High Speed Rolling Stock in Japan

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UIC Report “Necessity of future high speed rolling stock”

- Aim:

  Show general overview of issues which should be taken into account for future high speed rolling stock under the changing business and technical situations from a global perspective

- Report structure

  1 General Issue (mainly in Business aspects)

  Development, Procurement, Approval, Deployment, Maintenance, Life Cycle Cost, RAMS (Reliability, Availability, Maintenability, Safety), Standardization, Compatibility with infrastructure

  2 Basic technical aspects

  Dimensions, Performance, Safety, Environment, Aerodynamics, Comfort

  3 Commercial and human factors

  Ergonomics, PRM, Drivers cab, Cabin, Services

  4 Other technical aspects

  Body structure, Power/Brake system, Train control, Others

- UIC member swill soon be able to refer to this report
- World High Speed Rolling Stock table can be referred to by all people
- http://www.uic.org/

Basic idea of Shinkansen rolling stock design

➢High Speed dedicated infrastructure aimed at high speed, high capacity, and high level of safety like

Large curve radius
Less gradient
No level crossing
In-cab signaling (ATC)
Large loading gauge etc.

Rolling stock was designed as part of total HSR system

➢Distributed power (Electric Multiple Unit) for

-Light axle load
Low construction/maintenance cost of infrastructure
Low ground vibration emission etc
-High adhesion performance
Capable of high acceleration/deceleration
-"Multiple unit"=Robust against failure

Rolling stock aimed at better operational performance

➢Currently the variety has increased to meet customer/operational needs
Interoperable rolling stock to conventional line (smaller loading gauge),…

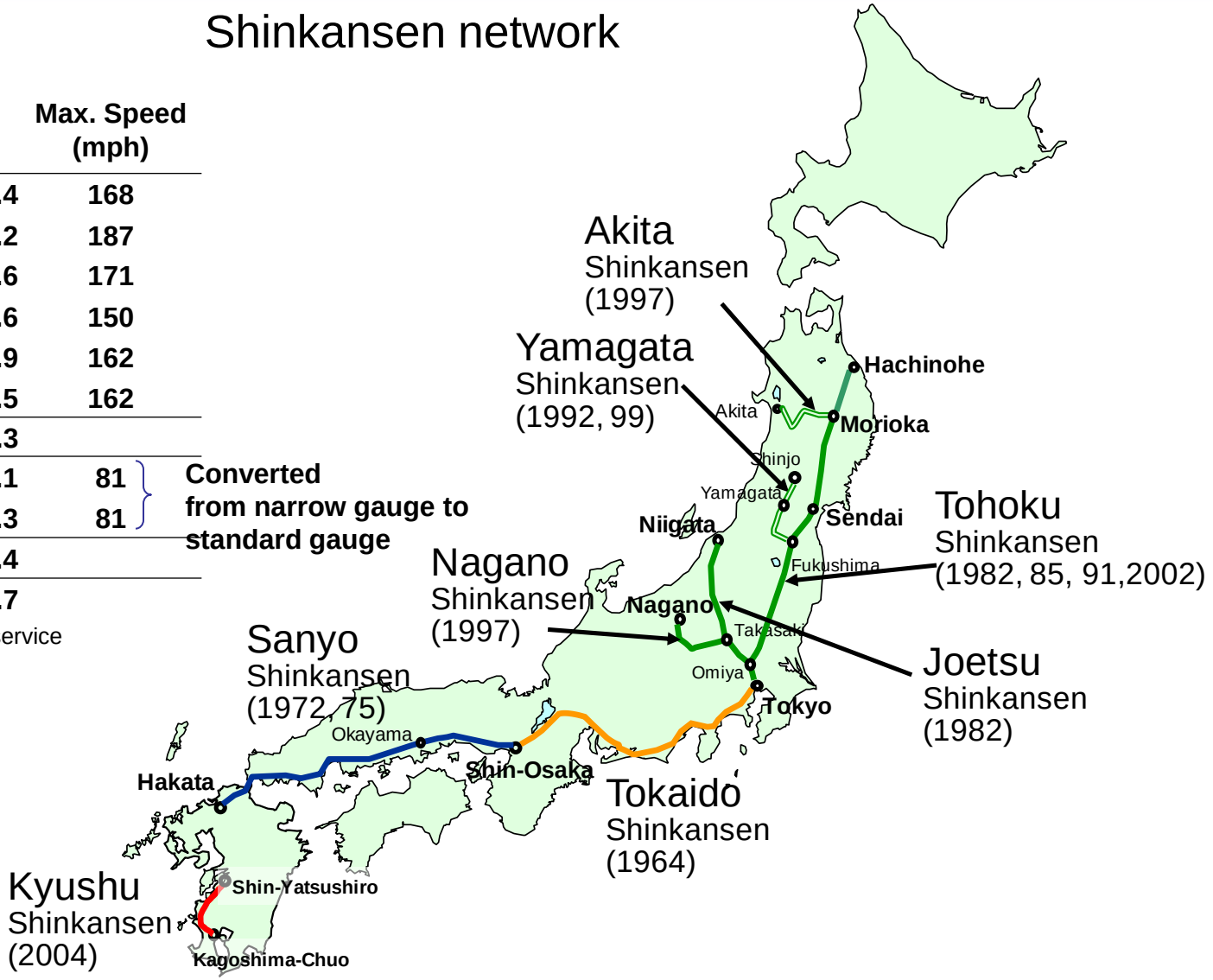
Series 0 (1964-2008)

Shinkansen network

Line	Section	Length (mile)	Max. Speed (mph)
Tokaido		343.4	168
Sanyo		400.2	187
Tohoku		392.6	171
Joetsu		188.6	150
Nagano		72.9	162
Kyushu		85.5	162
Sub Total		1483.3	
Akita		79.1	81
Yamagata		92.3	81
Sub Total		171.4	
Total		1654.7	

Converted from narrow gauge to standard gauge

*Length: mileage in revenue service



Structure of Shinkansen traffic

Network is expanding, environment is changing

Northbound from Tokyo:

Traffic is as a tree structure of which the root is thick

- Destinations are smaller cities
- Smaller population density along the line
- Large density in Tokyo metropolitan area
- Branch lines including converted conventional gauge line

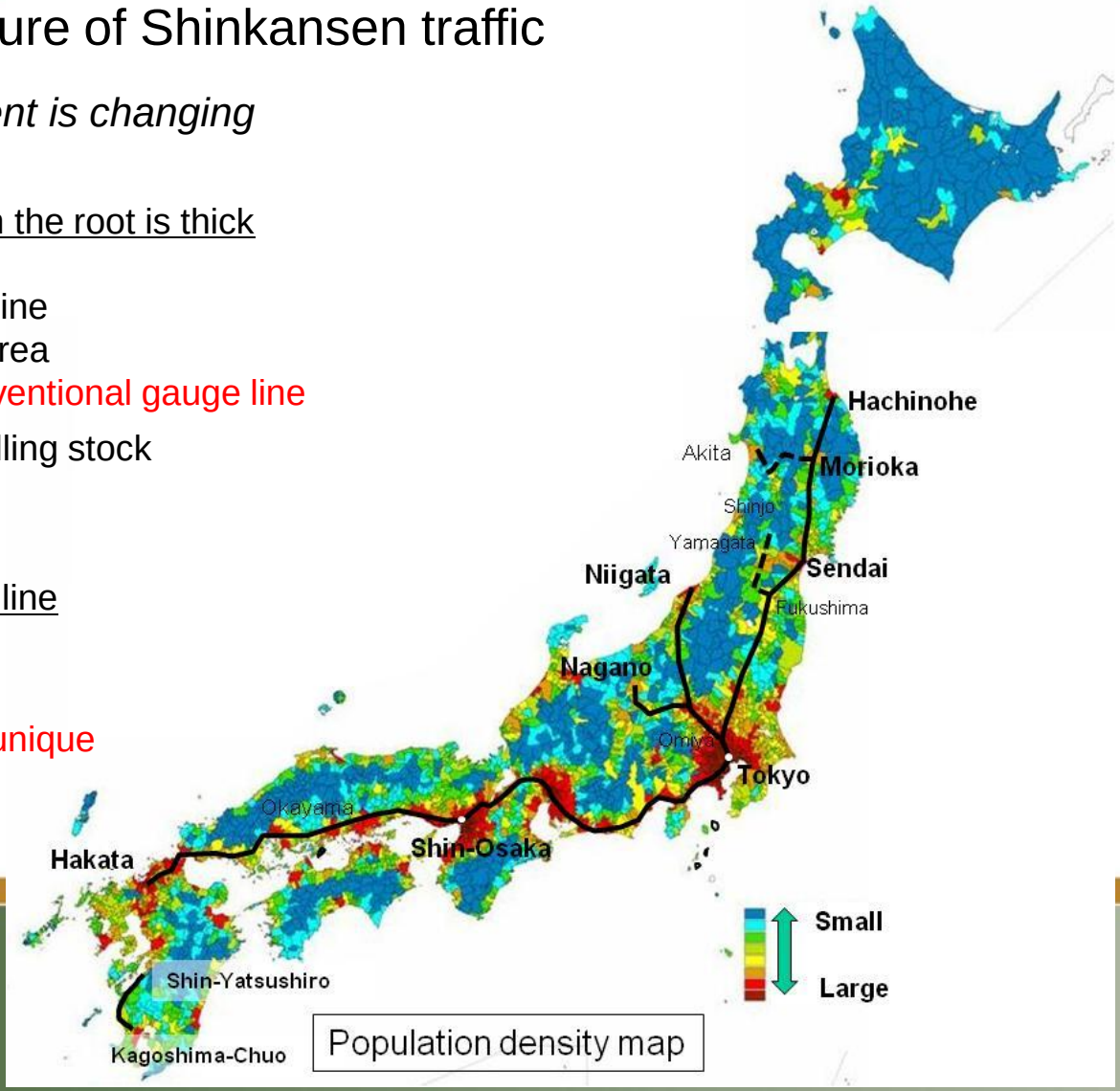
⇨ Tend to have wide variety of rolling stock depending on the demand

West bound from Tokyo:

Traffic is almost stable on the entire line

- Destinations are large cities
- Chain of large cities along the line

⇨ Tend to have rolling stock with unique specification



Variety of Shinkansen rolling stock operated in Japan

Series	Number of cars in a set	Year in service	Max speed(km/h)	Passenger capacity
100	6 or 4	1985-	220	394 (6)
300	16	1992-	270	1323
500	16 or 8	1996-	300	1324 (16)
700	16	1998-	285	1323
700-7000	8	2000-	285	571
N700	16	2007-	300	1323
800	6	2004-	260	392
200	10	1982-	240	762
400	16	1992-	240	399
E1	12	1994-	240	1235
E2	8	1997-	275	630
E2-1000	10	2002-	275	814
E3	6	1997-	275	338
E3-1000	7	1999-	275	402
E3-2000	7	2008-	275	394
E4	8	1997-	240	817

Source: UIC 'World high speed rolling stock '

100
300
500
700, 700-7000
N700

800

200
400
E1
E2
E2-1000
E3
E3-1000, E3-2000
E4

300
500
700
N700

Total number of train sets	352
Total number of cars	4169

Example of the variety of Shinkansen series

Three typical types of Shinkansen rolling stock for NORTHBOUND

Fast and high capacity transportation on main lines	Fast and capable of through operation to converted conventional lines	Highest capacity for commuter transport
Series E2 (E2-1000) "Standard" type	Series E3 Mini-Shinkansen type	Series E4 Double decker type

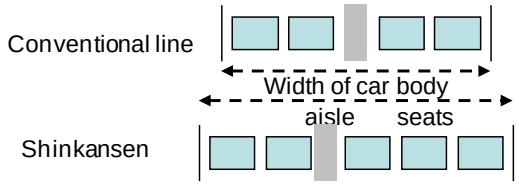
Based on similar technical concept to the west bound rolling stock

Comparison of typical rolling stock for northbound

Series	E2-1000	E3	E4
Train Configuration (train length)	8M2T (251m)	4M2T (128m)	4M4T (201m)
Capacity	814	338	817
Capacity /m	3.24	2.56	4.06
Approx. Max. axle load (loaded)	13.2t	12.2t	16t
Max. operating speed	171mph	171mph 81mph(on conventional)	149mph
Intermediate Car length	25m	20.5m	25m
Body width	3380mm	2945mm	3380mm
Motor power (continuous)	300kW	300kW	420kW
Coupling with (in normal operation)	E3	E2	E4 E3-1000,-2000, 400
Electrical system	AC25kV50Hz	AC25kV50Hz AC20kV50Hz	AC25kV50Hz
Signalling system	DS-ATC	DS-ATC, ATS-P	DS-ATC
Year in operation	2002	1997	1997

Features of Shinkansen rolling stock

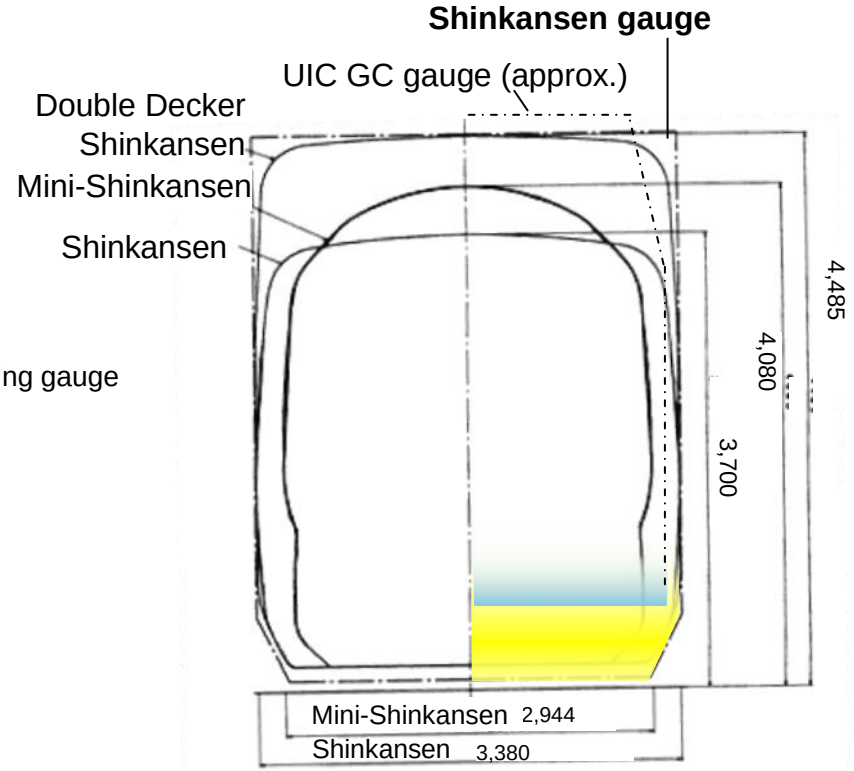
- Large loading gauge
  - -High capacity
    - 5 seats/row, easier application of double decker



* Mini-shinkansen has a smaller (same as conventional) loading gauge

  - -High comfort by larger space

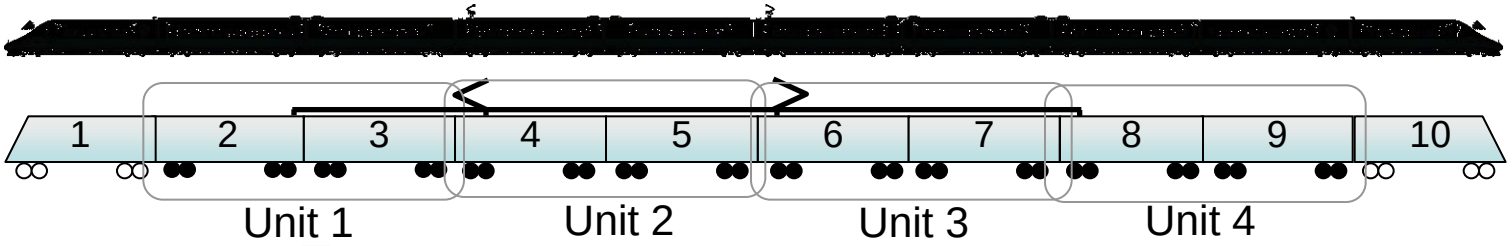
- Light maximum axle load
  - -Around 11-13 ton for single deck Shinkansen
  - -Distributed power
    - Heavy components are distributed
  - -Reduction of total weight
    - Light weight car body
      - Body shell, bogie, components,…
      - Structural strength against collisions can be reduced because of dedicated track
    - *Light weight will also reduce the energy consumption!*



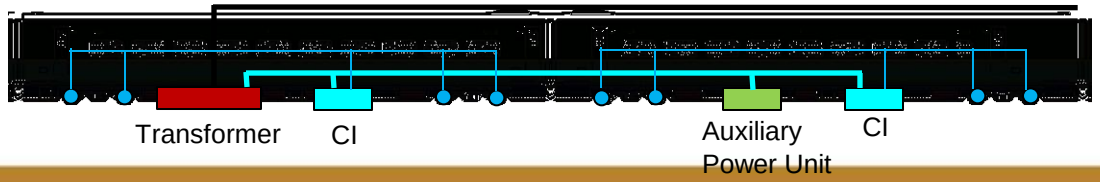
Features of Shinkansen rolling stock

- Distributed power (Electric Multiple Unit)
  - -Light axle load
  - -High rail/wheel adhesion performance
    - High acceleration/deceleration
    - Effective especially in case of slippery situation
  - -Large passenger capacity without locomotive
  - -"Multiple unit"=Robust against the failure

Ex. Series E2-1000



Unit 1

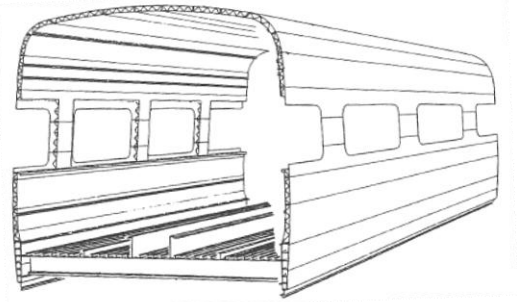


In case of failure of one unit

Main circuit failure: train runs by the rest of units
Auxiliary unit failure: service power is provided from other units

Features of Shinkansen rolling stock

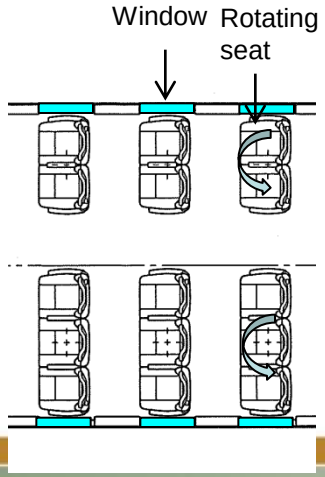
- Basic body design
  - Double skin aluminum alloy body in latest cars
    - Easy construction (possible to lower cost)
    - Stiff but light weight
  - Air tight body with continuous ventilation system
    - Avoiding internal pressure fluctuation in cabin
  - No standard strength value for collision
    - Mini-Shinkansen type is designed under consideration of level crossing collision
  - …



Aluminum double skin structure

- Cabin design
  - Every seat assures an outside view through the window
  - Rotating seat
  - Flatness of platform and cabin floor
    - Easy access for PRM (must be compatible with infrastructure)
  - …
  - No bistro car but catering space

Cabin design strongly depends on customer needs!

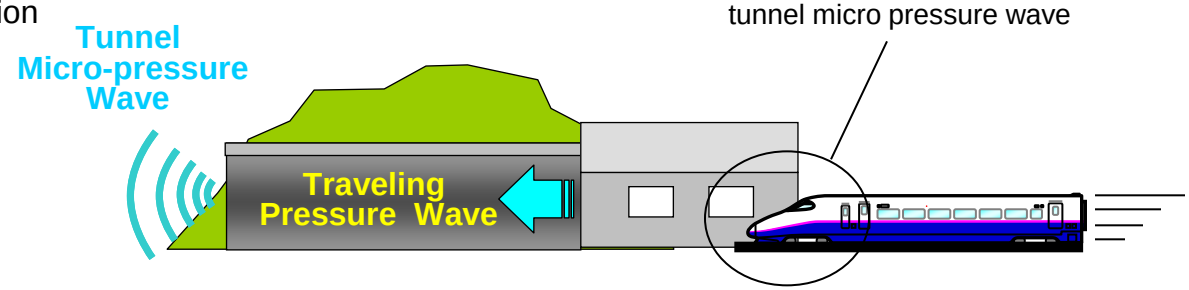


Features of Shinkansen rolling stock

➢Body design for environment

-Tunnel micro pressure wave reduction

Optimized nose shape



-Line side noise reduction

Measures for aerodynamic noise

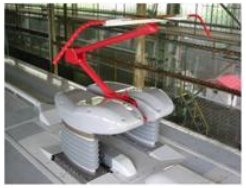
Pantograph (smooth design, reduction of the number in a set,…)

Smooth surface of the train (cover at car gaps and so on),…

Positive effect on reduction of aerodynamic resistance

Reduction of energy consumption

Reduction of noise from electrical and mechanical components



Design must be combined with infrastructure measures.

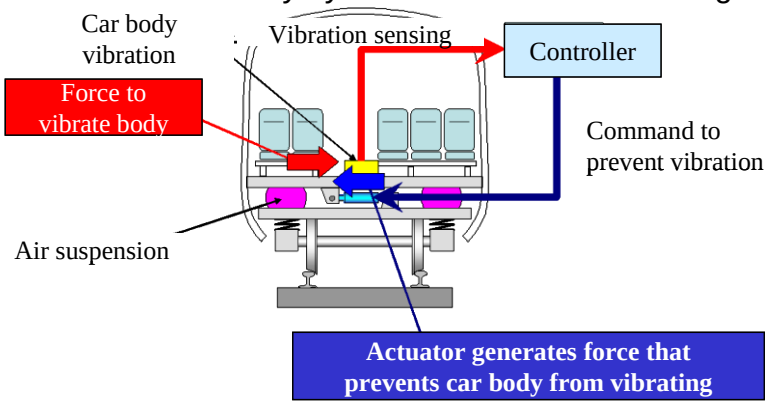
Measures depend on the local standard.

Japan strongly needs noise reduction because Shinkansen runs in residential area.

Features of Shinkansen rolling stock

- Bogie design
  - Safety running is assured with
    -Light weight structure (bolster-less type)
    -High level of ride comfort
  - Difference between Shinkansen and Mini-Shinkansen
    -Wheel base, Wheel profile, … compatible with infrastructure
  - Active suspension
    -Reduce lateral vibration of car body by actuators to increase riding comfort
  - Tilting system by air suspension control
    -Adopted on newest cars to allow increased speed on curves while maintaining riding comfort

Ex. Bogie (series E2)



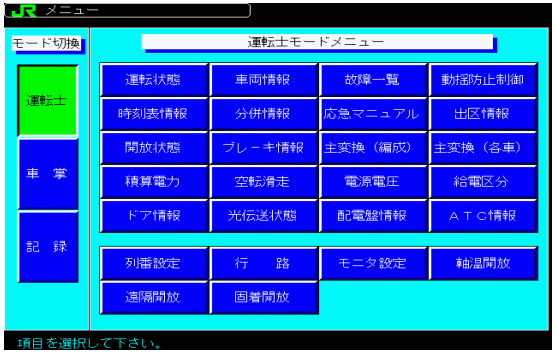
Ex. Full active suspension system

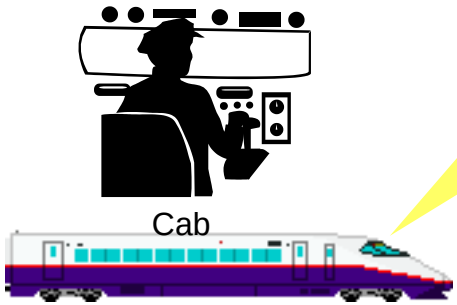
Features of Shinkansen rolling stock

- Main circuit system
  - -VVVF control, Induction motor
    low maintenance, energy efficiency mainly by regenerative brake
  - -Compact package is necessary especially for distributed powered train

- Train on-board information control system
  - -Important function can be controlled by back-up system
  - -Compatible with traffic control system

Display for the driver





Transmitted by Digital Wireless Radio

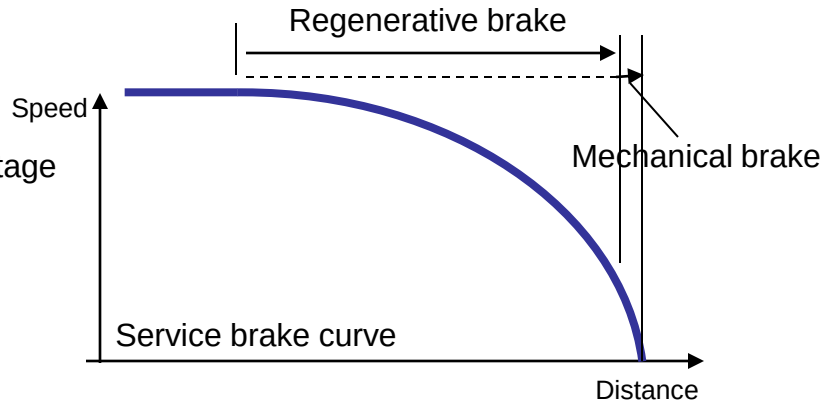
Supporting for emergency in trouble

Features of Shinkansen rolling stock

➢Braking system

-Mixture of regenerative brake and mechanical brake

-Maximize energy efficiency
-Reduction of wear of braking pad
-Back-up by the mechanical brake in case of failure or shortage of regenerative brake



-Three brakes

-Service brake
Activated automatically by ATC or manually by the driver
-Emergency brake
Activated automatically by ATC or manually by the driver in case of emergency situation
Braking force is increased from maximum value of service brake
-Urgent brake
Automatically activated in case of accidental decoupling. etc.

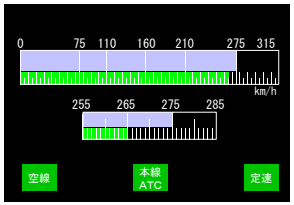
Reduction of train operation energy

	Series 0 (1964-2008)		Series E2-1000 (2002–)
			
Train set configuration	16-car configuration (16M）		10-car configuration (8M2T）
Train weight	970t/16cars (loaded) [Avg. 60.6t/car (loaded)]		442t/10cars (unloaded) [Avg. 49.6t/car (loaded)] *-18%*
Max. axle load	16	Energy consumption (10-car equivalence estimate) **－40%**	13
Power control system	Continuous thyristor phase control		VVVF inverter control
Braking system	Rheostatic braking		Regenerative braking

Features of Shinkansen rolling stock

- Safety system is designed to:
  - Reduce human errors
  - Assure safety by automated system
  - Apply fail-safe concept

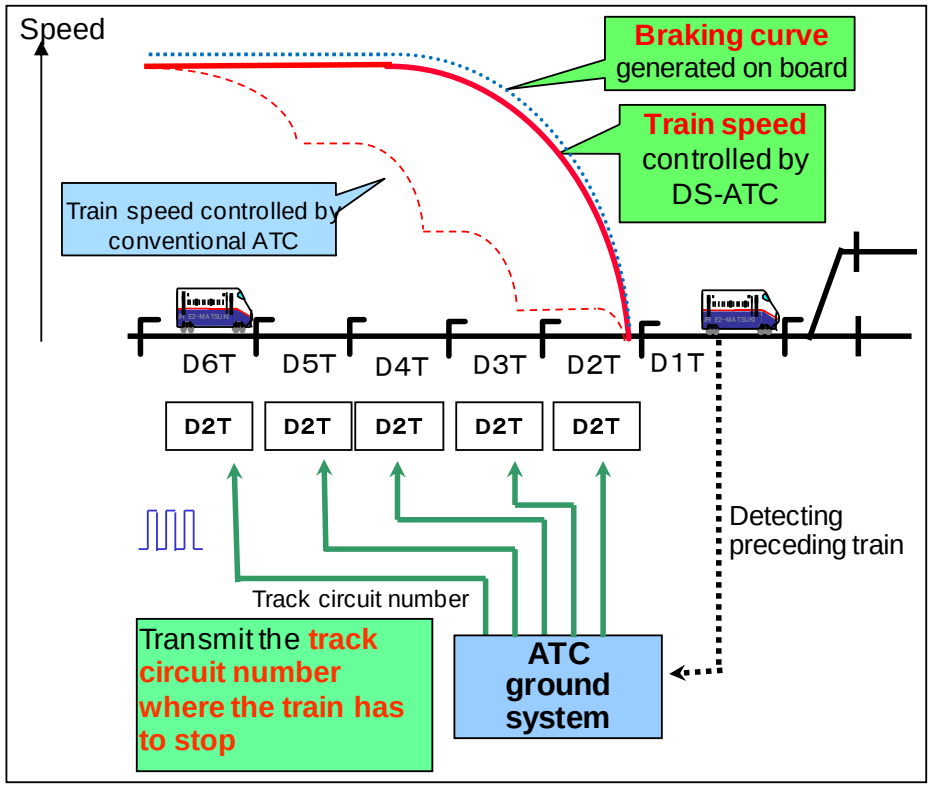
- ATC in-cab signalling system



  -Digital ATC

  Digital ATC has been modified from conventional ATC system
  - to increase the capacity of lines
  - to improve riding comfort

- Redundancy by multiplexing on-board system for safety and reliability



Features of Shinkansen rolling stock

➢Coupling system (used in northbound Shinkansen)

Akita

Series E3

<Morioka ~ Akita>
- Series E3 operation
- Operating speed: 130 km/h
(converted conventional line)

Series E2

Hachinohe

Morioka

Separating or coupling AUTOMATICALLY

Separating time: 2.5mim
Coupling time: 1.5min

Series E2 Series E3

<Tokyo ~ Morioka>
- Coupled operation of Series E2 & E3

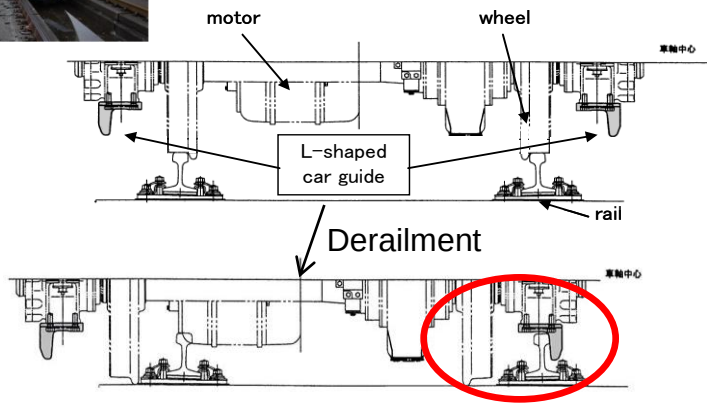
Tokyo

➢Fast and reliable system was developed to fit operation needs.

Features of Shinkansen rolling stock

➢Measures for natural conditions

- Earthquake
  - Niigata Chuetsu Earthquake (2005)
  - Measures have been applied to avoid catastrophe after derailment (JR East case)
  - Earthquake measures are combined with infrastructure (earthquake detection system, anti-derailment measure on infrastructures)

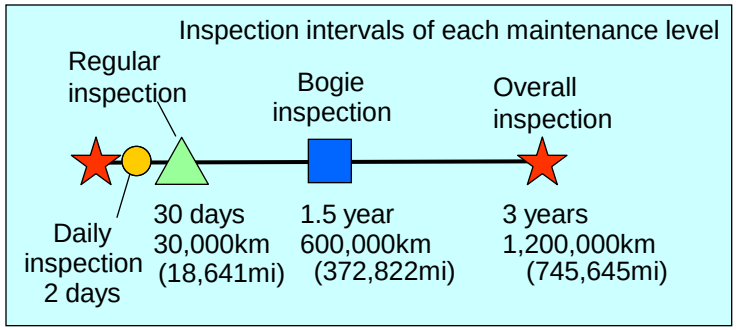


- Snow (mainly for northern bound Shinkansen)
  - Researching to avoid adhesion to the body
    Detached snow may hit the ballast
  - Snowproofing components
  - Snow plow

Measures should be combined with infrastructure measures
Elements to be taken into account strongly depend on the natural condition of the country
humidity, high or low temperature, …

Maintenance

➢Preventive maintenance



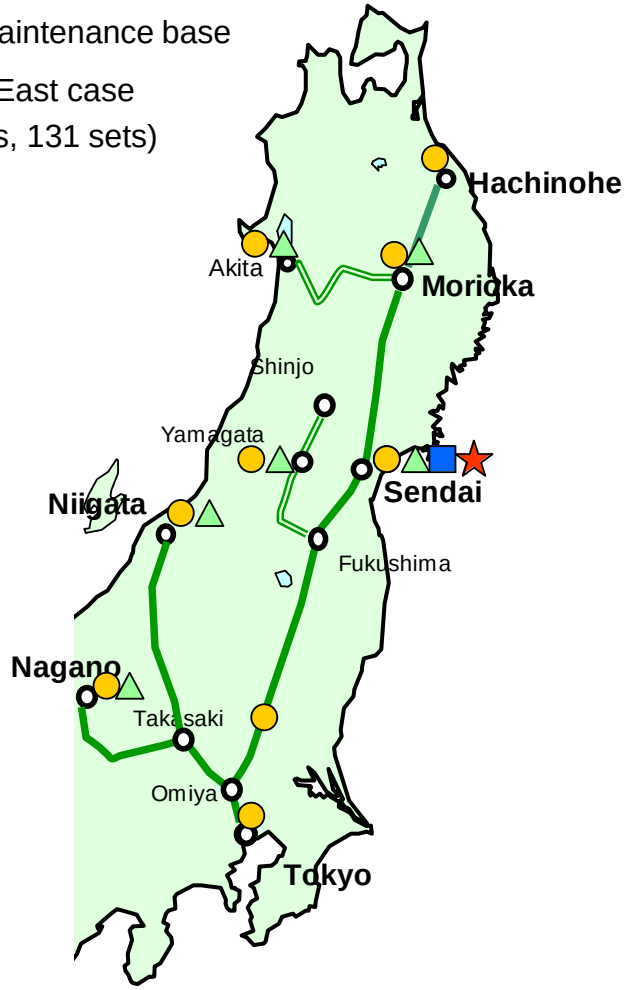
●	Daily inspection	Inspection of wear parts (pantograph strip,…), Refreshing water/waste …
▲	Regular inspection	Condition and function test, Inspection of important parts/components without decomposition (axle, …)
■	Bogie inspection	Inspection of bogie parts by decomposition
★	Overall inspection	Inspection of overall rolling stock by decomposition

➢Maintenance is managed by operators

Distribution of maintenance base

-Example of JR East case

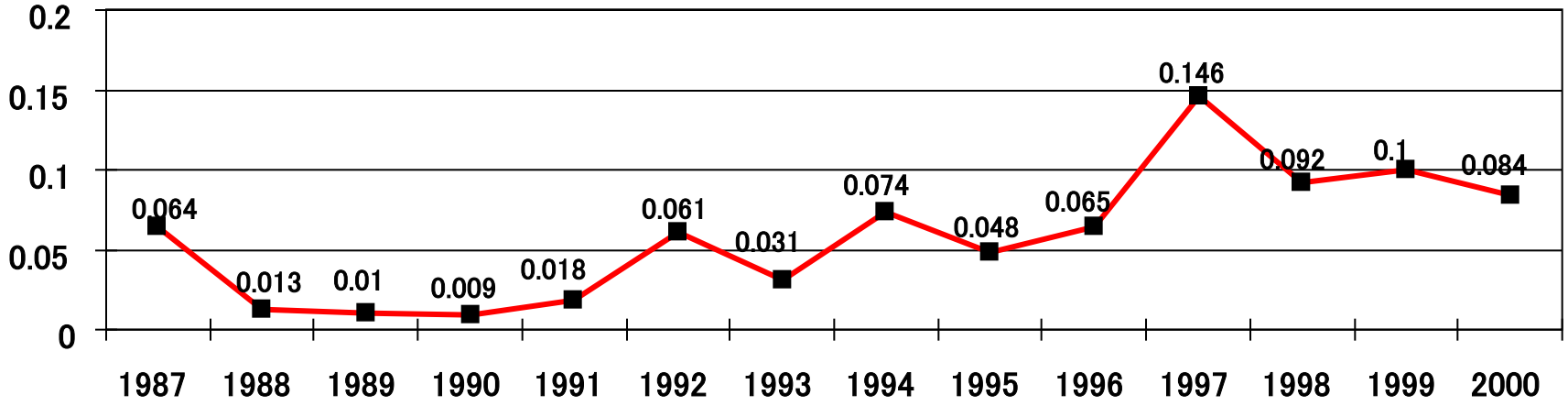
(Total: 9 series, 131 sets)



Maintenance

➢Reliability

Fluctuation in rolling stock failures (Data of JR East)
(Number of failures per 1 million kilometer (621,371mile) over 1987~2000)



*Definition of rolling stock failure

Failure in rolling stock that causes driving accidents and obstructions that result in passenger trains being suspended or delayed by 10 minutes or more or non-passenger trains being delayed by 30 minutes or more.

- High reliability assures high efficiency of train set use

The number of train sets can be kept to as few as possible!

Ex. Series E4 (JR East) case

Total number of train sets: 26 sets
-In operation: 25 sets
(including maintenance work)
-Stand-by: 1 set

→ 96.2% of train sets are always operated

Life Cycle

- Life cycle
  - From design to deployment
    - Normally 3-5 years (if new development is necessary, 3-5 more years should be added)
    - Design and development are led by JR companies with the close cooperation of rolling stock suppliers.
  - Usage
    - Normally less than 20 years - shorter than European rolling stock mainly because of
      -Fatigue
      -Following the changing customer demand and operational demand
      -Introducing new technology to improve performance and reduce maintenance cost
    - Maintenance is done by JR companies
    - Some series have been given major modification (renovation) to lengthen the life
  - Retirement
    - Material can be recycled

Example of latest commercial train (westbound)

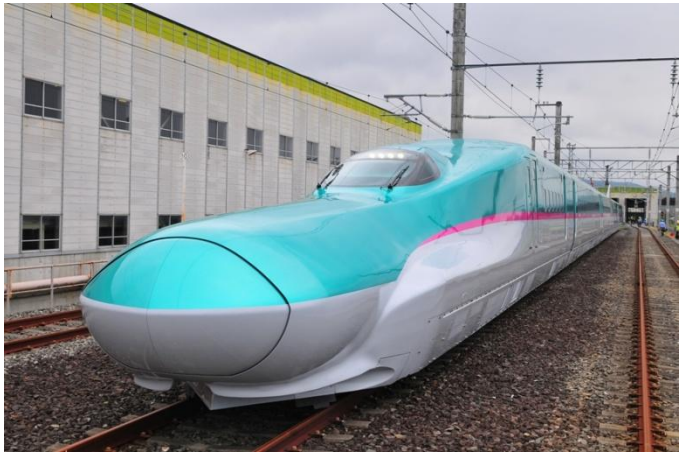
- Series N700

✓Aimed at reducing travel time on Tokaido and Sanyo line by increasing speed at curve and high acceleration.
✓Integration of high speed, quality riding comfort and environmental compatibility
✓Commercial operation started in 2007.

Formation	14M2T
Max Speed	300km/h (186.4mph)
Pass. Capacity	1323
Train Weight	Approx. 700t (loaded)
Train length	404.7m
Power system	25kV60Hz VVVF Control Induction Motor
Signalling	Digital ATC
Low noise structure Air suspension tilting Active suspension 10.7m aerodynamic nose for reduction of Tunnel Micro Pressure Wave	

Example of latest commercial train (northbound)

- Series E5 (being tested for commercial use)



✓Aimed to reduce travel time on Tohoku line by increasing maximum speed.
✓Research and development has been conducted by the operator (JR East) between 2002 and 2009. Tests had been conducted through dedicated experimental train sets.
✓Commercial operation will start in 2011 at 300km/h.

Formation	8M2T
Max Speed	320km/h (198.8mph)
Pass. Capacity	731
Train Weight	453t (loaded)
Train length	250m
Power system	25kV50Hz VVVF Control (IGBT) Induction Motor
Signalling	DS-ATC
Noise absorber Active suspension Air suspension tilting 15m aerodynamic nose for reduction of Tunnel Micro Pressure Wave	

Remarks

- Operators (JR companies) have intended to fit rolling stock to the market needs and social and natural situations.

- Operators have led development and improvement of rolling stock with close cooperation with suppliers as the responsible body of
  safe, stable, reliable, comfort, and convenient transportation
  under many technical constraints.

- This 'Market-in' style strongly affects Shinkansen rolling stock design.

- Rolling stock is only a part of total high speed rail system. The rolling stock should be designed as a part of total optimum system. Of course, it must be compatible with the infrastructure.

Thank you very much for your attention