High-Speed Railway In Japan

Railway Bureau, MLIT

5.December, 2011

MLIT

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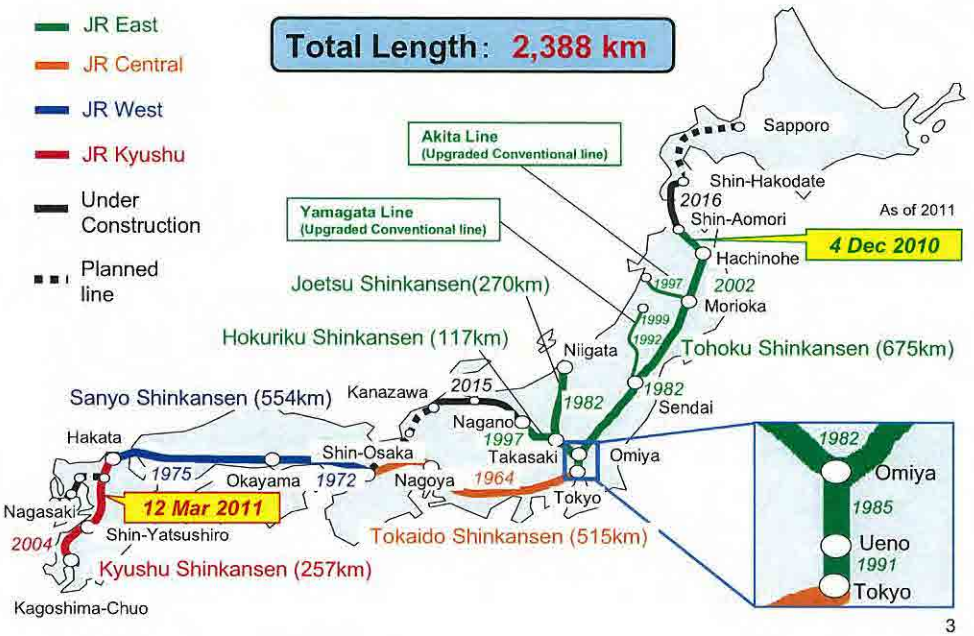
1. Japan's Current HSR Network

2. The Development of the Construction of Shinkansen

3. The earthquake-proof Shinkansen

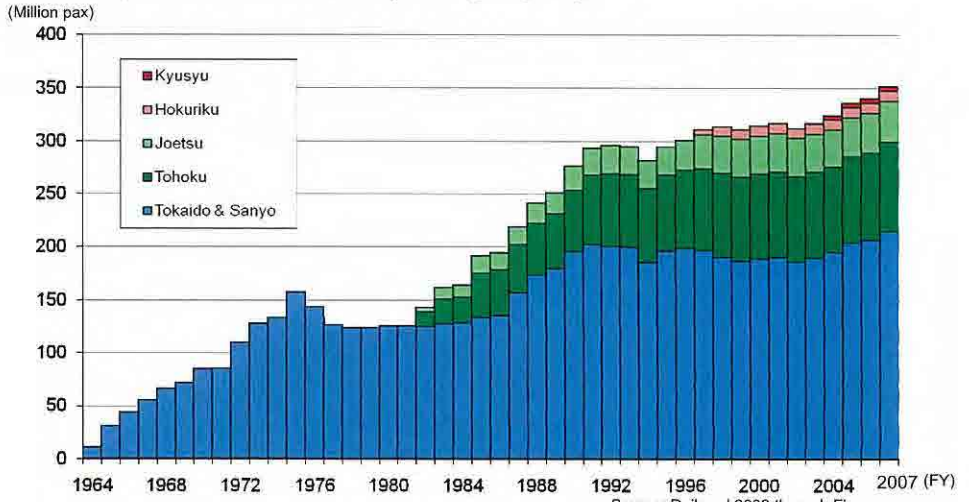
1. Japan's Current HSR Network



1. Japan's Current HSR Network
No. of Shinkansen Passengers

Annual No. of Shinkansen passengers has been steadily growing since its opening in 1964.

○ Changes in No. of Shinkansen passengers yearly



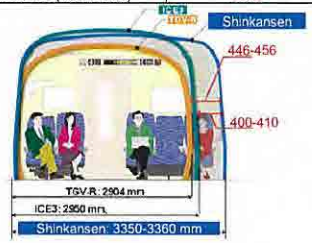
Source: Railroad 2009 through Figures, Shinkansen (Sankaido)

Shinkansen's car body is wider and lighter than other high speed rail trains

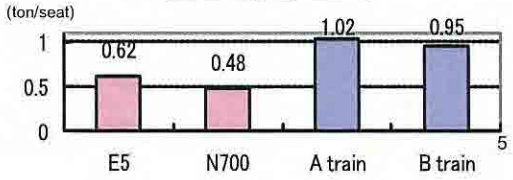
O Wide and lightweight car body

	Shinkansen Series E5	Shinkansen Series N700	A train	B train
Maximum Speed (km/h)	320	300	320	320
Width (mm)	3,350	3,360	2,904	2,950
Seat Pitch (mm)	1,040	1,040	900	920
Trainset(cars)	10	16	20	16
Seats (No.)	731	1,323	750	858
Train Weight (ton) *	454	635	766	818
Train Weight/Seat (ton/seat)	0.62	0.48	1.02	0.95

*Unloaded train data



Train weight per seat



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O What are the benefits reaped from these strengths?

- **High Energy Efficiency & Less CO_2 Emission**
  Lightweight
- **Low Noise Levels**
  World's strictest trackside-noise regulation applied
- **Passenger Comfort**
  Wider car body & longer seat pitch
- **Large Capacity**
  More passengers per train
- **Low Construction Cost**
  Smaller tunnel cross-section & lane sizes
- **Low Maintenance Cost**
  Lightweight

Established Record of Outstanding Safety & Reliability Over 46 Years

- Passenger casualties to date: **ZERO**
- Average delay time: less than **1 min**

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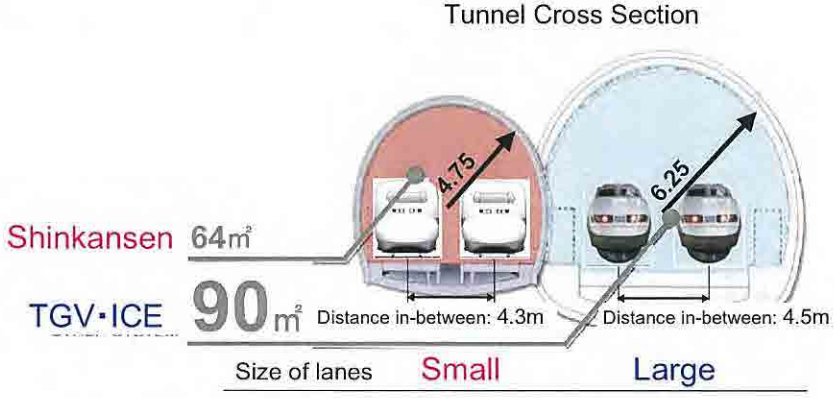
Shinkansen allows for smaller tunnel cross sectioning thanks to its excellent car body air tightness.

O Small infrastructure

Tunnel Cross Section



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1959 ~

Tokaido, Sanyo, Tohoku (Tokyo-Morioka), and Joetsu Shinkansen were mainly financed by **loans** with interest.

Privatization and division into six private companies of the Japanese National Railways (JNR) in 1987

~ Today

Other Shinkansens have been constructed in the form of public works projects with **subsidies from the national government and local governments involved.**

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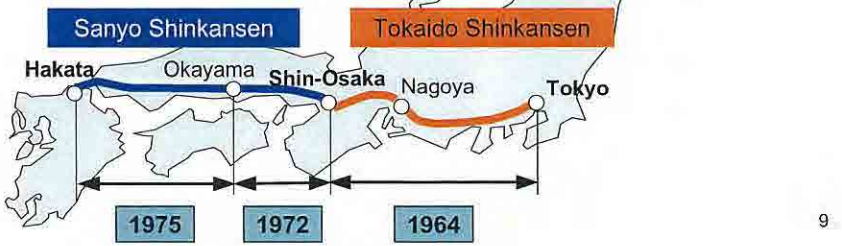
O Construction schemes for the Tokaido and Sanyo Shinkansen

- **No special scheme** existed for Shinkansen construction.
- The construction costs were fully covered by **loans** with interest.
- For the Tokaido Shinkansen, a **World Bank (IBRD) loan** of $320 million was provided, which accounted for 8.6% of the total construction cost of $3.7 billion.



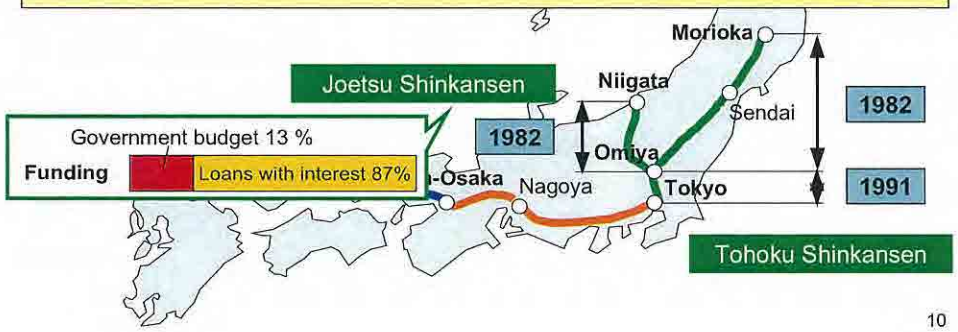
O Shinkansen Construction Costs(Before the reform JNR)

	Tokaido	Sanyo	Tohoku	Joetsu
Section	Tokyo～Shin-Osaka	Shin-Osaka～Hakata	Tokyo～Morioka	Omiya～Niigata
Route length	515km	554km	497km	270km
Construction period	1956～1964	1967～1975	1971～1991 ※1	1971～1982
Construction Costs	$3.7 billion	$10.1 billion	$29.6 billion	$18.1 billion
Cost per km	$7.2 million	$18.2 million	$59.6 million	$67.0 million
(Reference)				
Passengers per year	149.2 million	62.9 million	82.2 million	37.4 million
Passengers per day	409 thousand	172 thousand	225 thousand	102 thousand

※1 Ueno Tokyo during construction since the reform of JNR

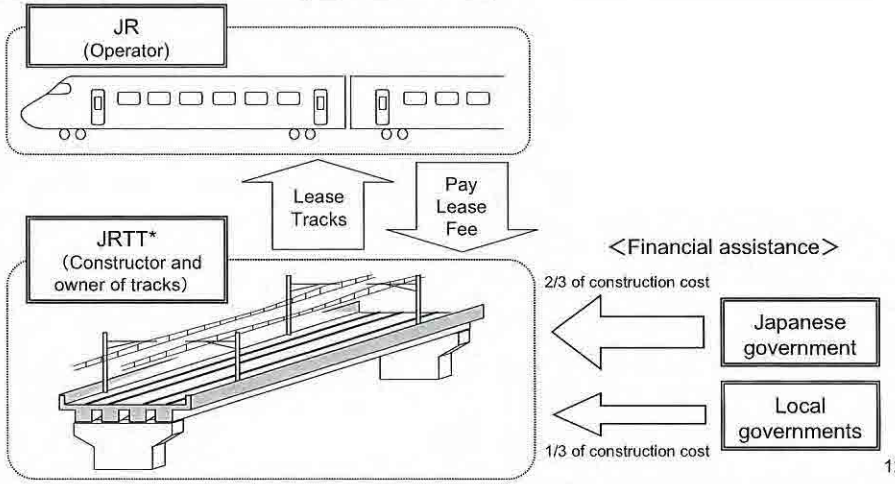
O Construction scheme for the Tohoku and Joetsu Shinkansen

- Tohoku Shinkansen (Tokyo-Morioka) & Joetsu Shinkansen (Omiya-Niigata) were constructed by the **JNR & Japan Railway Construction Public Corporation (JRCC) under the Nationwide Shinkansen Railway Development Law, enforced in 1970**.
- Government funding was partially used for the construction costs; however, a large part of the costs were still covered by **loans with interest**.



For the sustainable operation of Shinkansen, the operator, JR, does not shoulder an excessive burden of railway construction costs. The tailored construction-operation separation scheme was introduced in 1997, which is subsidized by the Japanese government and local governments involved.

O Construction-operation separation schemes



*JRTT: The Japan Railway Construction, Transport and Technology Agency

Criteria for starting construction

- ●Stable financial resources
- ●Profitability
  - Annual profit of operator >0
  - (average over the next 30 years after opening)
- ●Investment effect
  - Benefit/Cost > 1
  - (Effect of saving travel time, etc.)
- ●Consent of JR
- ●Consent of the local government for terminating JR operation of the current conventional line

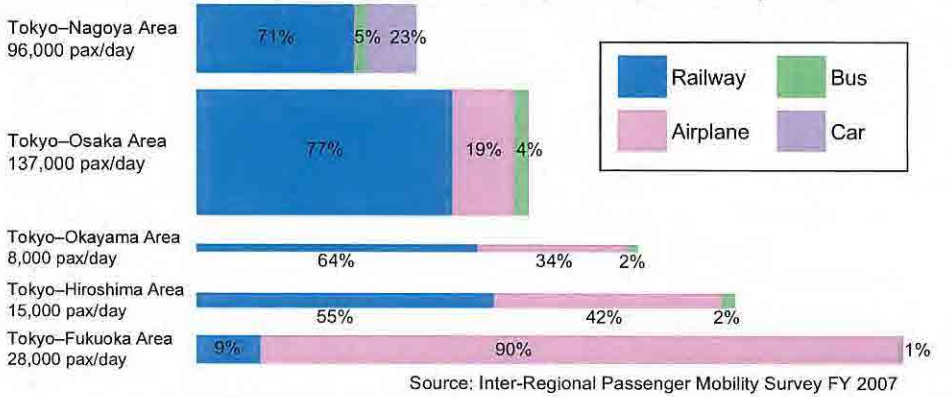
* Based on the basic policy on construction of new Shinkansen lines

○ Shinkansen Construction Costs(After the reform JNR)

	Tohoku	Hokuriku	Kyushu
Section	Morioka～Hachinohe	Takasaki～Nagano	Shin-yatsushiro～Kagoshima-chuo
Route length	97km	117km	127km
Construction period	1991～2002	1989～1997	1971～1991
Construction Costs	$5.1 billion	$9.2 billion	$7.0 billion
Cost per km	$52.6 million	$78.6 million	$55.1 million
(Reference)			
Passengers per year	82.2 million ※1	10.0 million	4 million
Passengers per day	225 thousand ※1	27 thousand	11 thousand

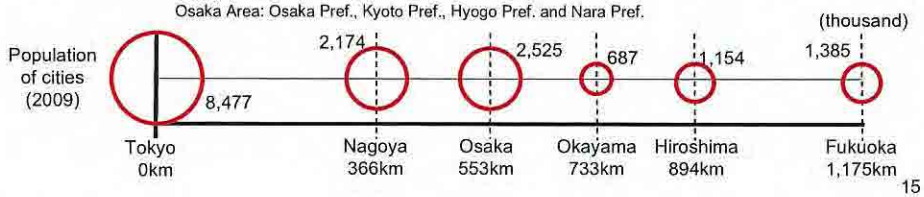
※1 Tokyo～Hachinohe data

○ Comparison of shares among modes of passenger transport for Tokyo–Fukuoka



Source: Inter-Regional Passenger Mobility Survey FY 2007

Note: Tokyo Area: Tokyo Metropolis, Kanagawa Pref., Chiba Pref., Saitama Pref. and Ibaraki Pref.
Nagoya Area: Aichi Pref., Gifu Pref. and Mie Pref.
Osaka Area: Osaka Pref., Kyoto Pref., Hyogo Pref. and Nara Pref.



Great East Japan Earthquake

<Date and time of occurrence>
March 11, 2011

<Strength of the earthquake>
Magnitude 9.0 on the Richter scale
(The strongest in the history of Japan)

<Number of casualties>
22,943 (As of June 20, 2011)

No casualties among passengers

・None of the Shinkansen trains were derailed. (27 Shinkansen trains were in operation, 19 of which were moving then.)
・No critical destruction to major structures such as viaducts, bridges, station installations and tunnels by this earthquake.

○Damage caused by the earthquake
No. of damaged sites: Approx. 1,200
・Broken, leaning, or cracked electrification masts: Approx. 540
・Severed power lines: Approx. 470
No. of damaged sites caused by the aftershock on 7 April: Approx. 550


Broken, leaning, or cracked electrification masts

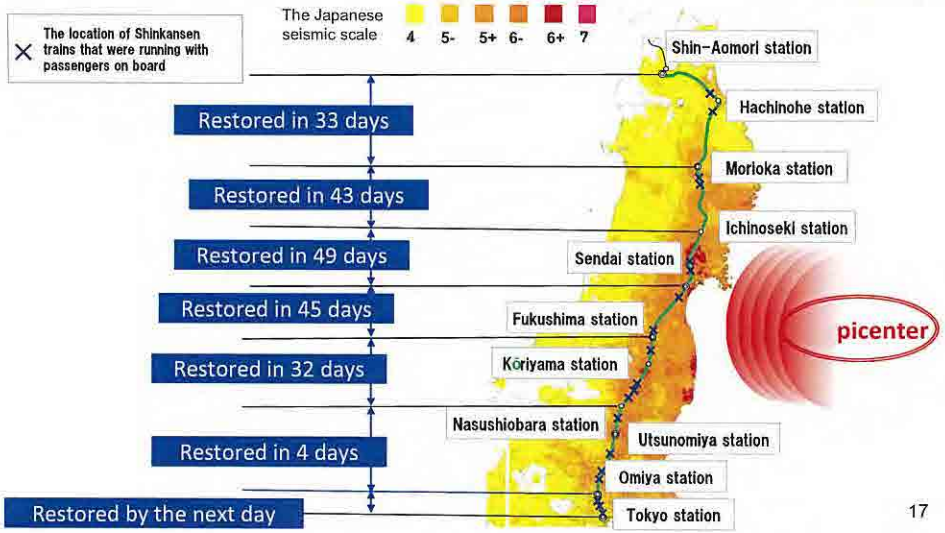

Severed power lines

3. The earthquake-proof Shinkansen

Ministry of Land, Infrastructure, Transport and Tourism

○The present status of Tohoku Shinkansen

Shinkansen services were completely restored 49 days after the earthquake occurred.



3. The earthquake-proof Shinkansen

Ministry of Land, Infrastructure, Transport and Tourism

○Anti-seismic reinforcement

Based on the experiences of past earthquakes, anti-seismic reinforcement to prevent shear failure of viaducts had been completed.
It prevented the viaducts from suffering critical damage; the restoration work was completed in a short time.

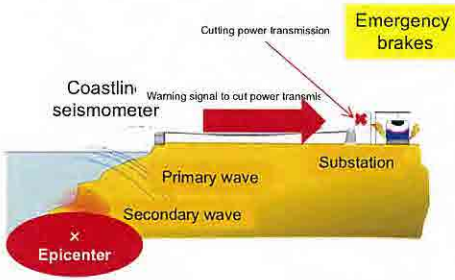
The damage to viaducts in Great Hanshin-Awaji Earthquake (occurred on 17 January 1997)	No damage to reinforced viaducts in Great East Japan Earthquake (occurred on 11 March 2011)

3. The earthquake-proof Shinkansen

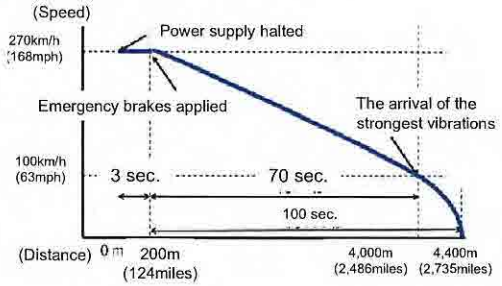
Ministry of Land, Infrastructure, Transport and Tourism

○Introducing "Early Earthquake Detection System"

・Before the arrival of the strongest vibrations, the "Early Earthquake Detection System" had functioned successfully.
・Immediately after the emergency brakes worked, Shinkansen trains that were running with passengers on board slowed down and stopped.
→No derailment



<The condition of Shinkansen moving around Sendai>



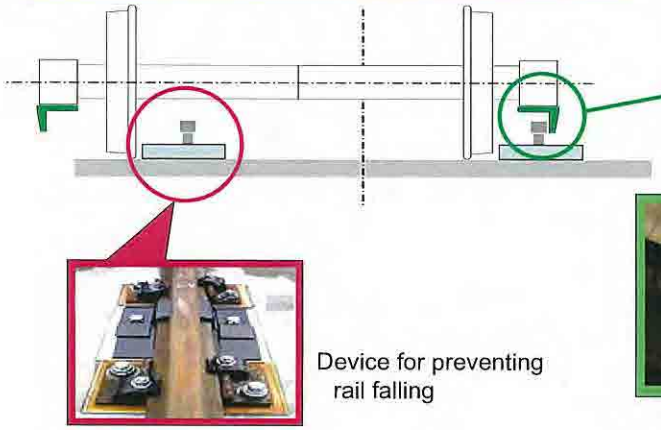
3. The earthquake-proof Shinkansen

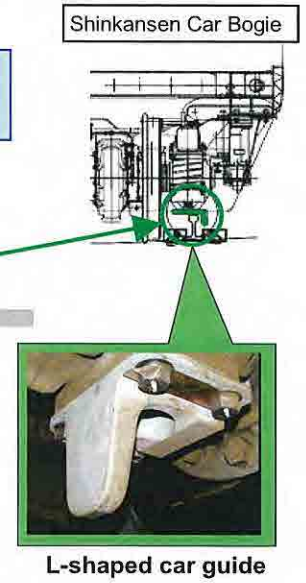
Ministry of Land, Infrastructure, Transport and Tourism

○Deviation/Derailment Preventive Measures

L-shaped car guide

Measures for preventing a derailed train from widely running off the tracks, using a L-shaped car guide installed with the bogie, which gets stuck onto the rail.






Thank you!

Technical Standards System of JAPAN

Railway Bureau
Ministry of Land, Infrastructure, Transport and Tourism

Status of Railway Transportation (Japan-EU-U.S.A)

		Japan	EU	U.S.A
Operating Distance (km)		27, 000	231, 000	226, 000
		(only JR) 20, 000		
Traffic Volume	Freight ×Hundred million (t・km)	230	18, 200	20, 000
	Passenger ×Hundred million (passenger・km)	4, 000	3, 900	500
		(only JR) 2, 500		

※All figures are shown in approximate number.
※ EU (27 countries) are quoted from the website of ERA.

Number of Accidents (Japan-EU-U.S.A)

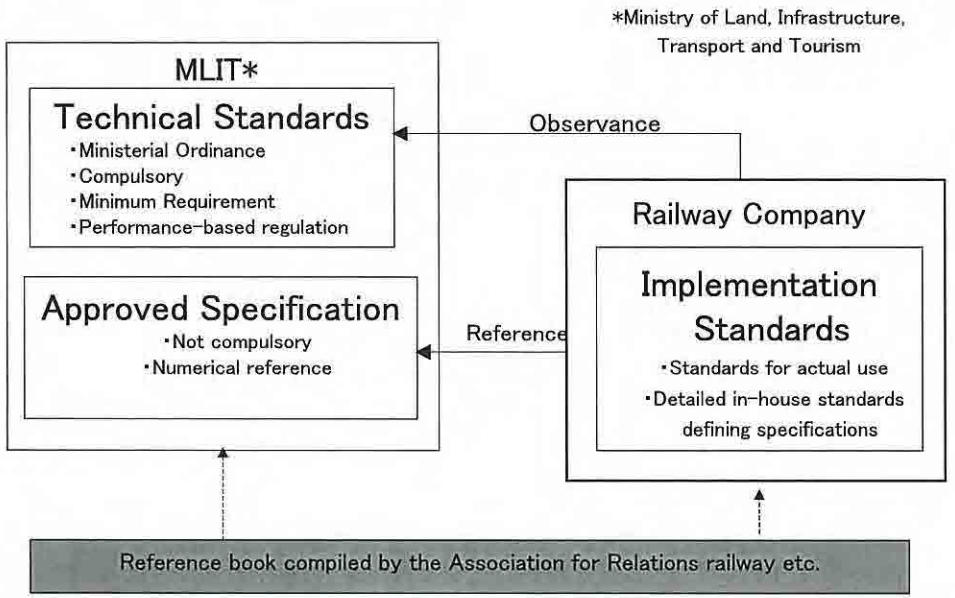
	Japan				EU				U.S.A			
	C	D	F	L	C	D	F	L	C	D	F	L
2006	1	13	0	362	673	499	257	1,355	201	2,194	21	2,941
2007	0	12	2	367	249	346	107	1,196	210	1,934	14	2,776
2008	0	7	2	333	269	319	88	1,034	191	1,778	10	2,430
2009	0	5	1	327	142	177	66	833	133	1,360	20	1,926

Type of Accident
C:Collision
D:Derailment
F:Fire
L:Level crossing

※ EU (27 countries) are quoted from the website of ERA.
※U.S.A. quoted from the homepage of the FRA.
※Selected range of railway in each country do not match.

Preventing collision, derailment, and fire

The Japanese railway system has various measures aiming to prevent railway accidents of collision, derailment and fire from happening to secure safety and stable transportation



- General Rule
- Staff
  - ①Safety Assurance of Train Operation
  - ②Education and Training of Staff
  - ③Duties of Crew to Operate a Motive Power Unit
- Facilities & Rolling Stocks
  - ①Guide way, ②Station, ③Intersection with road
  - ④Electric line facilities, ⑤Operation safety facilities
  - ⑥Rolling stocks
- Maintenance
  - Public Notice Concerning the Regular Inspection of Facilities and Rolling Stocks
- Train Operation
  - ①Loading limitation, ②Train operation, ③Signals

1. In order to prevent derailment, railway operators should install apparatus to prevent speed exceeding at curves .

2. Depending on structure and usage, railway operators appropriately maintain cars, signals, tracks, etc.

3. Railway operators should provide adequate education and training to their staff and crew, in order to be well versed in necessary knowledge and skills.

(Apparatus to Automatically Decelerate or Stop Trains)

Article 57.
In the case when trains are operated by the block system, apparatus to automatically decelerate or stop trains depending upon signal aspects and guide way conditions shall be installed.

In the cases listed below, automatic train stop devices to be located in accordance with the provisions shall be a type that can automatically slow down trains to a safe speed or stop them before the near side of a speed restriction point, a stop limit point, etc., when the train runs at a speed exceeding a certain level at a predetermined position.

There is a risk of overturn to the outside of curves when a train intending to enter a curve comes into the section at a speed enabling operation (i.e., the maximum speed between stations. However, in cases where there is a device to restrict speed in front, or where a train starts from a place where trains necessarily stop, such as at a terminal station, this shall be a speed that can be reached by normal operation under these conditions. The same shall apply hereafter in these items.).

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■ Maintenance of Facilities and Rolling Stocks

●Technical Standards (Ministerial Ordinance Chapter 10)

(87) Maintenance of Facilities and Rolling Stock
(88) Inspection and Field Test of Newly Installed Facilities and Newly Manufactured Rolling Stock
(89) Inspection tour and Monitoring of Main Track and Overhead Electric Line over the Main Track and Inspection of Train
(90) Regular Inspection of Facilities and Rolling Stocks

Public Notice
1) Purpose
2) Periodic Track Inspection
3) Periodic Inspection for Electric Facilities
4) Periodic Inspection for operational safety devices
5) Periodic Inspection of Rolling Stock
6) Special Cases of Inspection

(91) Record

◎ Public Notice Concerning the Regular Inspection of Track and Electric Facilities (Article 2 & 3)

Type of Facilities		Period	
		Shinkansen	Conventional line
Track	Track (Irregularity)	2months	1year
	Track (Others)	1year	
	Structures (Bridge, Tunnel, etc)	2years	2years
Electric Facilities	Circuit Breaker (Feeder side)	3months	1year
	Contact Line	6months	
	Other Electric Facilities	1year	2years

1. In order to prevent derailment, railway operators should install apparatus to prevent speed exceeding at curves .

2. Depending on structure and usage, railway operators appropriately maintain cars, signals, tracks, etc.

3. Railway operators should provide adequate education and training to their staff and crew, in order to be well versed in necessary knowledge and skills.

(Education and Training of Staff)

Article 10.
A railway operator shall provide adequate education and training to those who are directly engaged in train/car operation and do maintenance relevant works for rail facilities and rolling stock, in order for them to be well versed in necessary knowledge and skills.

▪
▪

◆Guide way Alignment

◎ Ministerial Ordinance (Article 13)
Radius of curve and gradient of the main track shall be able to ensure the high-speed and large capacity performance of the rail transport, taking the maximum design speed and tractive effort into consideration.

◆Radius of curvature

◎ Ministerial Ordinance (Article 14)
Radius of curvature shall be set in order not to impair safe car operations, taking the performance capability of negotiating a curve, the operation speed, and other relevant factors into consideration.

○ Approved Specification
- Curve radius of a main track shall be 400 meters or more.

□ Implementation Standard
- Curve radius of a main track shall be 4,000 meters or more.

◆ Track Alignments (Gradient)

◎ Ministerial Ordinance (Article 18. Excerption)
Gradient shall be set in the manner that a train can be started, operated continuously at a designated speed and brought to a stop within a designated braking distance, taking performance of tractive efforts of motive device, capability of braking device and train speed into consideration.
Gradient of the area where a train comes to a stop shall be set not to interfere with train departure and arrival, taking the braking performance of a train into consideration.

◎ Approved Specification (Excerption)
1) The maximum gradient of Shinkansen on the traveling area :
(A) 25/1000
(B) 35/1000 : where the above standard cannot be applied due to topographic or other reasons, considering the performance of the prime mover, power transmission equipment, running gear and brake equipment.
2) The maximum gradient in the stopping areas: 3/1000.

Examples of gradients

Steepest gradients of Shinkansen

Steepest gradients of Shinkansen network

	Tokaido	Sanyo	Tohoku	Joetsu	Hokuriku	Kyushu
steepest gradient (‰)	20	15	20	20	30	35

Approved Specification

◆Construction Gauge

○ Approved Specification

A railway company shall specify a construction gauge and make sure not to set up buildings or other structures within it. Standard drawings of construction gauge for straight tracks are shown in following Figs.

(1) Minimum clearance between construction gauge and basic rolling stock gauge for straight tracks shall be as follows.

–Sideward direction of windows of the rolling stock : 500mm

–Upward and sideward direction of platforms : 50mm

(2) Even within the basic construction gauge, certain constructions can be set up if they are necessary for the traveling of rolling stock or the maintenance of railway facilities and if there is no possibility to impair safe traveling of the rolling stock. In such a case, that shall be stipulated in the construction gauge provisions.

Ministerial Ordinance

◆Construction Gauge

◎ Ministerial Ordinance (Article 20)

Construction gauge at a tangent line shall be set to provide an adequate distance from the car clearance not to impair train operations and the safety of passengers and crew, taking the vibration caused be car operation in consideration.

2. Construction gauge at a tangent line where electric locomotive hauled or electric multiple units are operated, shall be determined in such a way as to provide a sufficient distance from the car clearance to prevent electric shock or fire.

3. Construction gauge at a curve shall be larger than those specified in the preceding two paragraphs depending upon the deviation of rolling stock, and shall be slanted according to the amount of the cant.

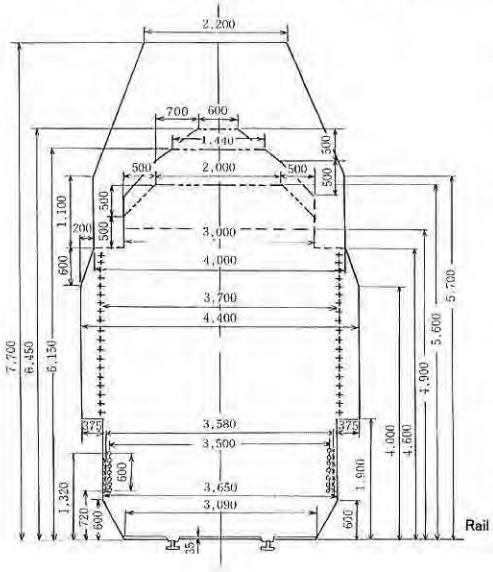
4. No building or structure shall be built within the construction gage.

5. Any object other than a train/car shall not be placed within the construction gage. This rule does not apply, however, to inevitable cases like carrying out necessary construction work, as long as appropriate precautions like speed restriction, for example, are taken to secure safety.

6. Nothing shall be placed even outside of the construction gauge that could fall into the construction gauge.

Examples of construction gauge

Standard drawings of construction gauge



Basic construction gauge

Gauge for tunnels, bridges, overbridges and platform sheds

Gauge for overbridges when the center of slack of messenger wire is used

Gauge for tunnels, bridges, overbridges and platform sheds when overhead contact lines are specially structured in line sections where trains travel at 120km/h or below

Gauge when no overhead contact lines are installed

Gauge for platforms (only if no passing trains), crewmen steps and rolling stock cleaning stations

Gauge for platforms (only if there are passing trains)

Gauge for facilities for rolling stock maintenance, inspection and repair and indicators inside depots

◆Distance between Track Centers

◎ Ministerial Ordinance (Article 22)

The distance between track centers at a tangent track shall be set to maintain the safe car operation by eliminating the possibility of pitching cars touching each other or hurting a passenger leaning out of a train window.
2. Distance between track centers at a curve shall be larger than the one described in the previous provision, according to the deviation of rolling stock.

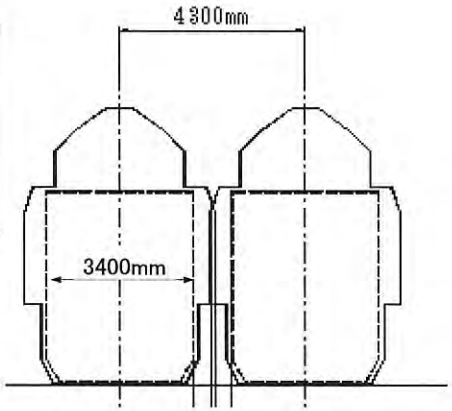
○ Approved Specification (Excerption)

Track-center distance shall be such that there is no possibility of detrimental effect on the safe traveling of the rolling stock and the safety of passengers and crewmen and shall conform to the following standards.
(1) The track-centre distance of a Shinkansen shall be as follows.
-The track-centre distance on the main track in straight-line sections shall be equal to or greater than the maximum value of the basic rolling stock gauge plus 800mm.
-The value shall be increased where necessary for work or the like.

☐ Implementation Standard

- Track-centre distance in a straight line section outside a station shall be 4300 mm or more.
- Track-centre distance in a station shall be 4600 mm or more.

Drawing of reference



The basic rolling stock gauge	:	3400mm
Plus	:	800mm
Increased where necessary for work	:	100mm
		4300mm

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◆ Structures

◎ Ministerial Ordinance (Article 24)

Structures such as earthwork, bridge, and tunnel shall be able to withstand the anticipated loads. They shall also be free from any impediment for the safe train operation like the deviation of structures caused by the load and impact of the train.

○ Approved Specification (Excerption)

The design of earth structures, bridges, tunnels and other structures shall conform to the notifications in the following "Design Standards for Railway Structures and Commentary."
・earthquake-resistant design, Earth Structures, Concrete Structures, Steel Composite Structures, Foundations and Retaining Structures, Shield Tunnels, Steel and Concrete Composite Structures, Earth Structures for Low Maintenance Tracks, Open Cut Tunnels, Mountain Tunneling Method for Urban Areas, Displacement Constraints

◆Contact Lines and Other Facilities

◎ Ministerial Ordinance (Article 41)

Catenary line , feeder line and their accessories including apparatus, wire and protection equipment shall be installed not to cause electric shock and fire, according to the location, installation method and standard.
2. Overhead contact line and feeder line shall be installed at an appropriate height depending upon the location, installation method and standard voltage to make them free from of the risk of electric shock or other impediment to train traffic,
3. Contact line shall be able to withstand the predictable maximum wind pressure load, tension of electric wire, etc. and also shall be installed appropriately to collect electricity without any impediment according to the train speed and feeder system.
4. Contact line and feeder line shall be installed in such a manner as to prevent failures caused by an inadvertent contact or confusion with other contact line or feeder line that differs in standard voltage, frequency and so on.
5. The voltage of contact line shall be maintained at a sufficient level to guarantee adequate train operations.

◆Contact Lines and Other Facilities

○ Approved Specification (Excerption)

-The overhead single-line system shall be used to install overhead contact lines.
-The height of overhead contact lines shall be 5 meters from the rail surface as standard, ranging between 4.8 and 5.3 meters.
-Contact wires for a main track shall be grooved hard drawn copper wires, grooved cooper alloy wires or grooved copper-covered steel wires with nominal cross-sectional area of 110 mm2 or more and conform to the Japanese Industrial Standards of "grooved hard drawn copper contact wires".
-Overhead contact lines shall be suspended by the catenary suspension system and installed in accordance with an automatic tensioner.
-The distance between supports shall be 60 meters when overhead contact lines are suspended by the simple catenary system.
-The standard voltage of overhead contact lines shall be 25,000 VAC, single-phase.

◆Proximity or Crossing of Overhead Electric Lines

◎ Ministerial Ordinance (Article 42)

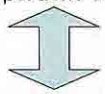
In case the voltage applied part of the overhead contact line, or feeder line is in proximity of or crossing other contact lines, manmade works, or vegetation, it shall be installed with caution to be free from chance of damaging any of the above and causing electric mixture, shock or fire.

○ Approved Specification

The distance of separation of the power-applied portions of overhead electric lines or overhead feeders from other electric lines, structures, etc. shall be of the value specified in the table below, or larger.

(for example)

Power-applied portions of overhead (25,000VAC)



3m or more

Structures (Buildings : When located above or to the side.)

Catenary suspension system,
110 mm² or more and conform to the Japanese Industrial Standards of "grooved hard drawn copper contact wires"

Thank you for your kind attention

※ Download data of Technical Standard for Japanese Railway

http://www.mlit.go.jp/english/2006/h_railway_bureau/Laws_concerning/14.pdf