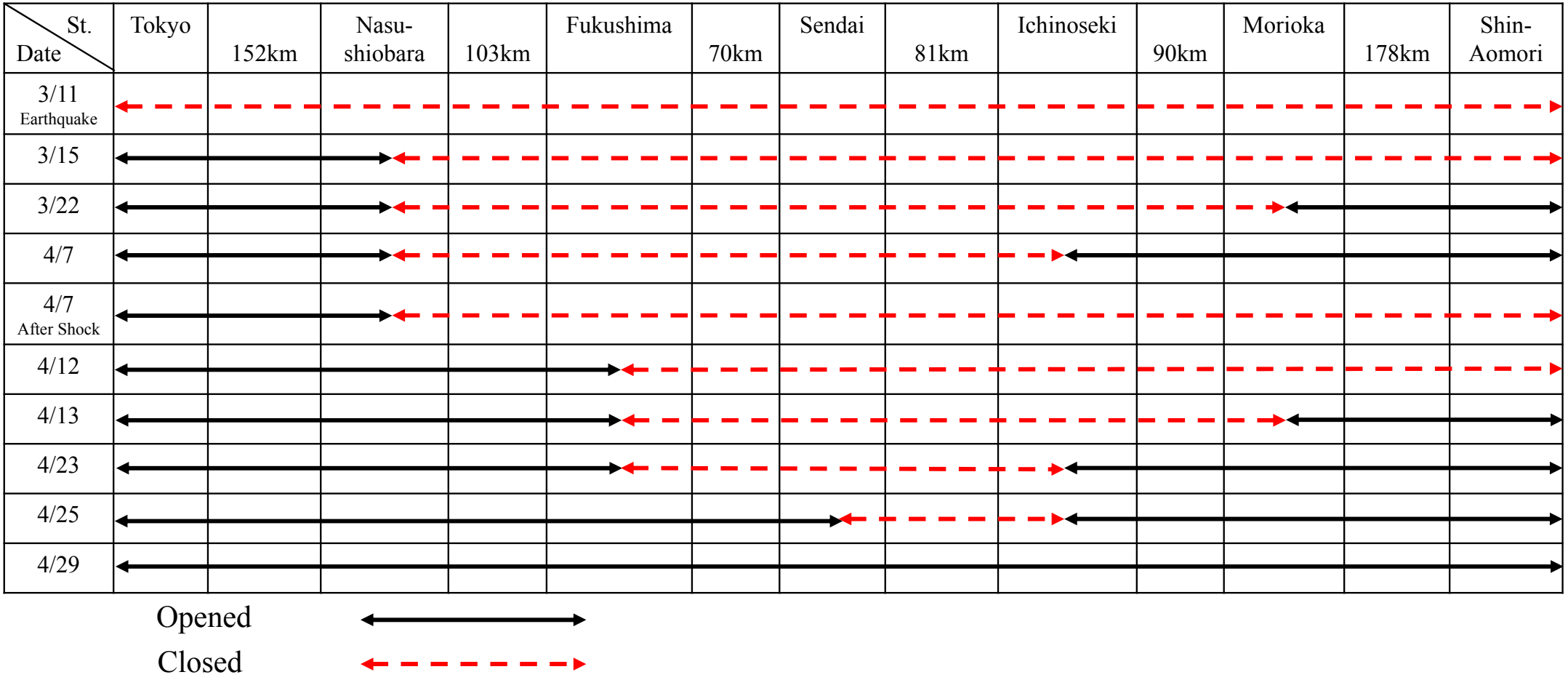
Sendai Station (Photo by Kahoku News paper)

Inclined electric pole (Photo by Kashima Co. Ltd)



Source: Ministry of Land, Infrastructure, Transport and Tourism

Restoration and Operation of Tohoku Shinkansen



Rikuzentakata St. 2008 10. 4

Rikuzentakata St. April 2011

Washed away railway bridge in Otsuchi Town in April 2011

Damaged railway in Otsuchi Town in April 2011

Overturned bridge pier in Otsuchi Town in April 2011

Unosumai St. in Kamaishi city in April 2011

JR Ordinary Line (Joban line, Shinchi St.)

Shinch Station after Tsunami attacked
By Kahoku News Paper April 10, 2011

Restoration of Railways

Case Study of Sanriku Railway

Sanriku Railway

- Sanriku Railway Co. Ltd. was founded in 1981 as private-public funded company
- Sanriku Railway started its service in 1984

  North-Rias line: 71.0 km

  South-Rias line: 36.6 km

  Gauge: 1,067mm

  Single Truck, Non-Electrified
- Capital: 300 million Yen

Number of Damaged Structures

Structure / Line	Embank-ment / Cut	Bridge	Tunnel	Station	Truck	Signal	Others	Total
North-Rias	11	15	0	1	38	5	0	70
South-Rias	61	20	4	4	96	52	10	247
Total	72	35	4	5	134	57	10	317

Damage by the Great East Japan Earthquake

Washed away Bridge (South-Rias Line)

Wreckage of Bridge (North-Rias Line)

Damage by the Great East Japan Earthquake

Debris on railway (South-Rias Line)

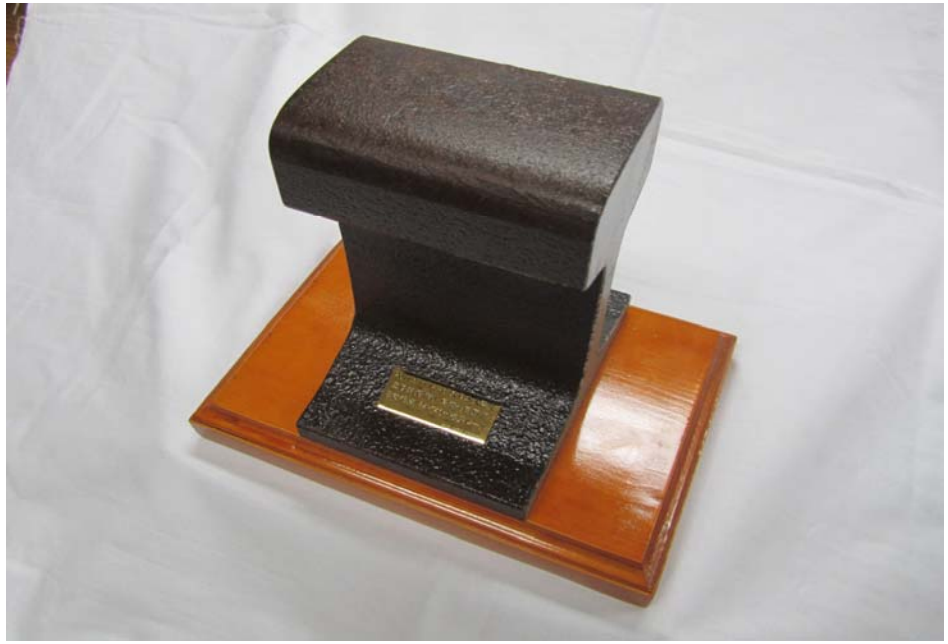
Drifted cars on railway (South-Rias Line)

Restoration Activities

Train car became temporary head-quarter of restoration since the main building of the company was damaged

Collecting the Fund (Even very small contribution..)

- Piece of damaged Rail was sold to collect the restoration fund
- 10 cm long rail : 50,000 JPY
- 5 cm long rail : 30,000 JPY



Restoration Fund Structure

- Total restoration amount was 10.8 billion Yen (1 million USD) in 3 years
- National government bore a half of the fund
- Prefecture government and Municipalities along the railroad bore the quarter respectively
- Prefecture government and Municipalities were funded by National government by Special grant tax
- Assets of Sanriku Railway was granted to Municipalities along the railroad
- The municipalities lease the assets to Sanriku Railway free of charge

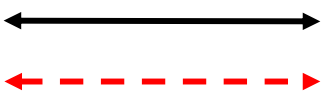
Donation from Kuwait Government

Donated Train by Kuwait government

The ambassador at the ceremony on April 5, 2014
(photo by Kuwait Embassy)

Restoration Construction

Restoration and Operation History



Line	North-Rias Line											South-Rias Line				
St. / Date	Kuji	11.1 km	Rikuchu-Noda	24.3 km	Tanohata	10.5 km	Omoto	12.4 km	Taro	12.7 km	Miyako	Kamaishi	15.0 km	Yoshi-hama	21.6 km	Sakari
2011 3/11	←										→	←				→
2011 3/16	←		→								→	←				→
2011 3/20	←		→						←		→	←				→
2011 3/29	←		→				→				→	←				→
2012 4/1	←				→		→				→	←				→
2013 4/3	←				→		→				→	←		→		
2014 4/5	←				→		→				→					→
2014 4/6	←										→					→

Before and After

Just after the earthquake (North-Rias Line)

After the restoration (Same place)

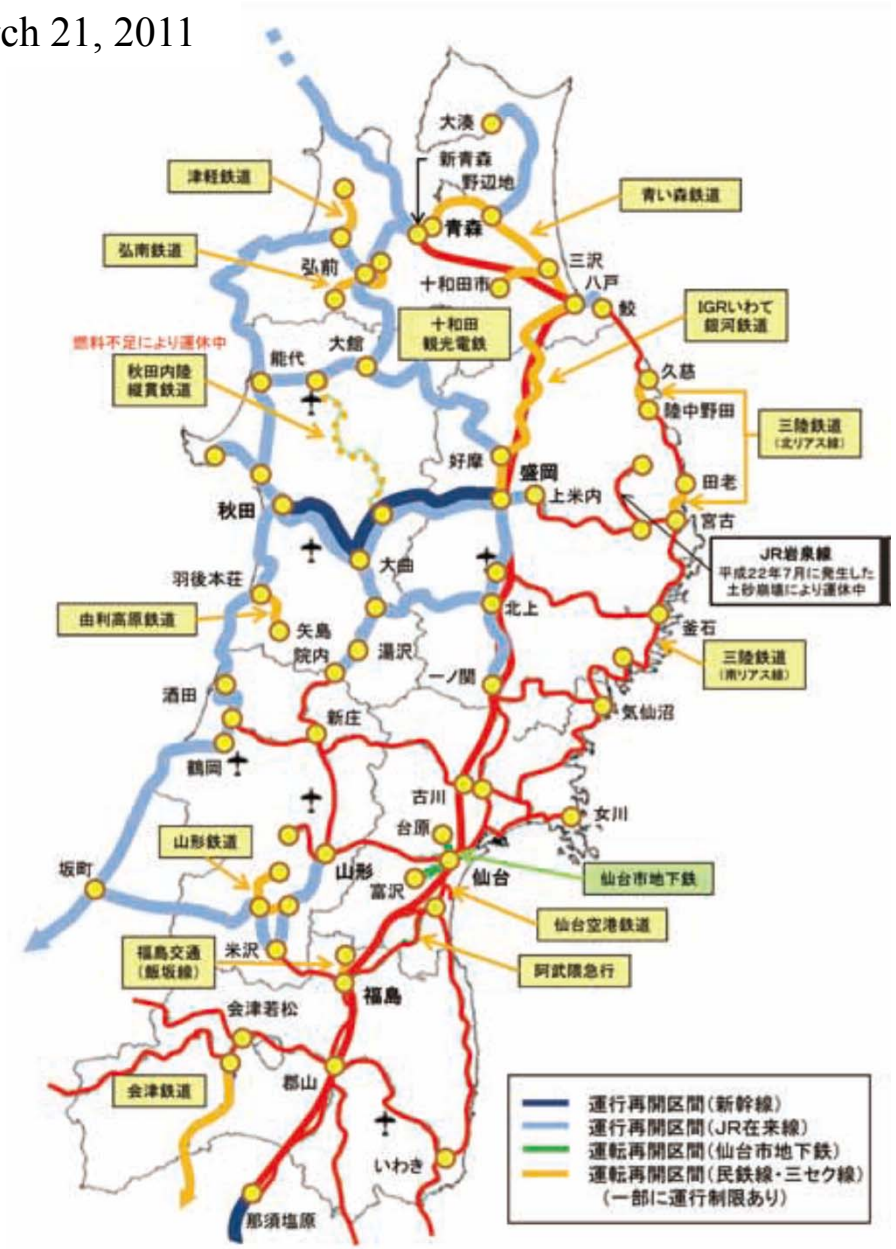
Celebration of re-opening

At the partial re-opening on April 1, 2012

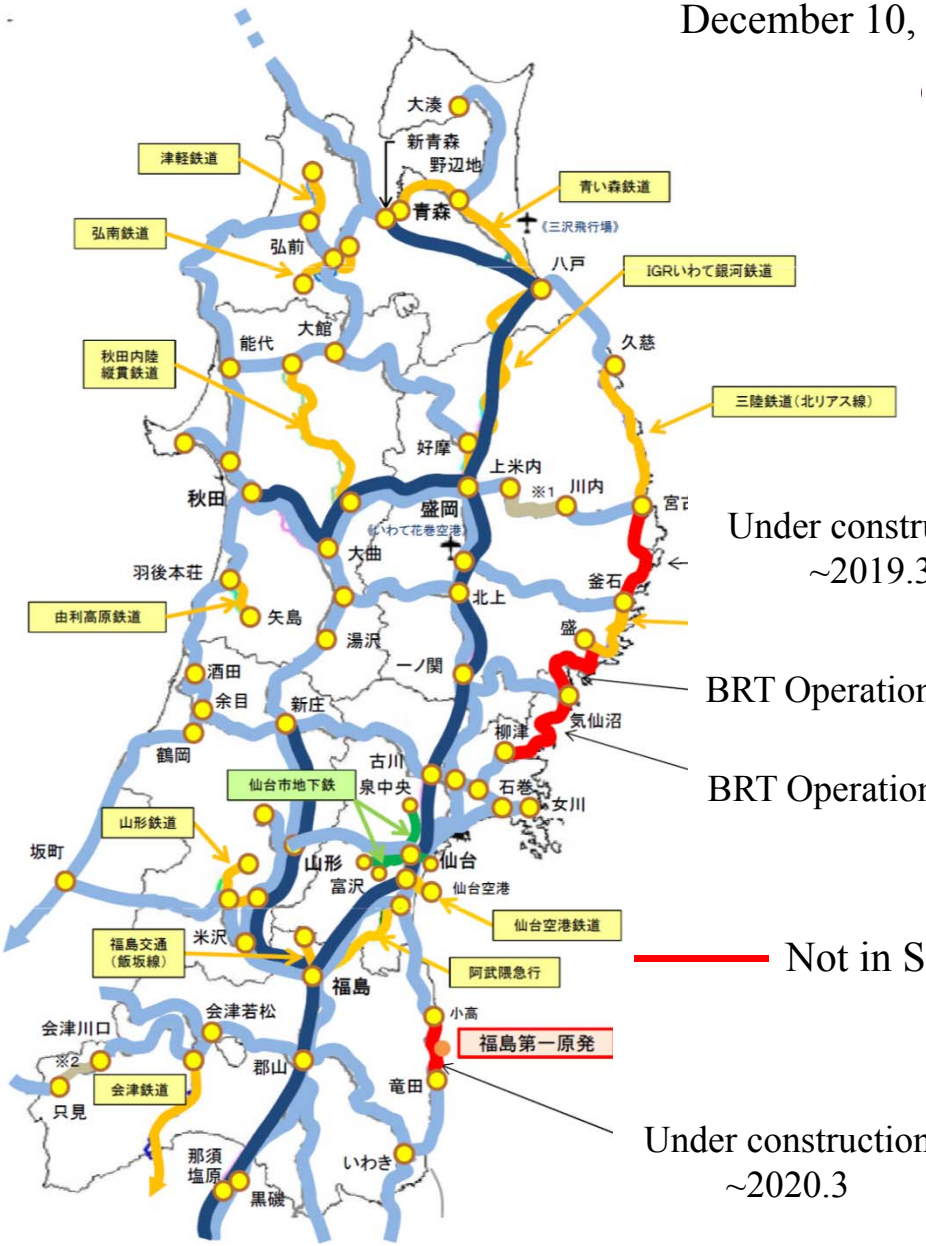
At the full re-opening on April 6, 2014

Present Situation of Railways in Devastated Area

March 21, 2011



December 10, 2016



Under construction
~2019.3

BRT Operation

BRT Operation

Not in Service

Under construction
~2020.3

Bus Rapid Transit System (BRT)

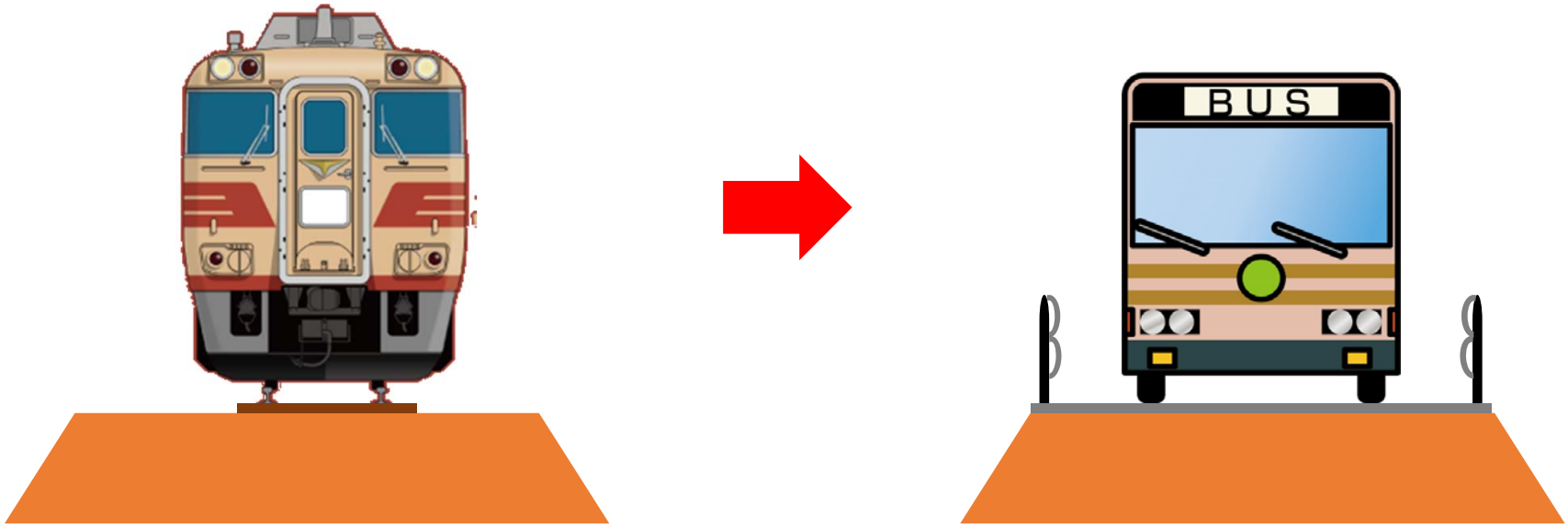
- Originally, BRT is to improve the capacity of ordinary bus system in urban area
- BRT is given own monopoly road way, so that it can keep punctuality and speed
- The function of BRT is similar to the tram
- Construction and maintenance cost is cheaper than tram or train
- Transportation capacity is between tram and ordinary bus
- The BRT in disaster damaged area is a substitute of the train which had been ineffective and costly before the disaster

Bus Rapid Transit System (BRT)

BRT in Mexico City

BRT in Delhi City

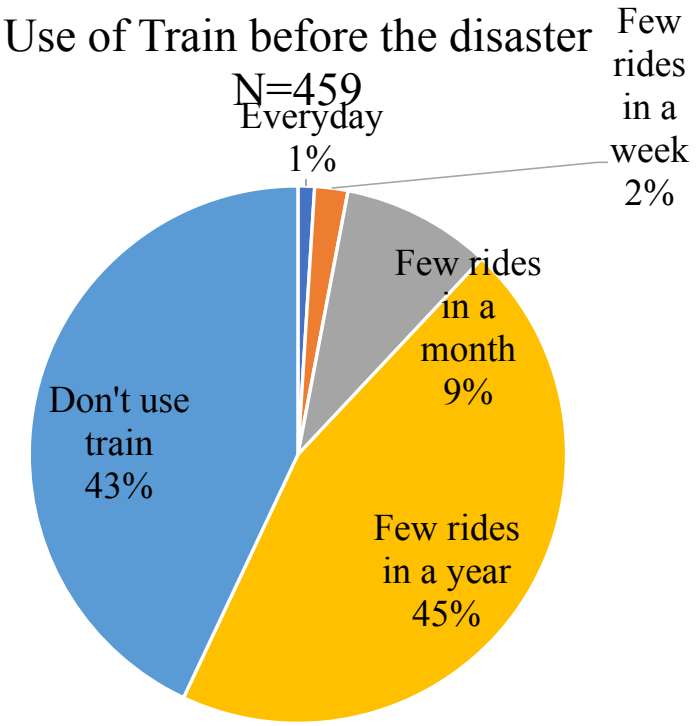
Bus Rapid Transit System (BRT)

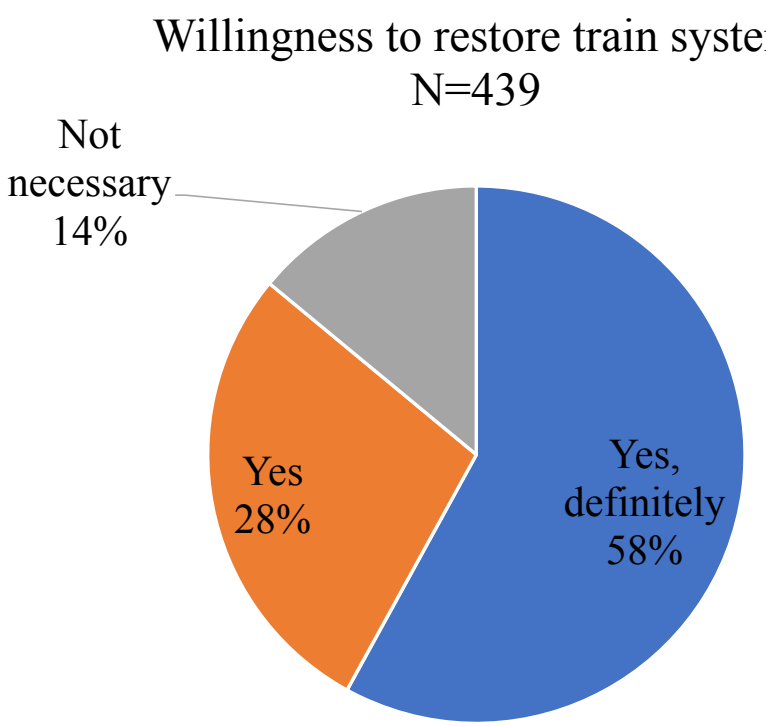


Bus Rapid Transit System (BRT)

	Train	BRT
Passenger Capacity	100 persons / Car	60 persons / Car
Maximum Speed	85 ~ 100 km/h	60 km/h
Punctuality	High	Low
Comfortableness	High	Low
Connectivity with Other Railway	Yes	No
Operation Cost	Expensive	Cheap
Maintenance Cost	Expensive	Cheap
Vehicle Initial Cost	Expensive (e.g. 2 million USD)	Cheap (e.g. 0.2 million USD)

Citizen's use and willingness to restore train system (In Kesennuma city, by Motoda 2015)






Sanriku North Line L=71.0km Opened
JR Yamada Line L=55.4km Closed
Sanriku South Line L=36.6km Opened
JR Ohfunato Line L=43.7km BRT
20 km
(C)Yahoo Japan,(C)OPeNBooK
岩手県
安代JCT
盛岡
花巻JCT
北上
北上JCT
遠野
釜石
住田
大船渡
宮古
久慈
黒崎
北山崎
岩泉
真崎
一関
水沢
奥州
気仙沼


平泉前沢
平泉
東稲山
595
平泉
343
陸前高田
895
室根山
大森山
429
厳美溪
一関
一関
784
気仙沼
唐桑半島
342
4
456
45
大森山
760
大島
若柳金成
456
45
JR Kesennuma Line L=55.3km BRT
くりこま高原
栗原
伊豆沼
内沼
築館
登米
長沼
342
南三陸
気仙沼線
東北
古川
108
美里
涌谷
北上川
追波湾

Entry to BRT Line (Kesennuma Line)

Crossing of BRT (Kesennuma Line)

Railway and BRT (at Sakari St.)

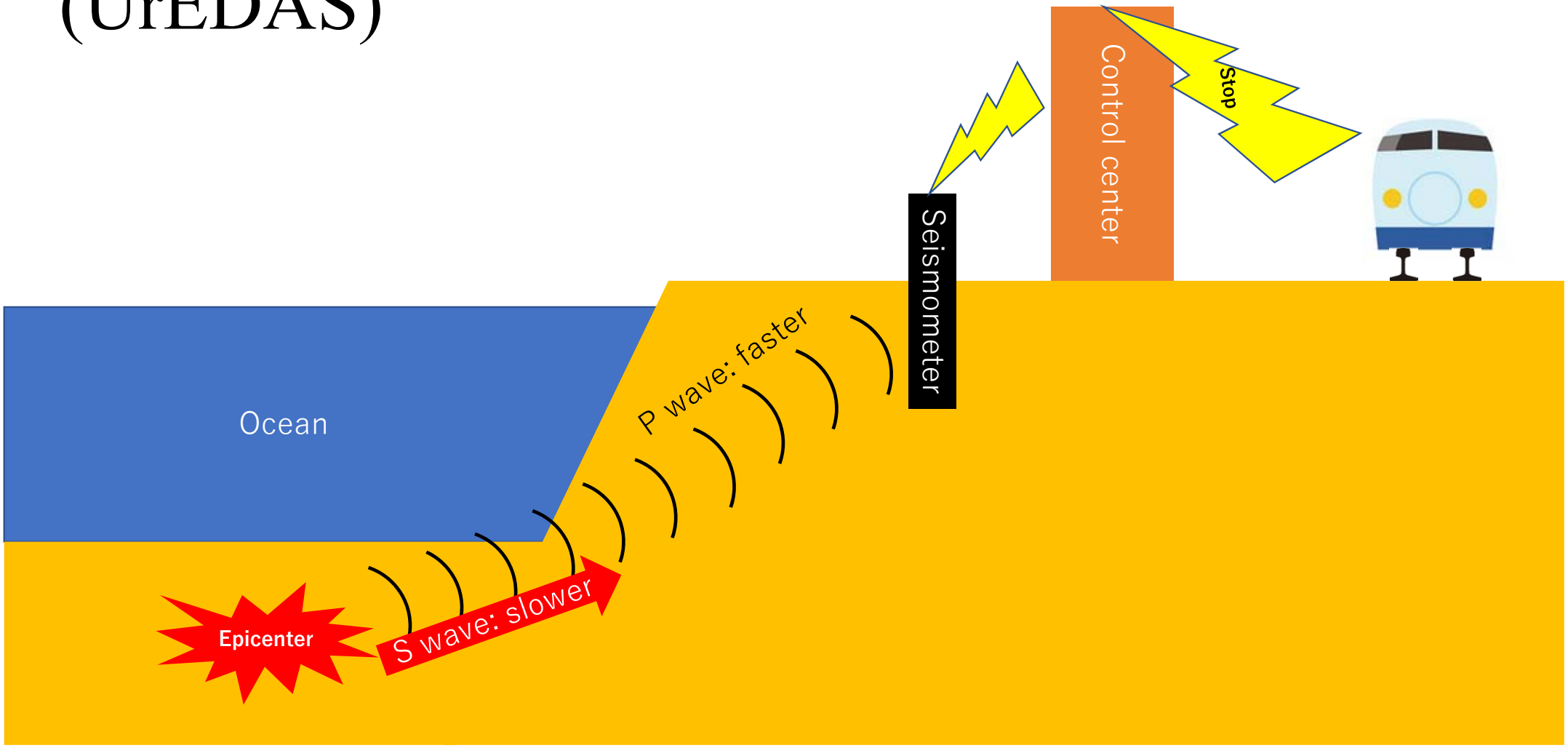
Problems and Lessons from the Disaster

Derailed Shinkansen cars by Niigata Prefecture Chuetsu Earthquake in October 2004

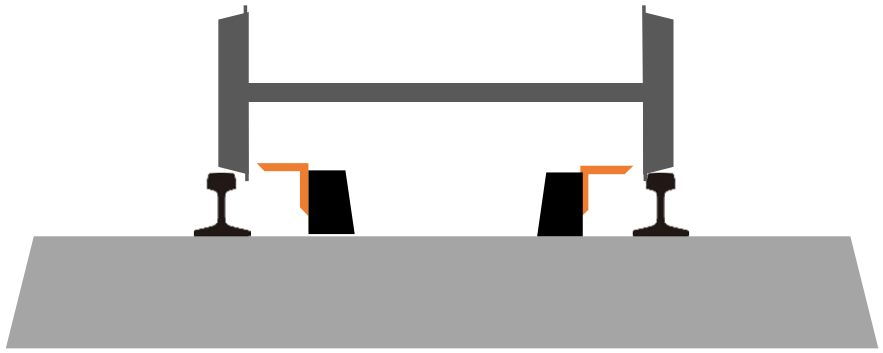
Urgent Earthquake Detection Alarm System(UrEDAS)

- To detect primary wave and transmit caution information to railway system before secondary wave which is slower but has destructive power than primary wave come to railway system
- Primary wave: longitudinal wave, velocity is faster than S wave (e.g. 5-7 km/sec)
- Secondary wave: Transverse wave , velocity is slower than P wave (e.g. 3-4 km/sec)
- When the epicenter is far way from railway, this system is effective.

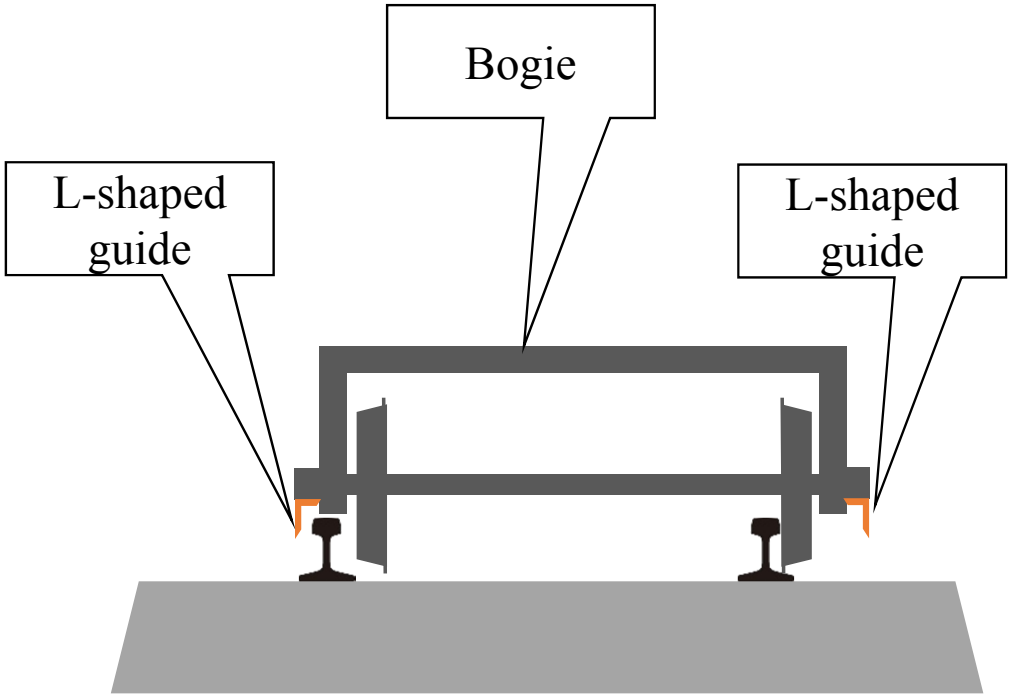
Urgent Earthquake Detection Alarm System (UrEDAS)



Derailment prevention guard



Prevention of deviation from rail



L-shaped guide to prevent deviation from rails

Photo: Technical Report of Nippon Steel and Sumitomo Metal, Vol.395, 2013

Retrofitting of Bridge Pier

Steel Jacketing (Tohoku Shinkansen, Morioka city)

Rib-bar retrofit (Tohoku Shinkansen, Morioka city)

Conclusion

- The railways along Pacific Ocean coast were severely damaged by Tsunami
- However, it is noted that there were no injury or fatality on board train
- UrEDAS, Retrofitting of Bridge and Derailment device were effective for mitigating damage of high speed train system
- Bus Rapid Transit system was first introduced in Japan as a substitute of train with low passenger needs


Thank you for your attention !