INTERNATIONAL UNION
OF RAILWAYS

unity, solidarity, universality

High speed rail

Fast track to sustainable mobility

Summary

Foreword

High speed rail encompasses a complex reality involving many technical aspects such as infrastructure, rolling stock and operations, as well as strategic and cross-sector issues including human factors and financial, commercial, and managerial aspects.

In addition, the high speed rail system combines all these various elements by using the highest level of technology and the most advanced conception for each of them.

High speed is a rapidly expanding new transport mode and is often described as the “transport mode of the future”. This is due to the three main and very important characteristics offered to customers and society: safety, capacity (“within velocity”), and sustainability (in particular respect to the environment).

However high speed is not always well understood as a transport system and its performance is not fully taken advantage of, which limits the potential development of high speed, the development of “classic rail”, and all other transport modes.

UIC has for a long time been paying particular attention to high speed and has prioritised among other objectives: the communication and dissemination of high speed performances, characteristics and application possibilities.

This brochure, published every two years on the occasion of the World Congress on High Speed (organised by UIC together with a national high speed member) is intended to shed some light on the principles and possibilities of high speed rail, in view of a better and more logical development.

HIGH SPEED SIGNIFIES OPERATIONS OF AT LEAST 250KM/H.

BUT IN FACT IT IS THE PERFORMANCE AS PERCEIVED BY CUSTOMERS IN TERMS OF TRAVEL TIME, FREQUENCY, AND COMFORT THAT IS REALLY IMPORTANT.

High speed rail principles

FIRST PRINCIPLE: HIGH SPEED IS A SYSTEM

High speed railways are very complex systems which are comprised of the state of the art of many different elements:

- Infrastructure (including civil engineering works, track, catenary)
- Stations (location, functional design, equipment)
- Rolling stock (technology, comfort, design)
- Operations (design and planning, control, rules)
- Signalling systems
- Maintenance policy and systems
- Financing
- Marketing procedures
- Management
- Legal issues

It is essential that each and every one of these components is considered, so as to save even a minute and be competitive. None may be neglected and it is absolutely vital to consider all these aspects simultaneously and ensure that each ties in correctly with the others. The time spent by customers buying a ticket, entering the station or waiting for a taxi on arrival, must be consistent with the time saved by using a high speed system containing high-level technology and significant investments.

SECOND PRINCIPLE: HIGH SPEED SYSTEMS ARE (EQUAL BUT) DIFFERENT EVERYWHERE

High speed systems depend on how all the composite elements are considered and adapted. The final system obtained (in terms of cost and performances) could be very different from one country to another depending on, among other things, commercial approach, operation criteria, and cost.

THE POSSIBILITIES OF "CLASSIC RAILWAYS"

Generally speaking, conventional railways can only run trains up to speeds of around 200-220km/h (with certain rare exceptions).

This is not only due to technical reasons but also due to the capacity problems which arise when attempting to operate trains running at speeds differing by more than 50km/h.

Revenue services at higher speeds require special consideration and it is at this moment that the concept of a "high speed system" starts to be of fundamental importance.

OPERATING AT HIGH SPEED REQUIRES:

Special trains. High speed operations require "train sets" instead of conventional trains (locomotive and cars), because of the power-to-weight ratio and various other technical reasons, such as aerodynamic conditions, reliability and safety.

Special dedicated lines. Conventional lines, even with major upgrades, are unable to operate at more than 200-220km/h.

The layout parameters, transverse sections, track quality, catenary and power supply, and special environmental conditions must be able to sustain high operational speeds.

Special signalling system. One particular aspect of the operating conditions is the signalling system. Line side signals are no longer useable at more than 200km/h because they may not always be observed in time. In-cab signalling is absolutely necessary for high speed operation.

2010

1,400 **million passengers** carried by TGV trains since 1981

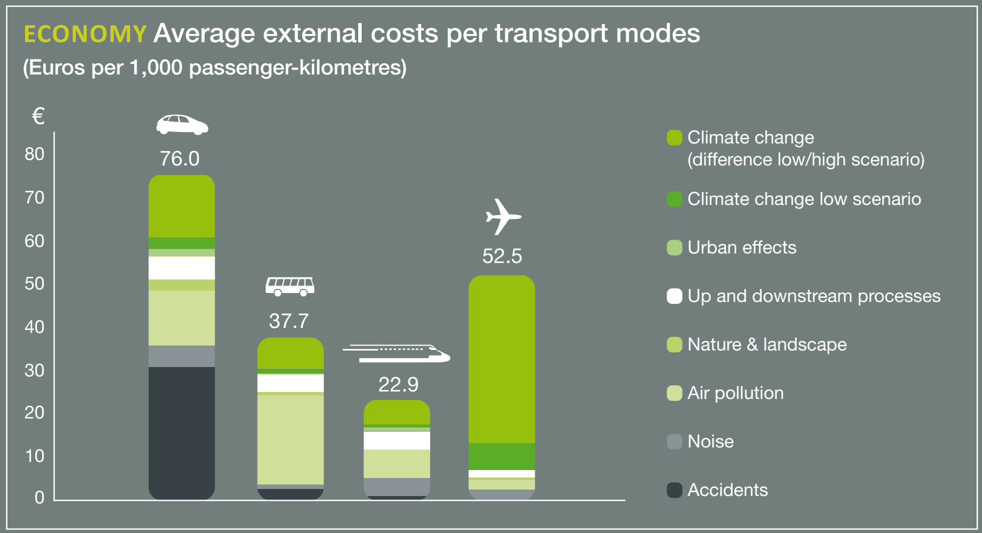
400,000 **passengers per day** on the Tokaido Shinkansen (Tokyo to Osaka, 515km)

1964 **1st October:** World's first high speed train service from Tokyo to Osaka

80% Modal split obtained by high speed trains in relation to air transport when travel time by train is less than 2.5 hours

574.8km/h World speed record - France 2007

Sustainability = environment + economy + social



SOCIETY

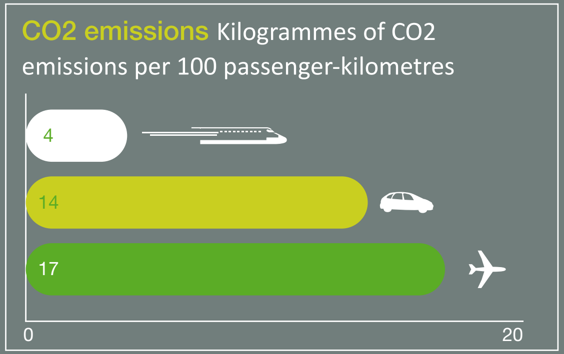
High speed rail is a tool for political integration: linking territories, encouraging the modernisation of other transport modes, and improving accessibility to broader geographic areas.
High speed increases the mobility of people and, as a metro network organises the city, high speed rail organises the territory.

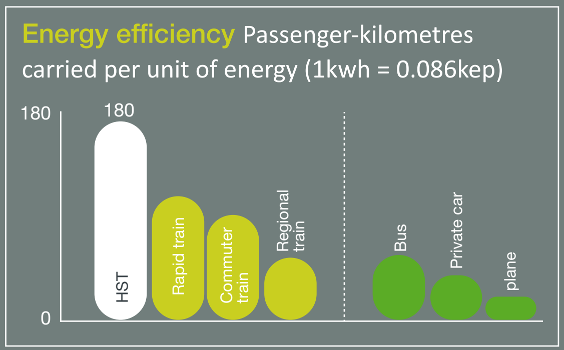
High speed performance invites people to move by a cleaner means of transport and improves quality of life.

HIGH SPEED IS SAFE!

UIC study on “High Speed Rail contribution to Environment and Sustainable Mobility” is available on the UIC-High Speed website: **www.uic.org/highspeed**

Land use





Due to high speed rail's very high transport capacity, the land needed for the large traffic volumes carried is much reduced.

AS AN EXAMPLE, SOME LAND USE RATIOS

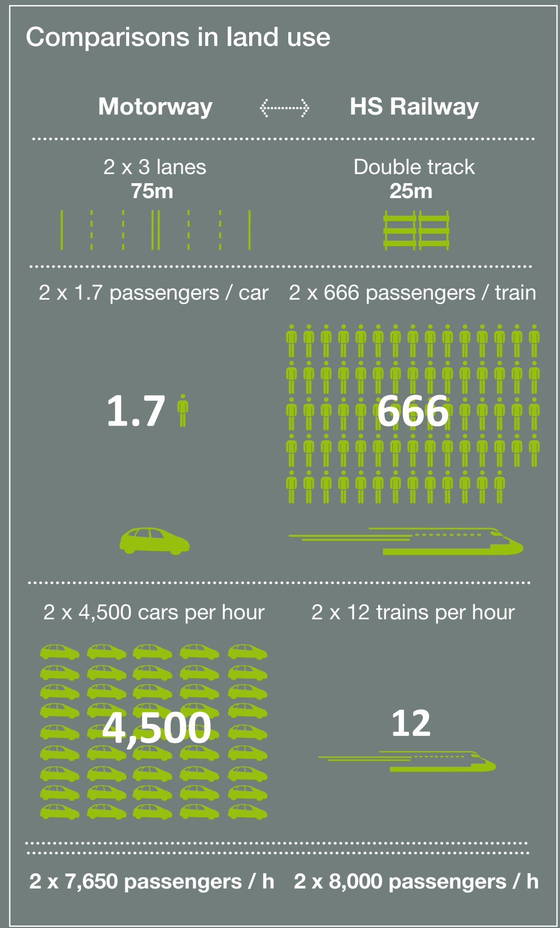
- An average high speed line uses 3.2ha/km
- An average motorway uses 9.3ha/km

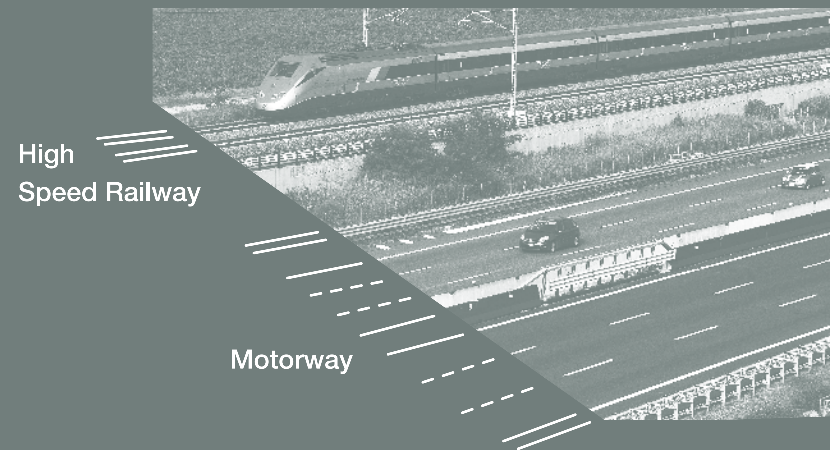
In addition, the impact on land use can be significantly reduced if new high speed lines are laid out parallel to existing motorways (where layout parameters permit).

EXAMPLES OF PARALLEL LAYOUTS

- Paris - Lyon (1981 - 1983) 60km (14%)
- Paris - Lille (1993) 135km (41%)
- Cologne - Frankfurt (2002) 140km (71%)
- Milan - Bologna (2008) 130km (72%)

The construction of a new high speed line is sometimes a good opportunity to upgrade and renovate spaces and landscapes.



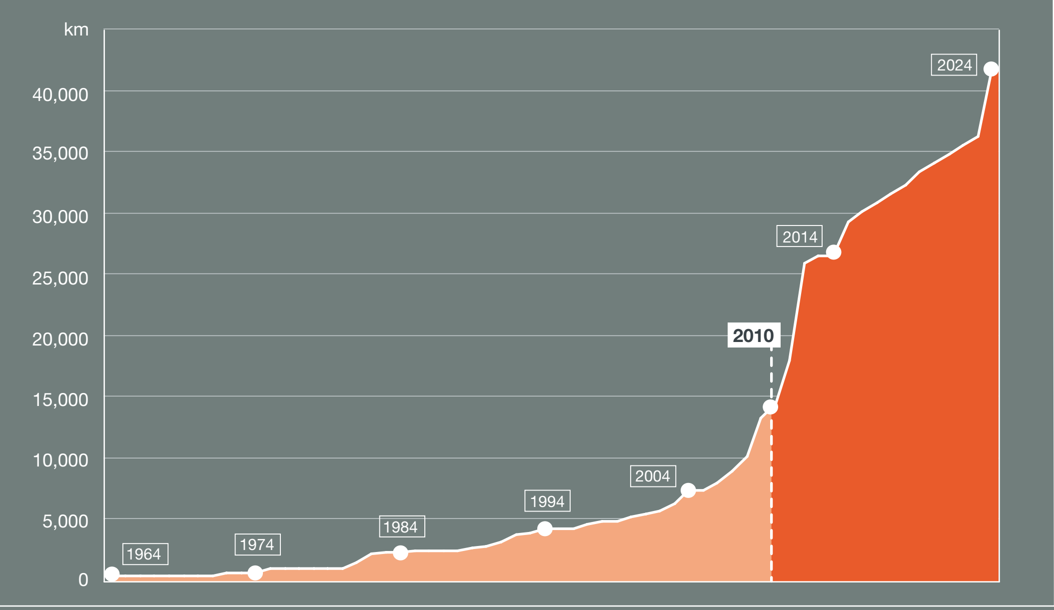


Infrastructure

The extent of the world's high-performance railway network is dramatically increasing.

- High speed rail infrastructure must be designed, inspected and maintained in optimum conditions.
- Layout requires large radius curves and limited gradients and track centre distances.
- Track geometric parameters must meet exacting tolerances.
- Slab track is in principle much more expensive than ballasted track, but it can be permanently operated with reduced maintenance frequency.
- Though slab track can be recommended in certain cases for viaducts and tunnels, discussion of the ideal track system must proceed on a case-by-case basis.
- Special catenary system and power supply system are required.
- On-board signalling system is required.

Development of the world high speed network



TECHNICAL ASPECTS

TYPICAL PARAMETERS FOR NEW HIGH SPEED LINES

Layout specifications

Maximum gradient (depending on geographic characteristic and operating conditions):

- Passenger traffic only: up to 35/40mm/m (with suitable rolling stock)
- Mixed traffic: up to 12/15mm/m

Horizontal curve radius	Minimum recommanded	Ideal
200km/h	2,500m	3,500m
300km/h	5,500m	7,000m

Track centre distance

200km/h: 4m
300km/h: 4.5/5m

Maximum cant

150/170mm

Track superstructure components (typical ballasted track)

- Rail type: Usually 60kg/m, welded
- Type and number of ties: Concrete monobloc or bi-bloc, 1,666 per km
- Fastening types: Elastic, many types
- Turnouts: Depending on the functionality of the line, they can have movable or fixed crossings

Electrification: Single phase. The most common voltages are 25kV, 50 or 60Hz or 15kV, 16 2/3Hz.

Signalling, communications and other equipment: above 200km/h, a full on-board signalling system is necessary.

UIC study on "Maintenance on high speed lines" is available on the UIC-High Speed website: **www.uic.org/highspeed**

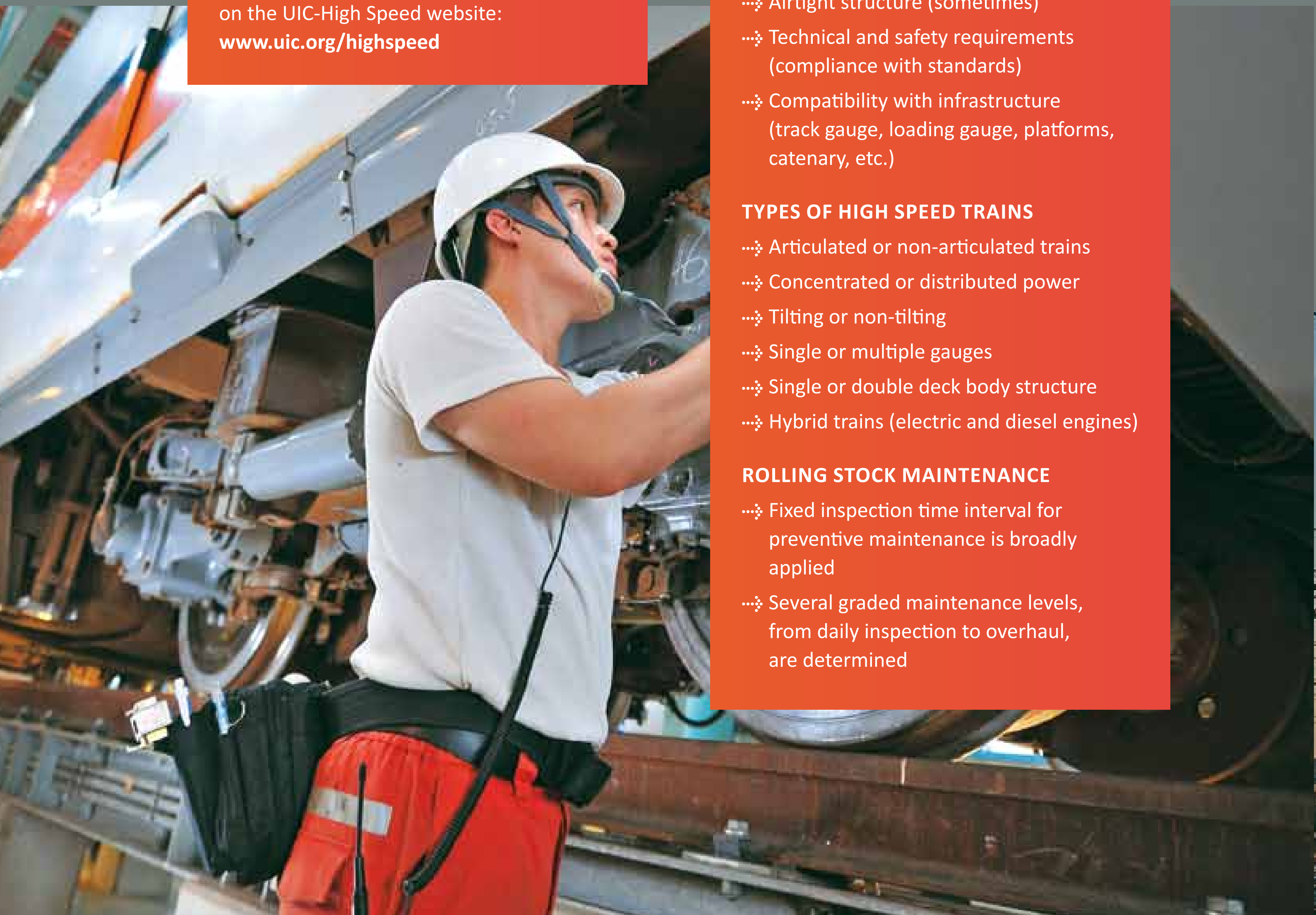
Rolling stock

The number of train sets in operation for a single line depends on the level of traffic scheduled and expected, the type of service and the use of conventional lines.

The need to manufacture high speed trains represents an important challenge for industry, both in terms of the quantity and quality of trains to be produced and the technological developments to be achieved in coming years.

Partnerships between industry and operators to manufacture and maintain high speed trains are a new formula for the future.

UIC study on “Necessities for future high speed rolling stock” is available on the UIC-High Speed website: **www.uic.org/highspeed**



COMMON BASIC CHARACTERISTICS OF HIGH SPEED TRAINS

- Self propelled, fixed composition and bi-directional
- High level of technology
- Limited axle load (11 to 17 tons for 300km/h)
- High traction power (approx. 11 to 24kW per ton)
- Power electronic equipment: GTO, IGBT
- Control circuits. Computer network. Automatic diagnostic system
- Optimized aerodynamics shape
- In-cab signalling system/s
- Several braking systems
- Improved commercial performance
- High level of RAMS (Reliability, Availability, Maintainability and Safety)
- Airtight structure (sometimes)
- Technical and safety requirements (compliance with standards)
- Compatibility with infrastructure (track gauge, loading gauge, platforms, catenary, etc.)

TYPES OF HIGH SPEED TRAINS

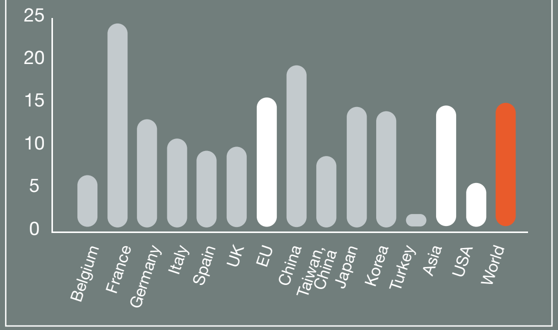
- Articulated or non-articulated trains
- Concentrated or distributed power
- Tilting or non-tilting
- Single or multiple gauges
- Single or double deck body structure
- Hybrid trains (electric and diesel engines)

ROLLING STOCK MAINTENANCE

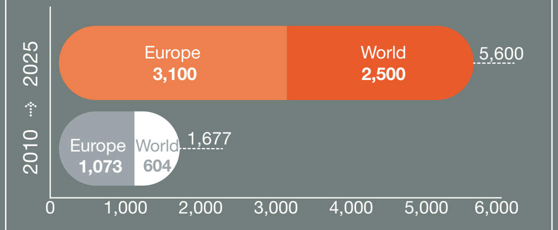
- Fixed inspection time interval for preventive maintenance is broadly applied
- Several graded maintenance levels, from daily inspection to overhaul, are determined

TECHNICAL ASPECTS

Number of train sets operated per 100km of high speed line



Forecast for the number of train sets in 2025



By the end of 2010, more than **2,100** high speed train sets (able to operate at least at 250km/h) were in operation across the world

Asia	**839**
Europe	**1,243**
North America	**20**
TOTAL	**2,102**

Years for inauguration of new design high speed rolling stock:
3-5 years for new technical development,
2-5 years for design and test

Number of manufactures of high speed rolling stock in the world: 14

TECHNICAL ASPECTS

Operations

PLANNING HIGH SPEED TRAFFIC ON NEW LINES REQUIRES

- Highly structured train path matrices
- Regular intervals (an asset commercially, but also efficient from an operational standpoint)
- Maximum use of available capacity
- High quality of service targeted

Maximum density of operation:
15 trains/hours

Safety record
No fatal accident on high speed lines since the beginning of high speed history

SECURITY

As a constituent part of society and a significant public investment, high speed systems need to be protected. Also, the demand for quality from customers is higher than for other train services.

Consequently, a very high level of security is essential to ensure that customers choose this mode of transport.

Security concerns range from simple cases of graffiti to more serious problems affecting customers, employees, equipment, installations, etc.

Opportunities are created from the implementation of new systems, tracks, stations and rolling stock.

SAFETY REGARDING NATURAL HAZARDS

- Earthquakes
- Extreme climate conditions: snow, cold weather, typhoons, etc.
- Cross wind

MISSIONS OF CONTROL-COMMAND CENTRE

Traffic management

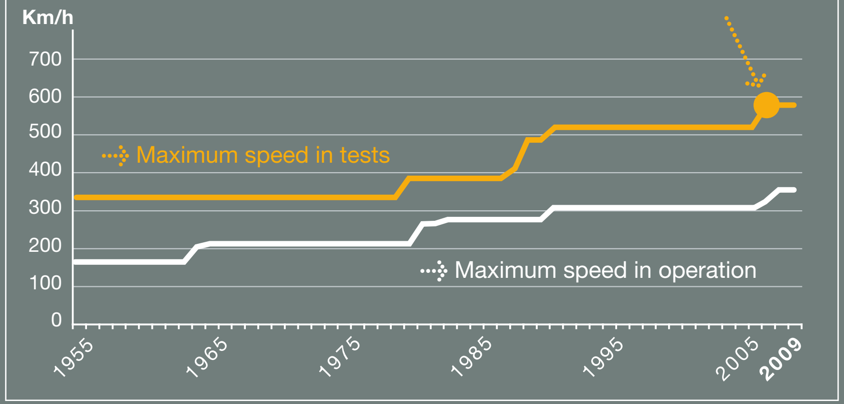
- Operational time table
- Calculate difference between scheduled/actual times
- Display as distance/time graph or station survey

Dispatching

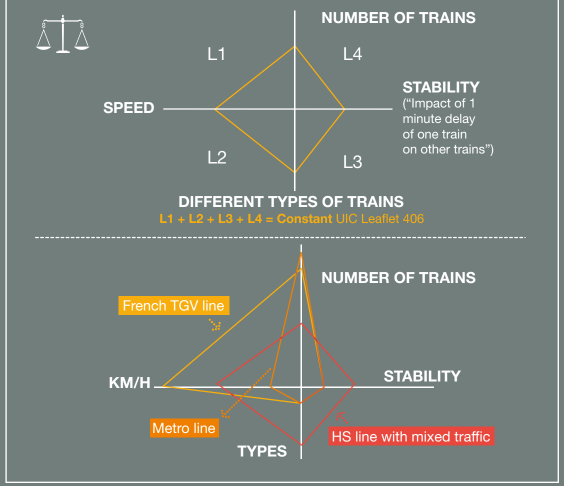
- Automatic intrusion detection
- Computer-aided conflict resolution with dynamic train running time calculations
- Preventive measures
- Power supply control
- Passenger information
- Station equipment control
- Video security

Evolution of maximum speeds on rails

WORLD SPEED RECORD: On 3rd April 2007 the world speed record for rail transport was set at **574.8km/h** by a special TGV trainset on the French TGV East high speed line



Balancing capacity when operating in mixed traffic



Operations

PERFORMANCE OF THE SIGNALLING SYSTEM

Scope

Safe train management, avoiding any collisions and/or accidents.

Principle

A train can proceed only when the track ahead is free of other trains/vehicles/obstacles.

Means

Automatic systems, manual procedures, specific rules or a combination of the above.

7 main goals for ERTMS:
- Interoperability
- Safety
- Capacity
- Availability
- Cost-effectiveness
- Less on-board equipment
- Open market

SIGNALLING SYSTEMS

Europe

ERTMS (European Rail Traffic Management System):
- ETCS (European Train Control System)
- GSM-R (Global System for Mobile Communications - Railways)
- TRAFFIC MANAGEMENT LAYER (and Automatic Centralised Traffic Control)

Japan ATC (Automatic Train Control)

China CTCS (Chinese Train Control System)

The maintenance and renewal of all the elements involved in a high speed system is essential to ensure the main operational parameters at the optimum level, in any moment and under any condition.

Monitoring, inspection, current maintenance and major renewal must be compatible with current operations.

MAGNITUDES

Some order of magnitude and distances concerning speed

Distance to accelerate from 0 to 300km/h → **10 - 20km**

Operating at 300km/h:

1km → **12sec**

5km → **1min**

Magnitude of usual braking distance (m)

- 200km/h → 1,900m
- 250km/h → 3,100m
- 300km/h → 4,700m
- 330km/h → 5,800m
- 350km/h → 6,700m

Strategic value of stations

The location of high speed stations is an important and strategic aspect for the success of the system as a whole.

They must be well located to benefit from the advantages of the reduced travel times offered, and they must be well connected with airports, mass transit systems and private transport.

The criteria for the station (one or more stations) in a given city must consider the optimal requirements of city and citizens, as well as those of the railway system.

A functional design is absolutely essential, and parallel business activities are a common feature of high speed stations.

STATIONS, *HIGH SPEED AND THE CITY*

HIGH SPEED ALSO MEANS HIGH CAPACITY.

Consequently, it's to be expected that high speed stations are high traffic volume stations. "Volume" must be understood in terms of trains, customers, private cars, taxis, and public transport.

In many cases, stations are the location in which railway operators clean their trains, replace their crews, check the trains, replace the catering, etc. This industrial activity involves sharing space with passengers.

Removing this activity from city centres can be positive due to the use of lower-cost land and because it can release important land (and industrial activity) in city centres.

HIGH SPEED SERVICES: high speed stations can be used to promote a high level of architecture and the revitalisation of abandoned city areas. The costs and benefits of this approach can be carefully studied.

UIC study on "High speed and the city" is available on the UIC high speed website:
www.uic.org/highspeed

Design concepts for high speed services

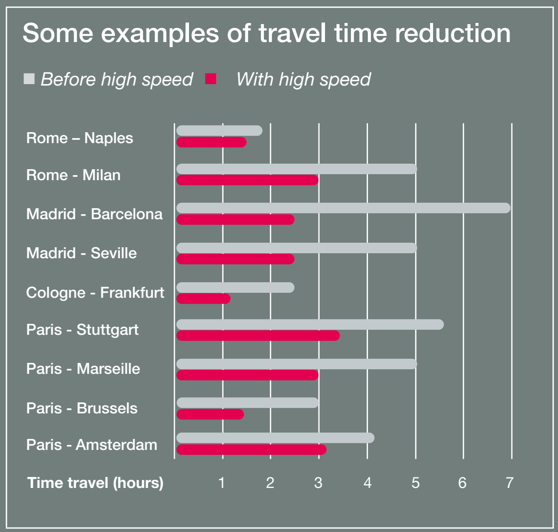
In terms of commercial concepts, a broad range of criteria may underpin high-performance passenger rail transport systems:

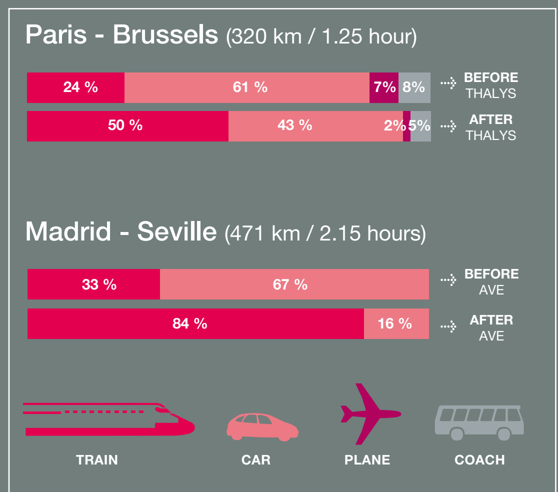
- Marketing procedures, including trademarks, and advertising
- Information, reservation and ticketing systems
- Ticket control (including the possibility of access control)
- On-board customer services, including WI-FI, and computer aids
- Post-travel services

SERVICES THAT HIGH SPEED CAN OFFER TO CUSTOMERS:

- Commercial speed
- Frequency
- Accessibility
- Comfort
- Attractive travel time (door to door)
- Reliability
- Price
- Safety
- Freedom (*)

(*) Freedom means that high speed rail is the only passenger transport mode in which it is not obligatory to be seated, use seat belts or listen to safety instructions. While travelling in a high speed train it is possible to stand or sit, walk around the train, have a coffee, work on a laptop or use a mobile phone at any time.





COMMERCIAL ASPECTS

PRICING SYSTEMS

High speed railway undertakings increasingly use variable prices for different types of service. Depending on motive (business or private), travel periods or other circumstances influencing demand, the prices offered (and the conditions of purchase) can vary considerably.

Various procedures, some imported from the airlines like "yield management" (which aims to the maximise the income per train), widespread use of the Internet, the use of "ticketless" procedures and the introduction of innovative ideas (like iD TGV in France) are consistent with the high-level technology used in trains, lines and signalling systems.

DISTRIBUTION

High speed travellers expect high speed access to information, reservation and fare transactions.

MARKET SHARE

If a new high speed rail system is well designed and implemented, customer response is, as a rule, very positive and traffic will reliably grow.

Traffic growth can be increased by the mobility gains created and the "network effect".

The consequence of the "network effect" is that the total number of kilometres of the network can be increased by 20% (as an example) and passenger traffic can increase by 100%.

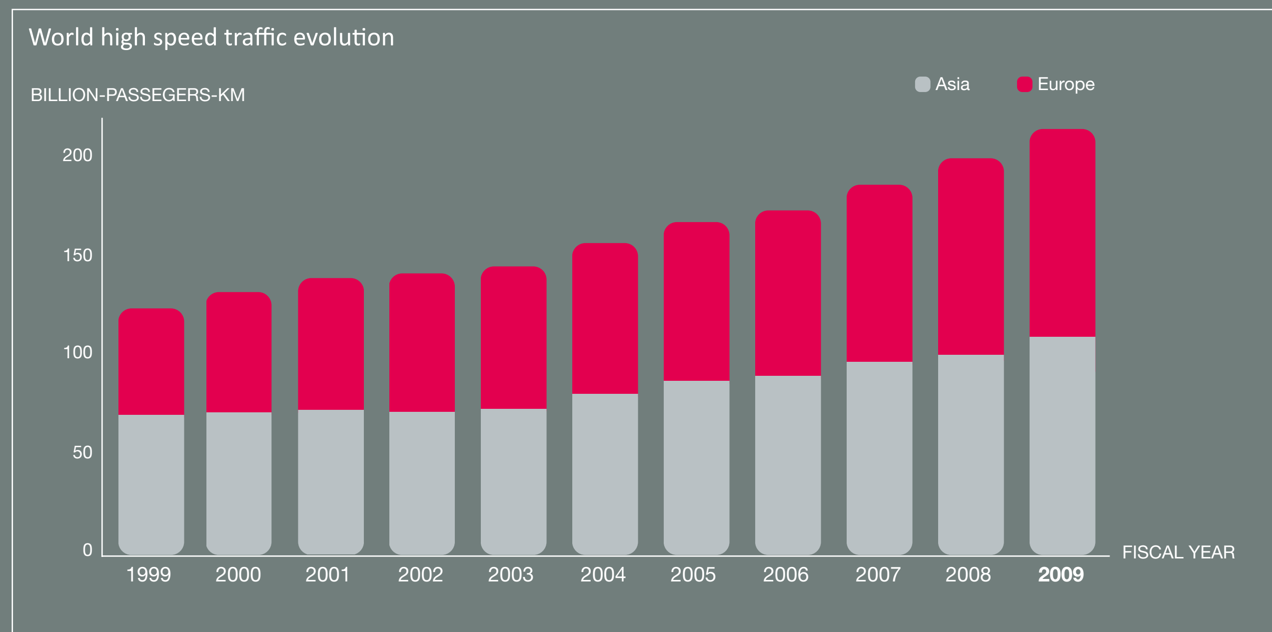
Also, the introduction of a new high speed corridor varies the modal split.

DESIGN FOR CUSTOMERS

New customer requirements demand new designs: working and meeting areas, spaces for families, full accessibility, special consideration for luggage (larger capacity for tourist trips, but limited spaces for business trips).

From the technical point of view, as more customers are using mobile phones and computers, new facilities such as electric plug sockets for power supply and on-board WI-FI are required.

UIC study on "High speed and territory management" is available on the UIC-High Speed website: **www.uic.org/highspeed**



ECONOMY AND FINANCES FOR HIGH SPEED

The costs of high speed rail systems

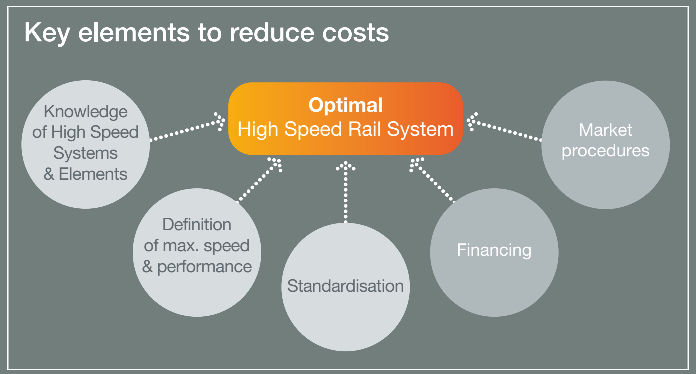
FUNDING / CALCULATING COSTS

- High speed requires significant investment, including public funding
- Consequently, detailed studies on traffic forecasting, costs and benefits which examine all the positive and negative impacts of a project —including calculating the costs of doing nothing— are needed
- The costs of high speed lines are generally paid for out of public funds (Japan, Europe, and Korea)
- The trend is to share funding and responsibilities between different public bodies (French TGV)
- In some cases, private funding can be attracted for part of the investment
- PPP (Public-Private Partnership) or BOT (Build - Operate - Transfer) are two possible ways of coordinating to combine public and private resources:
  - Private funder obtains Return On Investment (ROI)
  - Public funder ensures social benefits

MAGNITUDE OF COSTS OF HIGH SPEED SYSTEMS:

Average costs in Europe

Construction of 1 km of new high speed line	€12-30M
Maintenance of 1 km of new high speed line	€70,000 per year
Cost of a high speed train (350 places)	€20-25M
Maintenance of a high speed train (2€/km - 500,000km / train & year)	€1M per year



High Speed System in Europe Area

2010

more than 250km/h in operation

more than 250km/h in development

180 < v < 250km/h

Other lines

Situation as at 12.2010
Information given by the Railways

2025

more than 250km/h in operation

180 < v < 250km/h

Other lines

Forcasting 2025
Information given by the Railways

HIGH SPEED AROUND THE WORLD

High Speed System in *Americas*

High Speed System in *Asia*

UIC High Speed Department

PRINCIPAL OBJECTIVES

- **Coordinate** high speed activities of UIC members
- **Contribute** to logical development of high speed systems

ACTIVITIES

- **Updating** databases: lines, rolling stock, traffic, etc.
- **World** high speed maps
- **"Benchmarking"** and other working teams
- **Communications** and contacts
- Website
- High speed brochure and other publications

STUDIES

- High speed and the city
- High speed and territory management
- High speed contribution to sustainable development
- Maintenance of high speed lines
- Key Performance Indicator (KPI) for high speed
- ...

PREVIOUS STUDIES

- Reduction of travel time on classic lines
- Tilting trains
- Mixed traffic on high speed lines
- Design of lines for speeds of 300-350 km/h
- Approval of new high speed lines
- High speed rail compared to "low cost" competition
- Infrastructure charges for high speed services in Europe
- Modelling of regional traffic on high speed international lines
- Necessities for future high speed rolling stock

www.uic.org/highspeed

WORKSHOPS *(some examples)*

Daejeon City (Korea) 2009: 1st UIC World High Speed Interaction Workshop.

Marrakech (Morocco) 2009: Safety and Security requirements of High Speed Rail.

Paris (France) 2010: 1st Workshop on Global Standards for High Speed Rail Systems.

Mumbai (India) 2010: Security challenges and High Speed development.

WORLD CONGRESS ON HIGH SPEED

In the past, it was called "Eurailspeed"

Previous events: Lille (1992), Brussels (1995), Berlin (1998), Madrid (2002), Milan (2005), Amsterdam (2008), Beijing (2010).

TRAINING ON HIGH SPEED SYSTEMS

UIC members' cooperation helps ensure that 50 or so participants interact with around 55 speakers during a week-long session (from Monday to Friday), reviewing in detail all the components of a high speed rail system.
The training is aimed at decision-makers and is held every year during the month of June.

HIGH SPEED TOWARDS THE FUTURE

Research & development

FUTURE REQUIREMENTS FOR ROLLING STOCK TO BE CONSIDERED (FROM REPORT ON FUTURE NECESSITIES AND REQUIREMENTS FOR ROLLING STOCK)

- **Business and technical management** issue (development-procurement-approval-deployment, LCC*, RAMS*, standardisation and modularity, etc)
- **Basic dimension and performance** (capacity, loading gauge, axle load, train and car length, configuration of train set, compatibility with infrastructure, maximum speed, acceleration and deceleration)
- **Safety and security** (stability, crash resistance, fire safety, crosswind)
- **Environment** (CO2 and energy, EMC*, noise, LCA*, extreme climate)
- **Aerodynamics** (aerodynamic resistance, tunnel micro-pressure wave, flying ballast)
- **Comfort** (ride comfort, noise abatement, tilting system, airtight structure, air conditioning, passenger service)
- **Human factors** (ergonomics, accessibility for PRM*, cab design, cabin design, i.e. seating, toilet, luggage space)
- **Technology** (body and bogie structure, power and braking system, on board train control and information system, new auxiliary power units, coupling system)

* LCC = Life Cycle Cost
* RAMS = Reliability, Availability, Maintenability, Safety
* EMC = ElectroMagnetic Compatibility
* LCA = Life Cycle Assessment
* PRM = People with Reduced Mobility

UIC report on “Necessities for future high speed rolling stock” is available on the UIC-High Speed website:
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Technology for the future

Today's technology is fully competitive.

However it will not continue to be competitive beyond the next 20 years if we do not invest in research and development today.

Research and development for future high speed systems (infrastructure, tracks, electric power supply, signalling, rolling stock, operation and control elements, safety and security devices, etc.) must take into account requirements from customers, society, operators, etc.

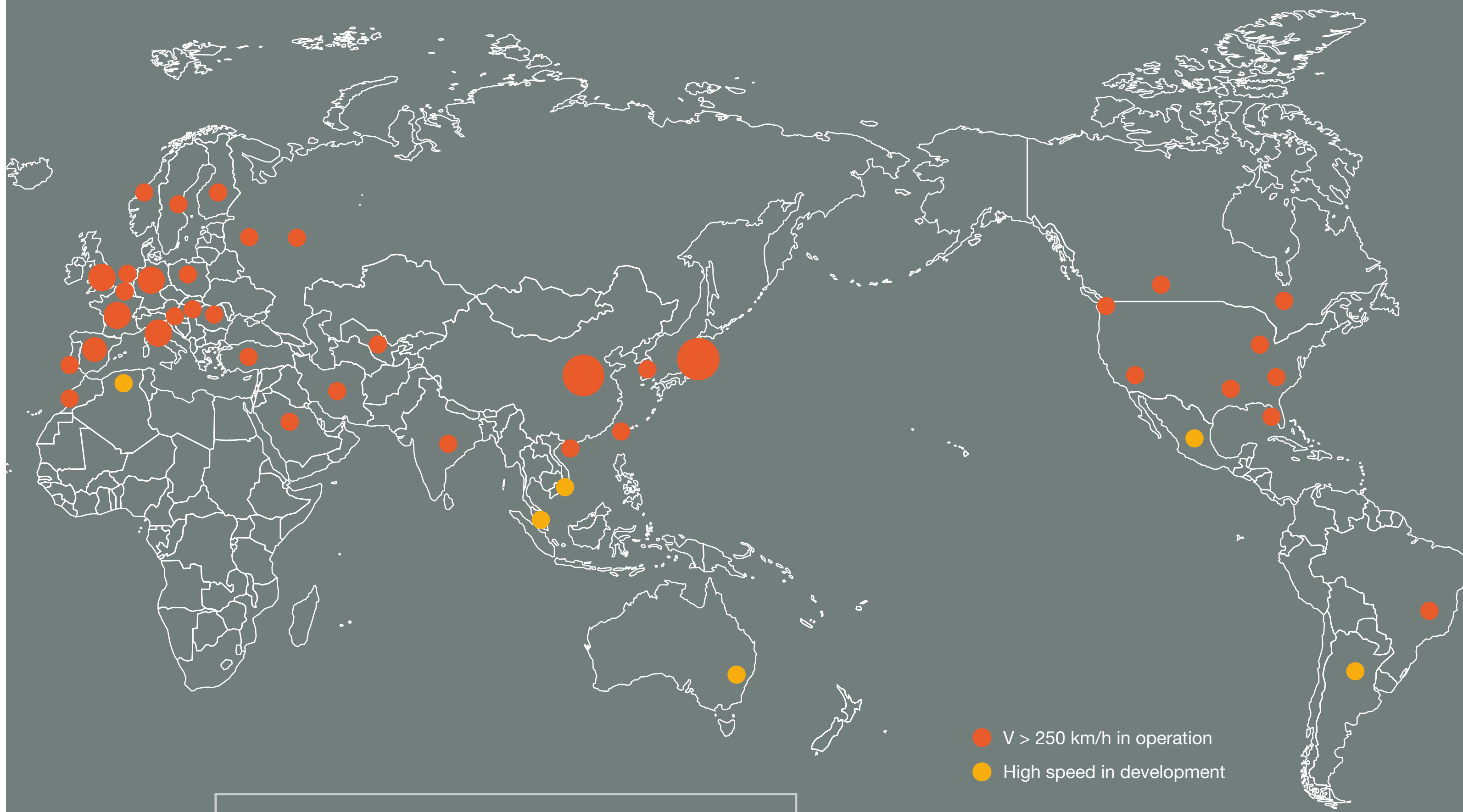
IN THE COMING YEARS, HIGH SPEED WILL MAKE PROGRESS ON:

- Higher service speeds
  - Maximum speeds in the range of 320 - 360km/h
  - More availability time for infrastructure
- New conception of infrastructure elements:
  - Ballasted or unballasted track, new fastening systems
  - New materials (i.e. catenary wires)
- Standardisation and modularity of rolling stock
- New braking systems
- More environmentally-friendly (noise, energy efficiency)
  - Improvements on safety, security and comfort
  - Cross winds, typhoons and earthquake detection, etc.
- New technologies (telecommunications, WI-FI, etc.)

IN THE COMING YEARS, HIGH SPEED RAIL OPERATORS WILL REQUIRE BUSINESS CONCEPTS TO DEAL WITH THE FOLLOWING:

- More capacity (double deck &/or 2 + 3 instead of 2 + 2)
- Greater availability and maintainability of trains (RAMS)
- Further reductions in costs of procurement and maintenance (LCC)
- Further reductions in fees for infrastructure use
- More energy efficiency and less energy consumption
- Optimisation of operating costs (i.e. during low occupancy)
- Globalisation
- ...

2025



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Director ⇢ Iñaki Barrón de Angoiti, *Director of the Passenger and High Speed Department*

Coordination team ⇢ Naoto Yanase, Begoña Cabo,
Isabel Guillén, *Passenger and High Speed Department*
Hervé Aubert, *Communications Department*
Henning Schwartz, Margrethe Sagevik,
Sustainable Development Division

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unity, solidarity, universality

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16 rue Jean Rey • F-75015 Paris

PASSENGER AND HIGH SPEED DEPARTMENT
Phone + 33 1 44 49 20 20
E-mail highspeed@uic.org
www.uic.org/highspeed

www.uic.org

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