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January 2009 - 2

High speed rail

Fast track to sustainable mobility

Union Internationale des Chemins de fer

Principles of high speed rail

High speed rail: definitions and requirements

High speed signifies operations of at least at 250 km/h, but in fact what is really important is the performance by customers, in terms of time travel, frequency, comfort, etc.

Operating at high speed requires:

SPECIAL TRAINS. High speed operations require "train sets" instead of conventional trains (locomotive and cars), because of the power weight / ratio and also for other technical reasons, such as aerodynamic conditions, reliability, safety, etc.

SPECIAL DEDICATED LINES. Conventional lines, even with major upgrading, are unable to operate at more than 200-220 km/h. The layout parameters, transverse sections, track quality, catenary and power supply, special environmental conditions, etc., must be able to sustain high operational speeds.

SPECIAL SIGNALLING SYSTEM. One particular aspect of operating conditions is the signalling system. Line side signals are no longer useable at more than 200 km/h because there is no guarantee that they will be observed in time. In-cab signalling is absolutely necessary to operate at high speed.

Generally, speeds of around 200-220 km/h (with certain rare exceptions) represent the threshold for conventional railways.

Revenue service at higher speeds requires special consideration and it is then that the concept of a "high speed system" starts to be of fundamental importance.

JR Kyushu

Summary

Understanding high speed rail

High speed railways are very complex systems comprising many different elements:

- Infrastructure (including civil engineering works, track, catenary, etc.)
- Stations (location, functional design, equipment, etc.)
- Rolling stock (from technical point of view, comfort, design, etc.)
- Operations (design and planning, control, rules)
- Signalling systems
- Maintenance policy and systems
- Financing
- Marketing procedures
- Management
- Etc.

As all these components are used at their respective state-of-the-art level (the best track, maintenance, power devices, etc.), each is vital in order to save even a minute. None may be neglected and it is essential to consider all these items 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 coherent with the time saving obtained by the use of high-level technology and significant investment.

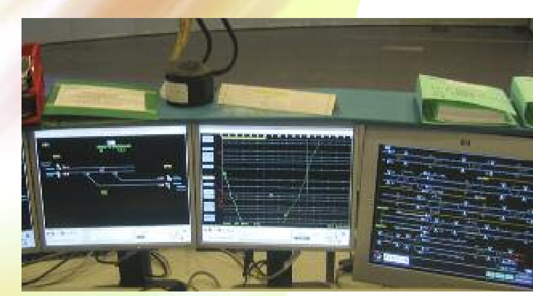
Renfe/Siemens

Orders of magnitude and distances concerning speed

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

Operating at 300 km/h: 1 km = 12 sec / 1 min = 5 km

Speed (km/h)	Braking distance (m)
200	1,940
250	3,130
300	4,690
330	5,840
350	6,729



The development of high speed rail: facts and figures

High speed started in Japan in October 1964, when the Shinkansen ("new track line") between Tokyo and Osaka (515 km) was inaugurated at the maximum speed of 210 km/h.

The system was developed in the fifties, bringing together the most advanced railway technical innovations. Its success prompted the construction of new lines and a very in-depth technological research programme.

The first high speed system in Europe was inaugurated in France, in September 1981, between Paris and Lyons (417 km, second half in 1983), at the maximum speed of 260 (later 270) km/h. It solved the problem of saturation of the conventional line and also, made use of the results of extensive technological research carried out in the seventies.

During the eighties and nineties, many European countries started with operations at 250 km/h or more (Germany, Italy, Spain, Belgium). The success of the first lines gave rise to the extension of national systems and, later, to the ambitious concept of an interoperable European high speed network.

The inauguration of new lines in the USA, North Korea and Taiwan and the development of new projects in Europe, Asia, Africa and South America, signals the entry of high speed systems (railways, industry, financial stake-holders, decision makers, etc.) into a truly global dimension.

SNCF

World speed record in 2007

Two important records were set during 2007:

- On 3rd April 2007, the world speed record for rail transport was broken by a TGV train set on the East European high speed line, which reached 574.8 km/h.

- Since the inauguration of the same line on 10th June 2007, the operating speed of an entire high speed line has for the first time reached 320 km/h.

World network and rolling stock

At the beginning of 2008, the worldwide network of lines in operation at 250 km/h or more represented a total of 9,780 kilometres.

At the same date, almost 1,750 train sets able to operate at 250 km/h or more were in service.

Alstom

Hitachi

JR East

Traffic figures

In Japan, after almost 45 years of high speed commercial operations, more than 4,000 million passengers have already travelled on Shinkansen trains, with no passenger injuries due to accident.

The Tokaido Shinkansen, from Tokyo to Osaka (515 km) is the busiest high speed line in the world, carrying more than 360,000 passengers every weekday.

In France, after more than 26 years, more than 1,400 million people have travelled on TGV trains.

In Europe, average annual traffic growth has been 10 % in the last 10 years.

In Korea, 100,000 passengers take the KTX Express every day, representing 50 % of rail customers.

81 % of passengers travelling from Paris to London by train or plane take Eurostar trains.

50 % of passengers travelling from Paris to Brussels (all modes) use Thalys services.

High speed rail serving customers and society

Renfe

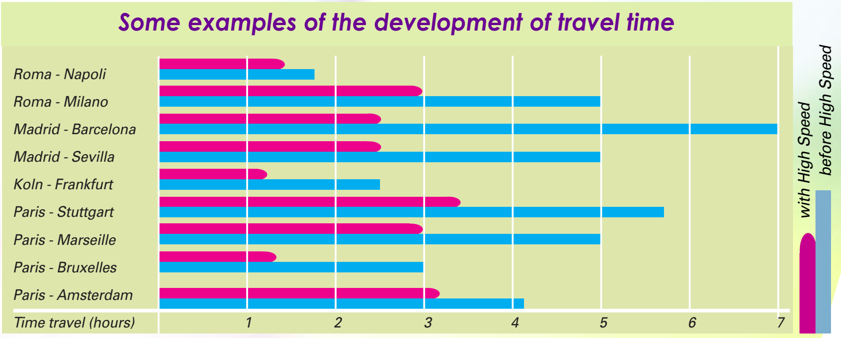
High speed rail performance for customers

Thalys SNCF

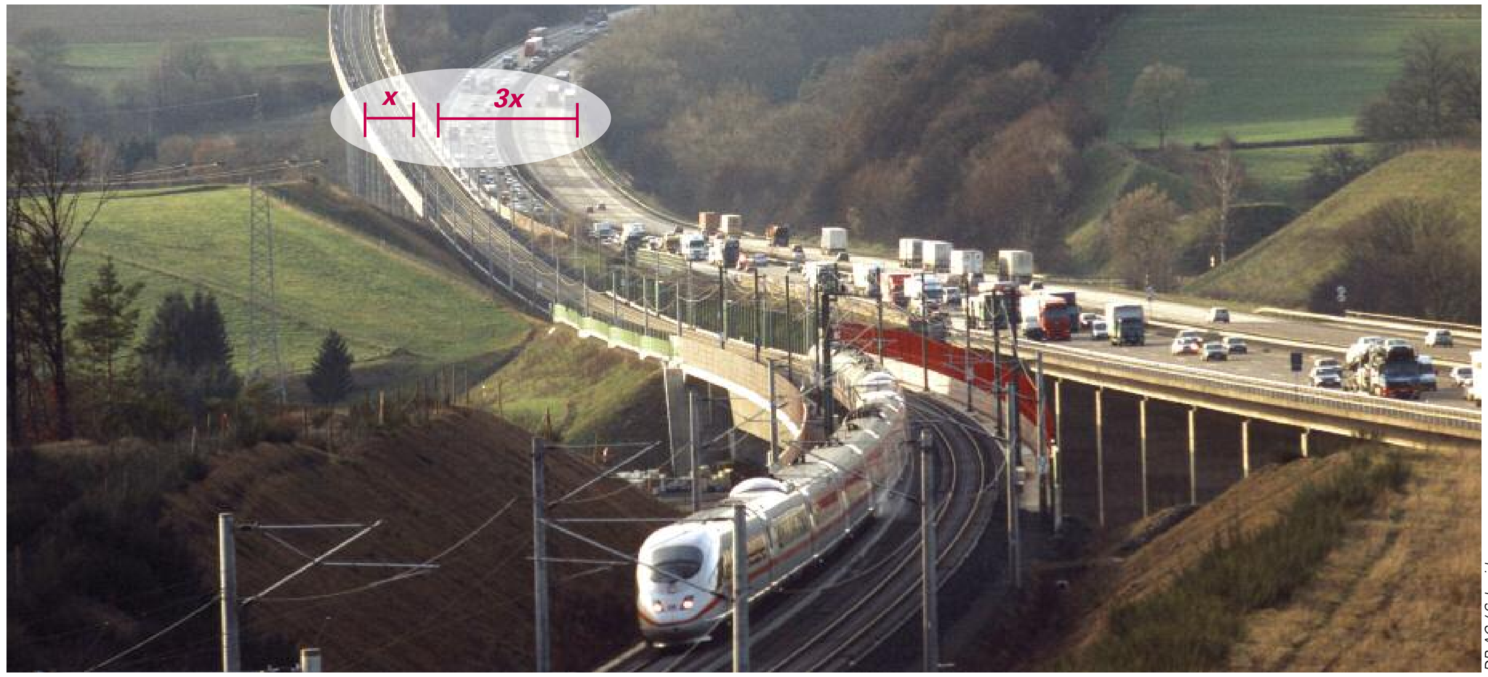
High speed services can offer customers

- Commercial speed
- Frequency
- Accessibility
- Comfort
- Total travel time (door to door)
- Reliability
- Price
- Safety

- Freedom
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. Travelling in a high speed train one may stand or sit, walk around the train, have a coffee, work on a laptop or use a mobile phone at any time.



High speed rail's advantages for society



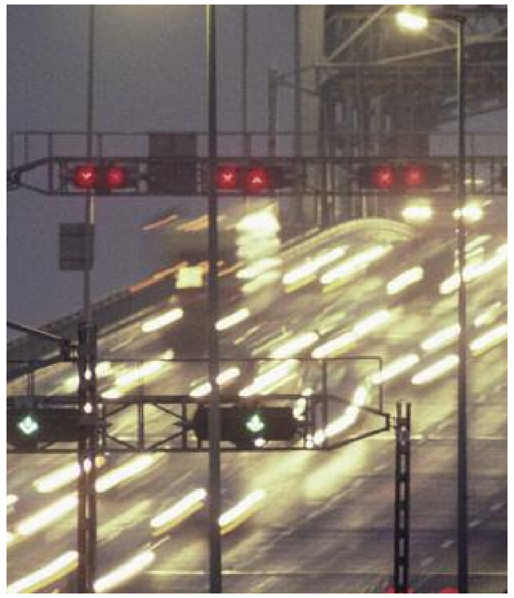
DB AG / Schmid

High transport capacity

- Up to 360,000 passengers per day
- Facilitates and increases mobility
- Boosts economic development
- Reduces traffic congestion
- Promotes logical town and country planning
- Helps contain urban sprawl

Respects the environment

- Efficient use of land
- Energy efficiency



High speed transport systems make a significant contribution to railway revitalisation and supporting sustainable development policies. The commercial success of high speed trains is currently engendering modal shift from less environmentally-friendly transport modes - mainly cars and planes - to rail, whilst helping to reduce overall "external costs" (the costs borne by society for road accidents, pollution, climate change and noise).

High speed rail systems play an important role for economic and social development wherever they have been introduced. Because of the high return for market and society, new high speed rail projects (new lines and infrastructure, line upgrades, new operating systems and rolling stock) should attract funding from all public stake-holders. It is a way of "internalising" the external environmental costs.

High speed rail and the environment

SNCF

SNCF

Land use

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

As an example, some land use ratios:

■ Average high speed lines	3.2 ha / km
■ Average motorways	9.3 ha / km

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

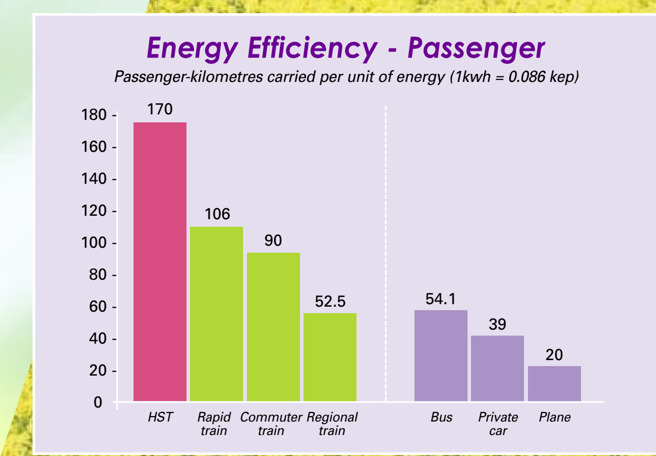
Examples of the increased use of parallel layouts in recent years

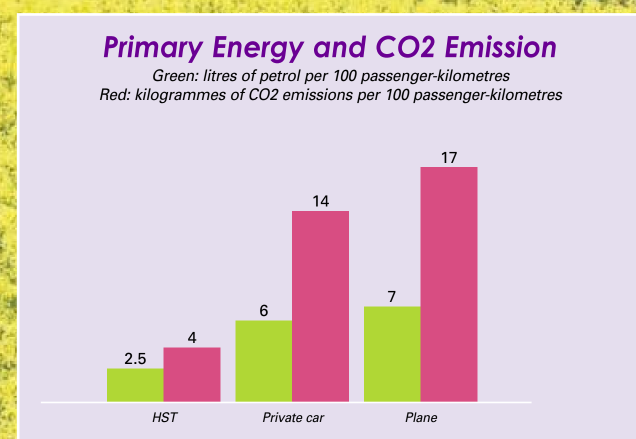
■ Paris-Lyons (1981-1983)	60 km (14 %)
■ Paris-Lille (1993)	135 km (41 %)
■ Cologne-Frankfurt (2002)	140 km (71 %)

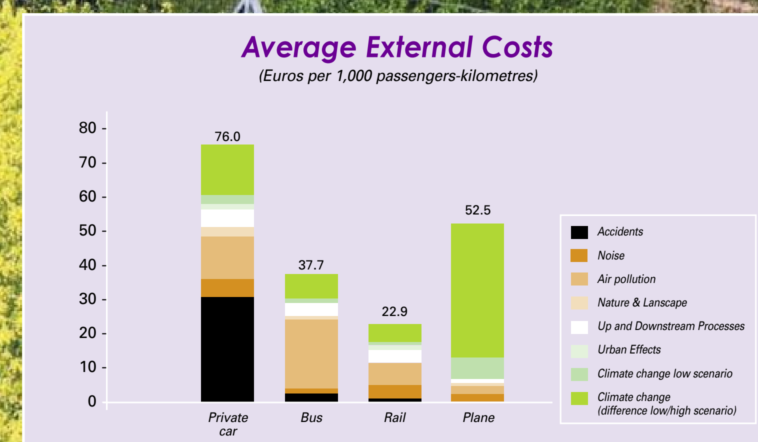
The construction of a new high speed line is sometimes a good opportunity to upgrade and renovate spaces and landscapes.

Comparisons in land use

HS Railway	Motorway
Double track **25 m**	2x3 lanes **75 m**
2x12 trains per hour	2x4,500 cars per hour
2x666 passengers / train capacity	2x1.7 passengers / car capacity
2x8,000 passengers / hour	2x7,650 passengers / hour







Technical aspects - Infrastructure

Adif

The length of the world's high-performance railway network is rapidly 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.
The geometric parameters for high speed tracks must be of optimum quality.
Slab track is in principle much more expensive than ballasted track, but it can be permanently operated with almost no maintenance.
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.

QR

Track Gauge

At present, all high speed lines have been built to the standard gauge (1,435 mm).
Nevertheless, new lines are planned in broad gauges (1,520 mm, 1,676 mm).
In metre gauge, progress is being made to obtain high performance, including tilting technology.

Typical parameters for new high speed lines

Layout specifications

Maximum gradient depending on geographical characteristics and operating conditions
- passenger traffic only: up to 35 / 40 mm/m (suitable rolling stock).
- mixed traffic: up to 12 / 15 mm/m.

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

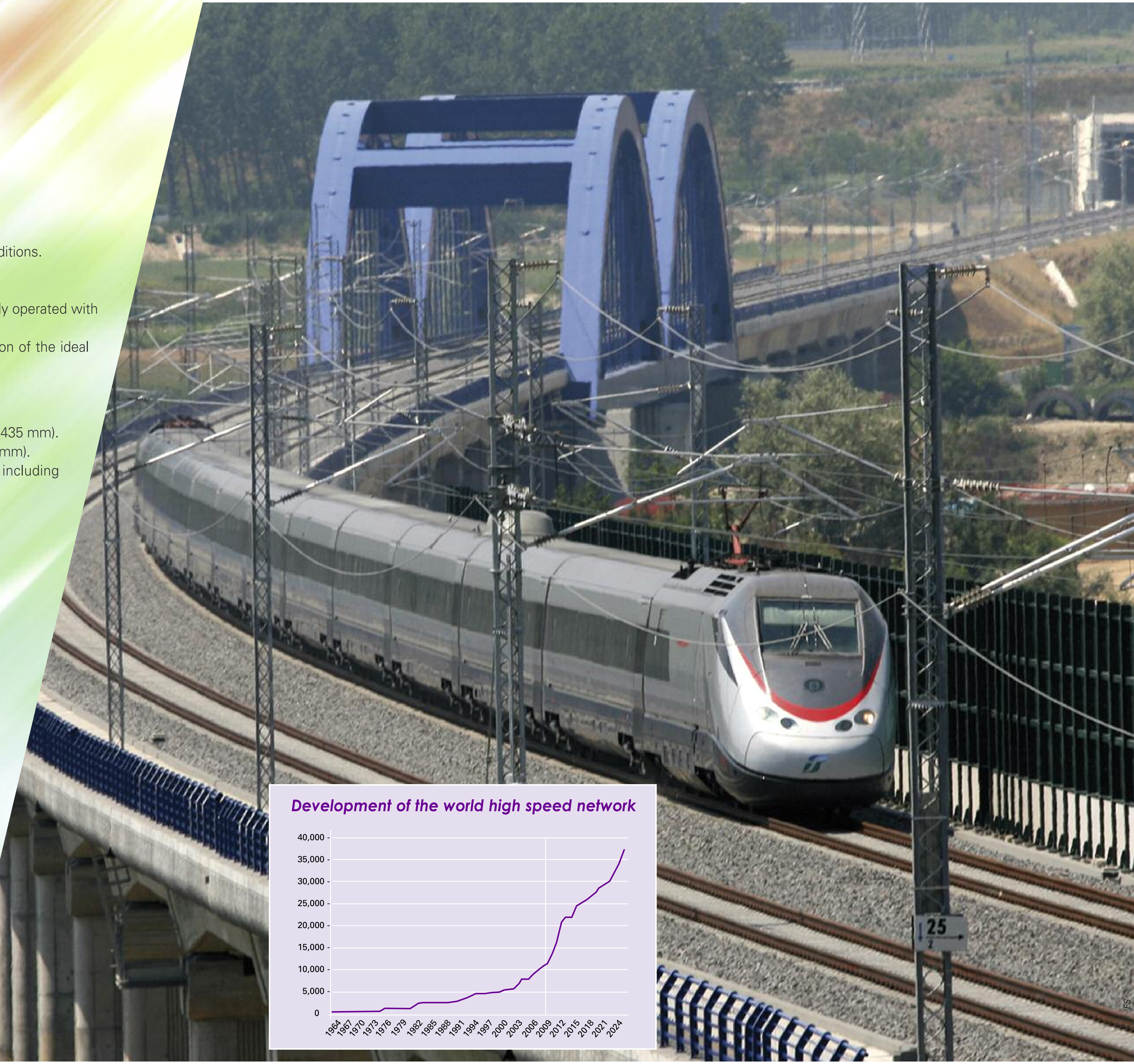
Track centre distance
200 km/h: 4 m
300 km/h: 4.5 / 5 m

Maximum cant
150 / 170 mm

Track superstructure components (typical ballasted track)
- Rail type: Usually, 60 kg/m, welded.
- Type and number of ties: Concrete monobloc or bibloc, 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 25 kV, 50 or 60 Hz or 15 kV, 16 2/3 Hz.

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



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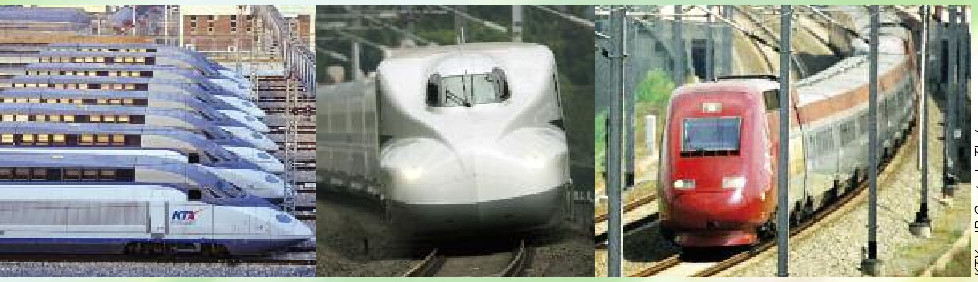
Technical aspects - Rolling Stock



KTX - JR Central - Thalys

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.

Common basic characteristics of high speed trains

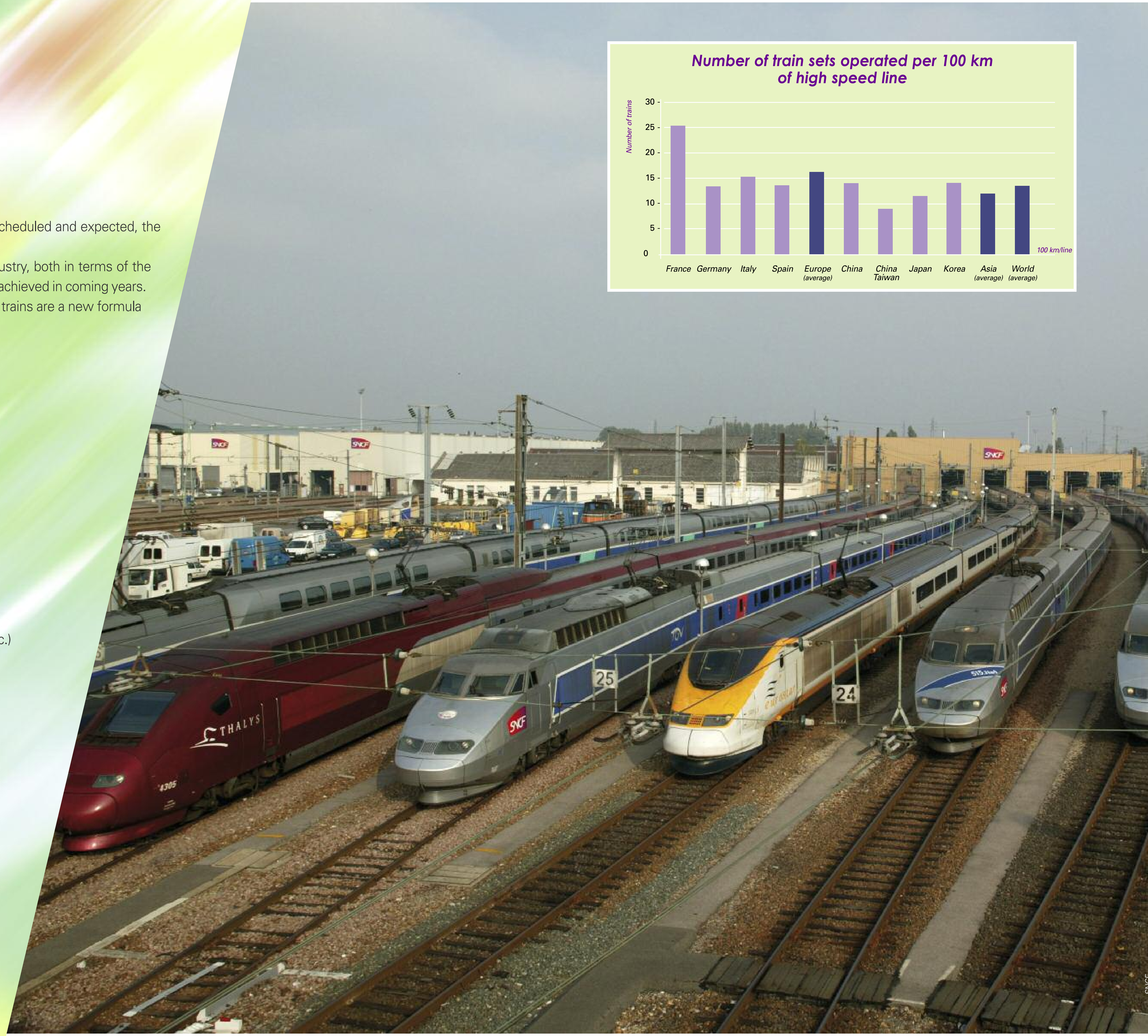
- Self-propelled, fixed composition and bi-directional
- High level of technology
- Limited axle load (11 to 17 tons for 300 km/h)
- High tractive power (approx. 20 kW per ton)
- Power electronic equipment: GTO, IGBT
- Control circuits. Computer network. Automatic diagnosis system
- Aerodynamics
- In cab signalling system/s
- Several braking systems
- Improved commercial performances
- High level of R.A.M.S. (Reliability, Availability, Maintainability and Safety)
- Sometimes pressurised
- Technical and safety requirements (compliance with standards)
- Compatibility with infrastructure (track gauge, loading gauge, platforms, catenary, etc.)

Types of high speed train

- Articulated or non-articulated trains
- Concentrated or distributed power
- Tilting or non-tilting
- Single or multiple gauges

In January 2008, 1,737 high speed train sets (able to operate at least at 250 km/h) were in operation across the world

Europe	1,050
Japan	427
Korea	47
China	163
Taiwan	30
USA	20



SNCF

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

Technical aspects - Operations

Infrabel - Adif

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

Missions of the Control-Command Centre

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

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

Performance of the signalling system

- Scope

Safe train management, avoiding any collisions and/or accidents

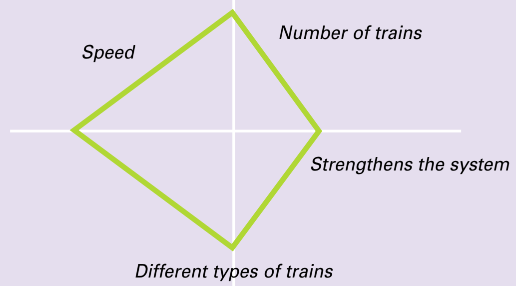
- Principle

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

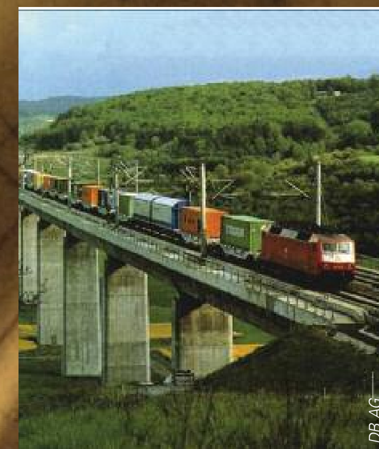
- Means

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

Balancing capacity when mixed traffic operated on high speed lines

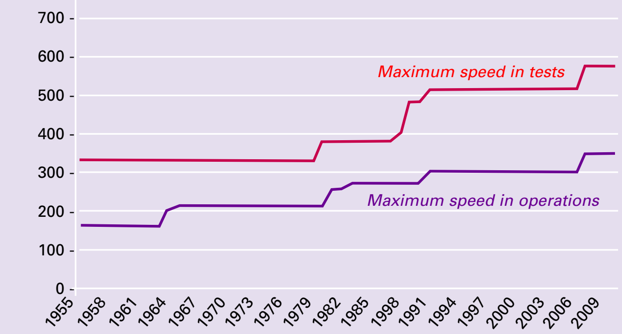


The type of traffic admitted in the line influences the total capacity. Optimising the capacity requires establish the balance between operating speed, different types of trains, number of trains and regularity.

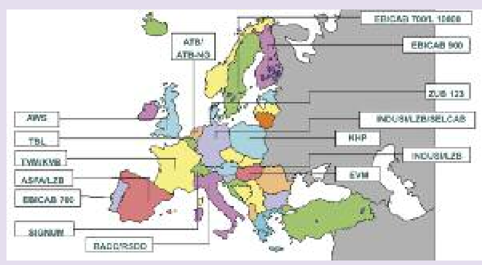


DB AG

Evolution of maximum speed on rails



Signalling systems in Europe - 7 main goals for ERTMS:

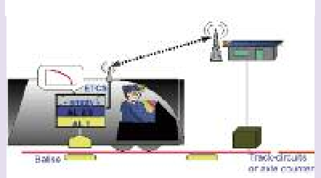


- Interoperability
- Safety
- Capacity
- Availability
- Cost-effectiveness
- Less on-board equipment
- Open market

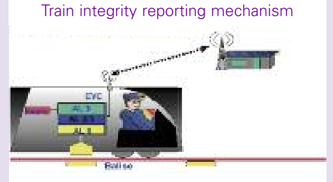
ERTMS
(European Rail Transport Management System)
=
ETCS
(European Train Control System)
+
GSM-R
(Global System for Mobile Communications - Railways)
+
TRAFFIC MANAGEMENT LAYER
(and Automatic Centralised Traffic Control)

ETCS - Application level 1
Overlay to optical signals,
fixed block

ETCS - Application level 2
Fixed block
Trackside devices for train detection



ETCS - Application level 3
No fixed block necessary
No trackside devices for train detection
Train integrity reporting mechanism



Infrabel

Commercial aspects

Varying 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 trade marks, advertising, etc.
- Information, reservation and ticketing systems
- Ticket control (including the possibility of access control)
- On-board customer services, including wi-fi, computer aids, etc.
- Post-travel services

Pricing systems

High speed railway undertakings increasingly use variable prices for different types of services. Depending on whether it is a business or private journey, 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 sophisticated technology used in trains, on lines and in signalling systems.

Strategic value of the location 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 (or stations) in a given city must consider the optimal requirements of the cities and citizens, as well as those of the railway system.

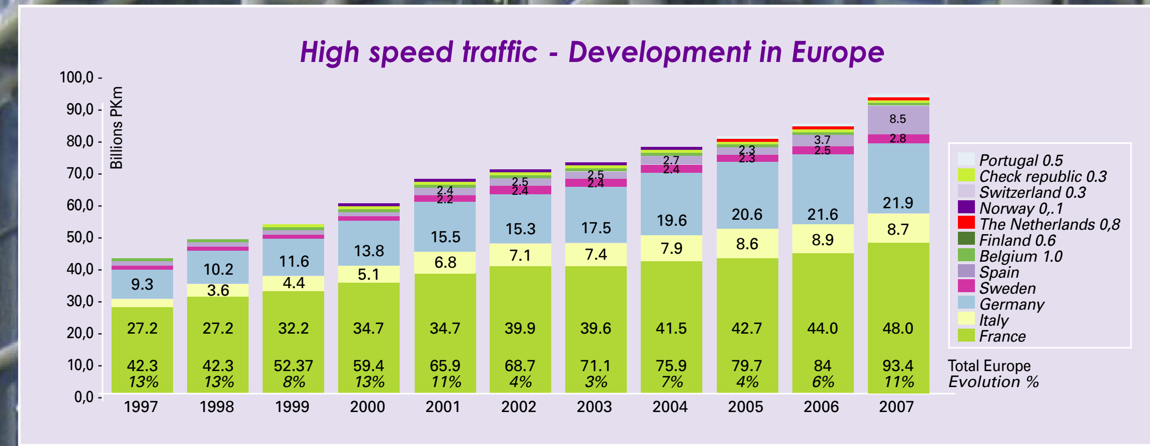
A functional design is absolutely essential, and parallel business activities are often a feature of high speed stations.

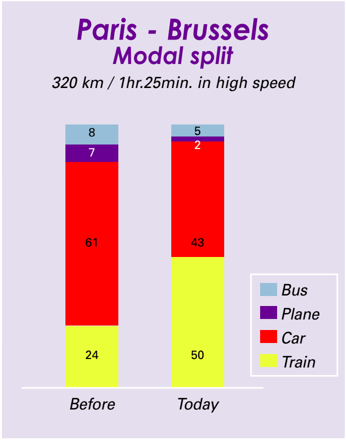
Market share

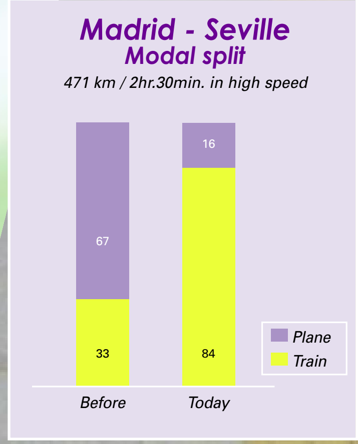
If a new high speed rail system is well designed and implemented, customer response is, as a rule, very positive and traffic will (reliably) grow. Traffic growth can be increased by the mobility gains created and the "network effect".

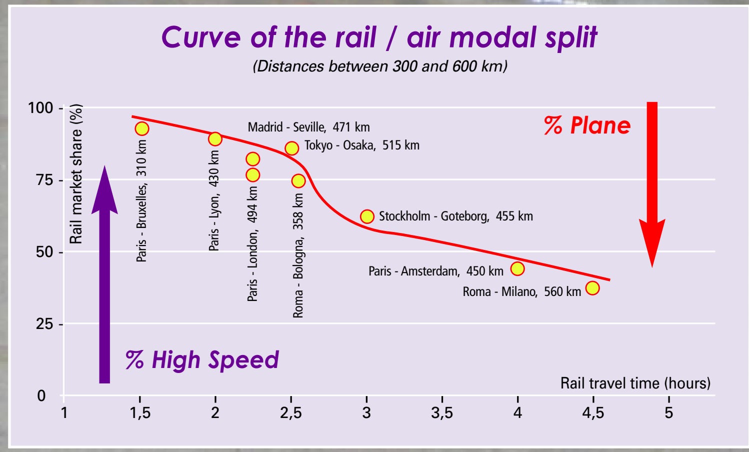
In the last 10 years, the consequence of this "network effect" in Europe has been that the total number of service kilometres has increased by 70 % and passenger traffic has increased by 160 %.

Also, the introduction of a new high speed corridor has an impact on the modal split.









The costs of high speed rail systems

JR Kyushu - KTX

Funding / Calculating Costs

- High Speed requires significant investment, including public funding
- Consequently, detailed studies on traffic forecasting, costs and benefits are needed, examining all the project's impacts, - positive and negative - and including calculating the **costs of doing nothing.**

Costs of high speed systems

Average costs in Europe

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

Funding Costs

- 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, i.e. Spain - France link) or BOT (Build - Operate - Transfer, i.e. China-Taiwan) are two possible ways of combining public and private resources:
  - Private funder obtains ROI (Return On Investment)
  - Public funder ensures social benefits

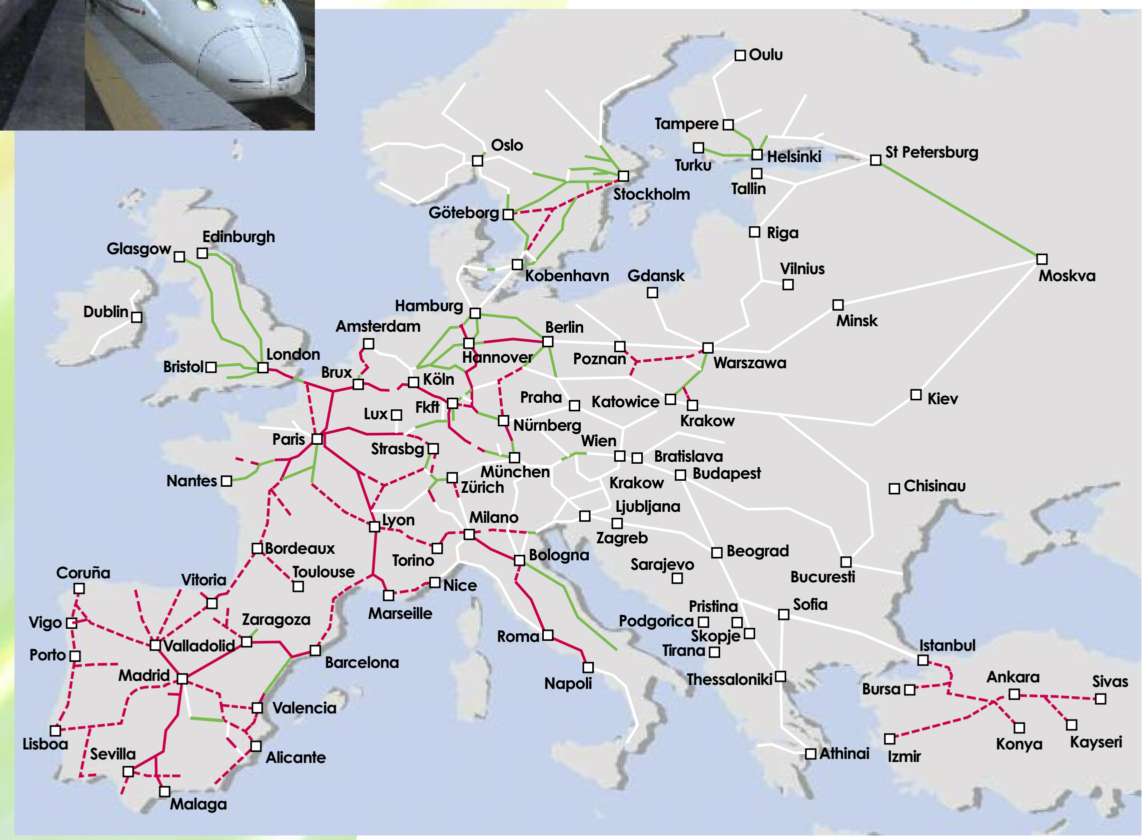
Rente

Siemens España

High speed around the world

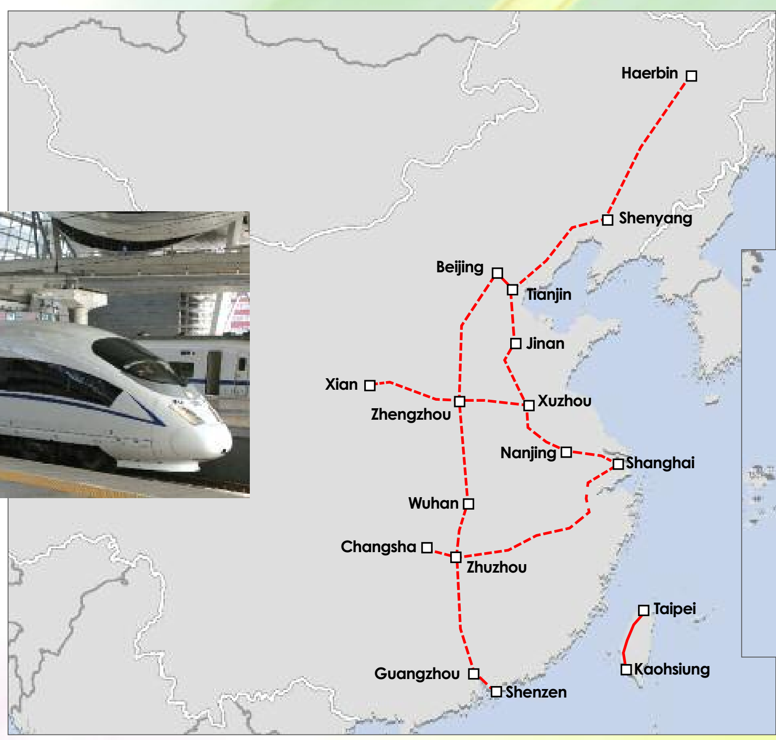
Systems in operation

- Belgium
- France
- Germany
- Italy
- Spain
- United Kingdom
- China - Taiwan
- Japan
- Korea
- USA



Europe 2008

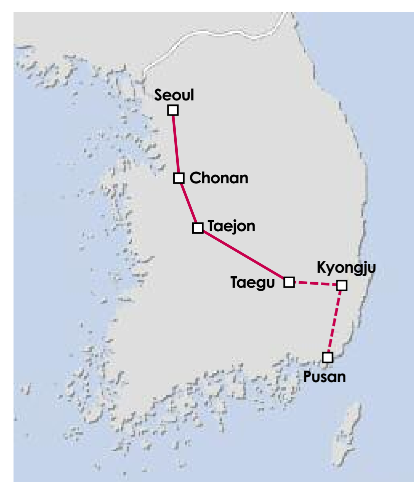
Europe 2025



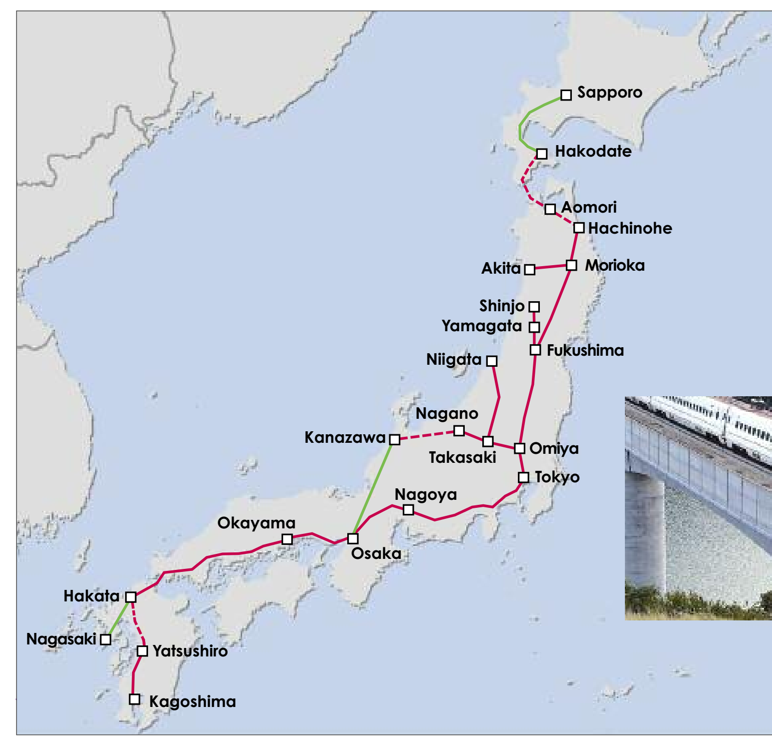
China

Taiwan

USA



Korea



Japan

High speed in operation
High speed line in development phase
Upgraded conventional lines

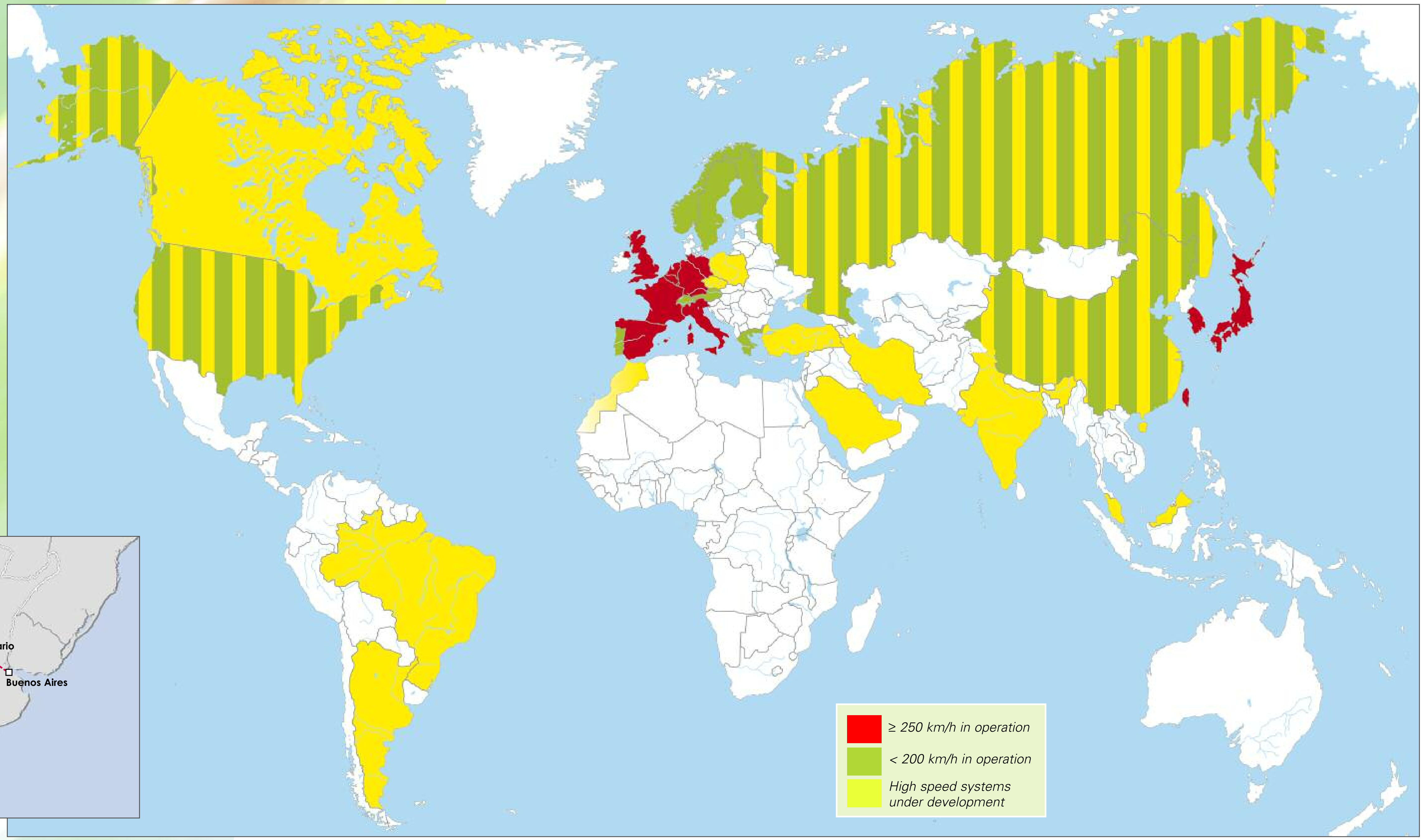
High speed around the world

Systems under construction

- China
- Iran
- The Netherlands
- Turkey

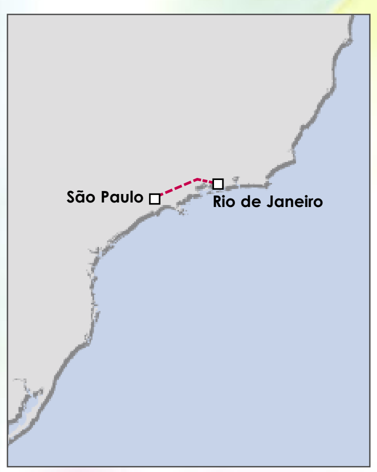
Systems under development

- Argentina
- Brazil
- India
- Morocco
- Poland
- Portugal
- Russia
- Saudi Arabia

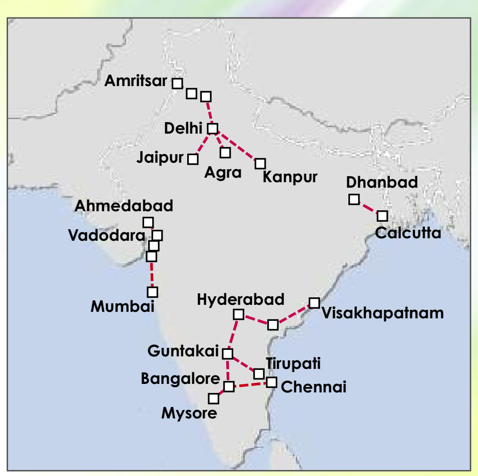


Alstom

Argentina



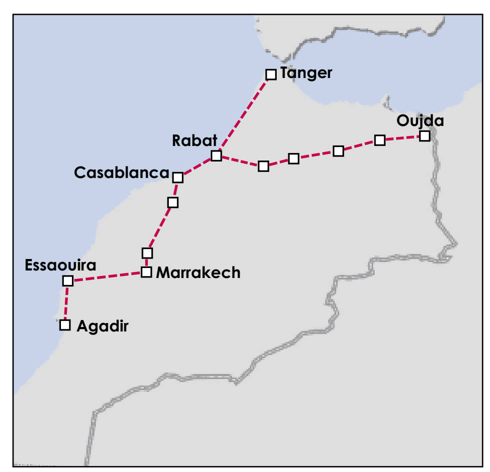
Brazil



India

Iran

Saudi Arabia



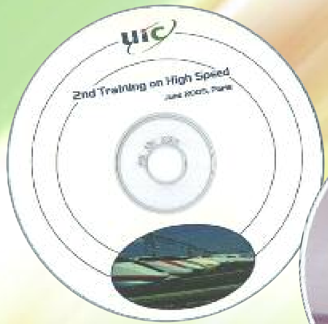
Morocco

CAF

ONCF

Turkey

UIC-High speed department



Principal objectives

- Co-ordinate high speed activities of UIC members
- Contribute to logical development of high speed systems

Activities

- Database (cartography, statistics, documentary)
- Passenger traffic forecasts (other previous studies exist)
- Working teams: benchmarking costs, approval of new high speed lines, tilting trains, "RTPLC"
- Studies: traffic forecasts, high speed rail's competitors and challenges (budget airlines, car), infrastructure fees, etc.
- Communications: internet site, monographs and other publications, etc.

World Congress on High Speed

- In the past, it was called "Eurailspeed"
- Previous congresses: Lille (1992), Brussels (1995), Berlin (1998), Madrid (2002), Milan (2005) and Amsterdam (2008)
- Next congress: China (2010)

Training on High Speed Systems

UIC members' cooperation helps ensure that some 50 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 in June.

Infrabel - DB AG - JR East

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JR East