INTERNATIONAL UNION
OF RAILWAYS

unity, solidarity, universality

HIGH SPEED RAIL

FAST TRACK TO SUSTAINABLE MOBILITY

SUMMARY

3 HIGH SPEED RAIL GENERAL OVERVIEW
4-5 HIGH SPEED RAIL HISTORY
6-7 HIGH SPEED RAIL PRINCIPLES
8-11 HIGH SPEED RAIL AND SUSTAINABILITY
12-13 TECHNICAL ASPECTS - INFRASTRUCTURE
14-15 TECHNICAL ASPECTS - ROLLING STOCK
16-19 TECHNICAL ASPECTS - OPERATIONS
20-21 STATIONS, HIGH SPEED RAIL AND THE CITY
22-23 HIGH SPEED RAIL AND THE CUSTOMERS
24-25 ECONOMY AND FINANCES FOR HIGH SPEED RAIL
26-29 HIGH SPEED RAIL AROUND THE WORLD
30-33 FUNDAMENTAL VALUES OF HIGH SPEED RAIL
34-37 HIGH SPEED RAIL TOWARDS THE FUTURE
38-39 HIGH SPEED RAIL AT UIC
40 CREDITS

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 components.

In addition, a 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 with respect to the environment).

However high speed rail is not always well understood as a whole 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.

For a long time UIC has been paying particular attention to high speed and has prioritised among other objectives the communication and dissemination of high speed performances, characteristics and potential applications.

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

WHAT DOES HIGH SPEED RAIL MEAN ?

The high speed criteria used by UIC is for operations of at least 250km/h. Of course, these technical criteria should not mask the performance as perceived by customers in terms of travel time, frequency, comfort, and price that is really important.

HIGH SPEED RAIL HISTORY

FROM BIRTH OF RAIWAYS TO HSR

19TH - 20TH CENTURY

The history of railways is a history of speed.
Since the origin of railways in Europe during the Industrial Revolution at the beginning of the 19th Century, the speed of passenger trains was an essential argument to compete, not necessarily with other transport modes (the railway in itself changed the scale of time for passenger travel) but among the different companies. The speed on rails also constituted an evidence of technological development of the most advanced countries at that time.
It's easy to imagine that the 50 km/h reached by the impressive "Rocket" locomotive from George Stephenson in 1829 represented a true high speed consideration for railways since the beginning.
And very soon railways reached even much more impressive speeds: 100 km/h before 1850, 130 km/h in 1854, and even 200 km/h at the beginning of the 20th century. In any case, these were just speed records. The maximum speed in revenue operation was much more modest but nevertheless important, reaching 180 km/h as the top speed and 135 km/h as the average speed between two cities in the 1930s, with steam, electric or diesel power..
But the appearance on stage of other transport modes, aviation (offering more speed) and private cars (offering point to point travels in privacy and forgetting frequency), forced passenger railways to use their best arguments to compete.

THE BIRTH OF SHINKANSEN

1964

After some significant speed records in Europe (Germany, Italy, UK and specially France, 331 km/h in 1955), the world was surprised when, on 1 October 1964, Japanese national railways started the operation of a fully brand new 515 km standard gauge line (1435 mm, apart from conventional lines previously built in Japan, in meter gauge), the Tokaido Shinkansen, from Tokyo Central to Shin Osaka. This line was built to provide capacity to the new transport system necessary for the impressively rapid growth of the Japanese economy. JNR president Shinji Sogo and Vice President for Engineering Hideo Shima promoted the concept of not only a new line, but a new transport system, called to be extended later to the rest of the country and to become the backbone of passenger transport for the future generations of citizens in Japan.
The Tokaido Shinkansen was designed to operate at 210 km/h (later increased), broad loading gauge, electric motor units powered at 25 kV AC, Automatic Train Control (ATC), Centralised Traffic Control (CTC) and other modern improvements.
High speed rail (HSR) was born.

THE BIRTH OF TGV

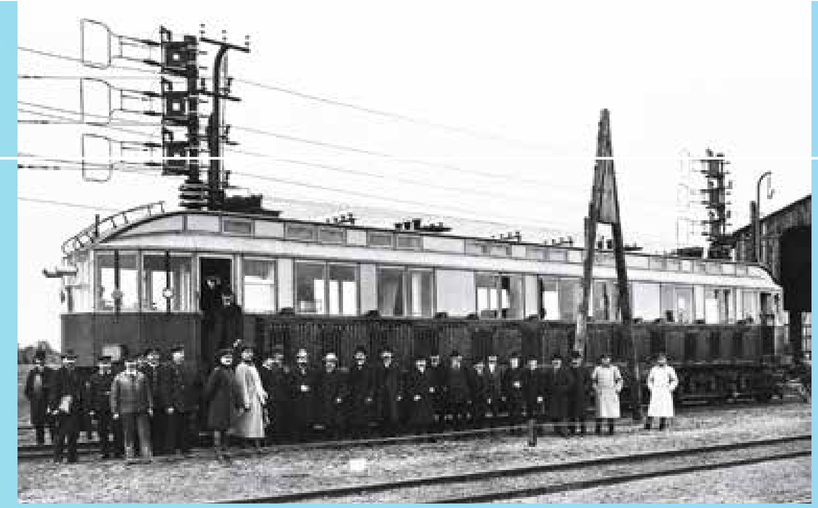
1964 - 1981

After the big success of the Shinkansen operation, technical progress in several European countries, particularly France, Germany, Italy and UK, developed new technologies and innovations aimed to establish the basis for the «passenger railway of the future». Despite an unknown future (Concorde, political opposition, 1973 first petroleum crisis, etc.) and even if several other existing or new transport modes intended to compete with the classic railway concept, finally SNCF, the French national railway company, started the operation of the first high speed line between Paris to Lyons on 27 September 1981, at a maximum speed of 260 km/h.
The European HSR was born, but in contrast to the Shinkansen concept, the new European HSR was fully compatible with existing railways and this largely conditioned the further development of the system in the Old Continent.

HSR SERVICES SPREADING IN THE WORLD

1981-2009

Once again, after the big success of the TGV, each European country looked for the new generation of competitive long and medium distance passenger rail services, in some cases by developing its new technology and in others by importing.
Joining the group of countries offering high speed rail services in Europe were Italy and Germany in 1988, Spain in 1992, Belgium in 1997, the United Kingdom in 2003 and the Netherlands in 2009.
In the meantime, some similar cases appeared in other countries and regions, such as China in 2003 (even if the big development came later, in 2008), South Korea in 2004, Taiwan Railway High Speed Corporation in 2007 and Turkey in 2009.



FROM YESTERDAY TO TOMORROW THE HSR OF THE FUTURE

2009 AND BEYOND

A new dimension and a new perspective for HSR started in China on 1 August 2008. The 120 km high speed line between Beijing to Tianjin represents just the first step in a huge development to transform the way of travelling for the most populated country in the world. Since 2008, China has implemented almost 20,000 kilometres of new high speed lines and thanks to an enormous fleet of more than 1,500 train sets, carries 800 million passengers per year (2014 and growing), more than the half of the total high speed traffic in the world.
And following the example led by China, new high speed systems are under development around the world: Morocco, Saudi Arabia, USA, etc.
Accordingly with 2015 expectations, and in spite of the development of other transport modes (for example the Maglev, automatic driving cars, improvements in aviation, etc.), by 2030-2035, the extension of the world HSR network could reach more than 80,000 kilometres, representing an important challenge for operators, industry, authorities, etc.
High speed must be continuously developed and performed in order to continue to be present in passenger transport in the next 50 years (or more).

- **1830** – The "Rocket" locomotive by George Stephenson reaches 50 km/h
- **1903** – Siemens & AEG electric railcar obtains 210 km/h
- **1964** – 1st October, the first high speed system in the world, Shinkansen starts in Japan
- **1981** – The TGV, first European high speed train, operates in France at 260 km/h
- **1988** – "Pendolino" in Italy and ICE in Germany
- **1989** – The TGV "Atlantique", first train to operate regularly at 300 km/h
- **1992** – AVE in Spain
- **1997** – High speed in Belgium
- **2003** – HS1 in the United Kingdom
- **2004** – KTX in South Korea
- **2007** – 574.8km/h world speed record in France
- **2007** – Taiwan High Speed Rail Corporation
- **2008** – CRH in China
- **2009** – High speed in the Netherlands and in Turkey
- **2015** – High speed lines in the world extends over almost 30,000 kilometres

HIGH SPEED RAIL PRINCIPLES

1ST PRINCIPLE: HIGH SPEED RAIL IS A SYSTEM

High speed railways are very complex systems which combine the state of the art in many different fields:

- **Infrastructure** (including civil engineering works, track, signalling, power supply and catenary, etc.)
- **Stations** (location, functional design, equipment)
- **Rolling stock** (technology, comfort, design)
- **Operations** (design and planning, control, rules, quality management)
- **Maintenance strategy and corresponding facilities**
- **Financing**
- **Marketing**
- **Management**
- **Legal issues, regulations.**

It is essential that all these components contribute to the quantitative and qualitative global technical performance and commercial attractiveness. None of them is to be neglected neither in itself nor in conjunction with the others. From the customer viewpoint, the true speed is the comparison between the time spent buying a ticket, accessing to and entering the station or waiting for a taxi on arrival, with the door-to-door distance and not only the time saved by using a high speed train as a result of high-level technology and significant investments.

2ND PRINCIPLE: HIGH SPEED RAIL SYSTEMS ARE (EQUAL BUT) DIFFERENT EVERYWHERE

High speed systems depend on how all their components are designed and interact.
The final system obtained (in terms of cost and performances) can be very different from one country to another depending on, among other things, commercial approach, operation criteria and cost management.

3RD PRINCIPLE: HIGH SPEED RAIL SYSTEMS MEANS CAPACITY

Accordingly with the main characteristic of railway, **high speed rail is synonym of capacity and sustainability** and consequently, will be more adequate when more potential demand of traffic will serve. Also, capacity requires accessibility, complementarities and multimodal approach. The coherence in the application of all these three principles is essential in order to obtain the success in the application of this modality of rail transport.

1964 1ST OCTOBER: WORLD'S FIRST HIGH SPEED TRAIN SERVICE FROM TOKYO TO OSAKA

29,792 KM OF HIGH SPEED LINES IN THE WORLD (1 APRIL 2015)

3,603 HIGH SPEED TRAIN SETS IN OPERATION (APRIL 2015)

574.8 KM/H WORLD SPEED RECORD (FRANCE 2007)

320 KM/H MAXIMUM SPEED IN REVENUE OPERATION (APRIL 2015)

1,600 MILLION PASSENGERS PER YEAR CARRIED BY HIGH SPEED TRAINS IN THE WORLD
800 MILLION PASSENGERS PER YEAR IN CHINA
355 MILLION PASSENGERS PER YEAR IN JAPAN
130 MILLION PASSENGERS PER YEAR IN FRANCE
315 MILLION PASSENGERS PER YEAR IN THE REST OF THE WORLD

80% MODAL SPLIT OBTAINED BY HIGH SPEED TRAINS IN RELATION TO AIR TRANSPORT WHEN TRAVEL TIME BY TRAIN IS LESS THAN 2.5 HOURS

TECHNOLOGY REQUIREMENTS

From a strictly technical point of view, operating high speed rail systems require:

- **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, reliability and safety constraints.

- **Special Dedicated Lines**

Conventional lines, even with major up-grades, are unable to allow speeds above 200-220 km/h. The layout parameters (horizontal and vertical profiles as well as other parameters such as the cant), transverse sections, track quality, catenary and power supply, and special environmental conditions must be designed so as to make high operational speeds sustainable.

- **Special Signalling System**

Line side signals are no longer useable above 200 km/h, because they may not always be observed in time by the drivers. In-cab signalling is definitely the solution for high speed operation.

THE POSSIBILITIES OF «CLASSIC RAILWAYS»

Generally speaking, conventional railways can only run trains up to 200-220 km/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 50 km/h, on the same infrastructure.
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. In any case, it is highly important considering the time, cost and trouble necessary to upgrade a classic railway line.

SUSTAINABILITY

AVOID, SHIFT, IMPROVE

There are three primary strategies responding to the challenge of reducing the sustainability impact of transport.

- **The first is 'avoid' where the demand for transport is reduced; such as land-use planning and transport integration in order to enable efficient interconnectivity and reductions in km travelled.**

High speed rail (HSR) does have a part to play to avoid strategies within integrated land use and spatial planning. Reducing local journeys for intercity and international passengers is one of the main functions of rail stations. For instance, in the case of city centre location, compared to airports, HSR allows customers to reduce the needs of urban and local transport once the main journey in the door-to-door chain is completed. In addition, most of the HSR stations are important nodal points in city centres and they serve wider social functions, by offering accessibility to a comprehensive and wide range of services, such as post offices or shopping facilities.

- **The second strategy is 'shift', where journeys are made by lower CO_2 per passenger emitting modes.** HSR advantages in terms of energy consumption and Green House Gas (GHG) emissions compared to competitors are one of the main drivers to reduce carbon footprint in transport sector.

Therefore, moving passengers onto high speed rail from air and road transport can deliver reductions in terms of total CO_2 emissions in the corridor. A study for UIC, which analysed HSR in France and China, concluded that the carbon footprint of HSR can be up to 14 times less carbon intensive than car travel and up to 15 times less than aviation even when measured over the full life-cycle of planning, construction and operation.
The potential for modal shift to rail and consequent CO_2 reductions in the transport market revealed strong potential. In Europe, the Transport White Paper stipulates that the majority of medium-distance passenger transport should be by rail by 2050.

- **The third strategy is to 'improve' the efficiency of existing transport modes.** In this strategy HSR has worked for a long time to reduce energy costs and to keep and improve the energy advantage of rail, more efficient vehicles and infrastructure. An integrated approach to energy consumption provides a synergic frame with a high potential of reduction.

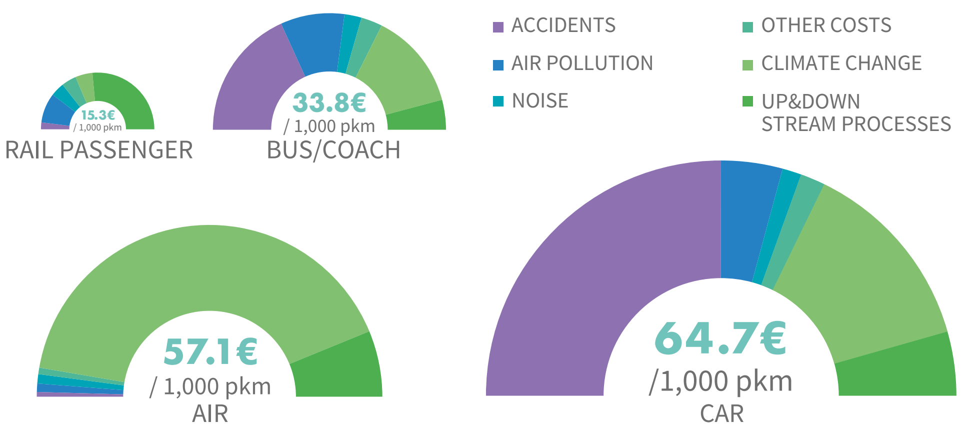
The energy consumption per passenger of high speed trains is usually lower than in existing and slower trains running between the same stations, according to several advantages of the high speed trains such as a more homogeneous speed profile, a new line design with less distance, a lower ancillary service consumption, less mass per seat and smoother trains, more efficient aerodynamic profile, bigger trains, better load factor and more efficient electric system.

EXTERNALITIES

Across the various transport modes, the passenger does not pay the entire cost generated by his trip. He may pay the energy, maintenance (even the possession) of the vehicle costs, as well as the infrastructure and operation costs such as the salary of the crew, etc., but he does not pay the full costs of the damage to the environment and to society generated by his mobility: noise, accidents, air pollution, nature and landscape, climate change, etc.

All these costs are called external costs or externalities (not directly linked to the operations) and usually remain partly uncovered and are either a nuisance or a burden for society as a whole.
Estimation on average externalities in Europe for different modes of transport is regularly updated by UIC and other bodies. These calculations can contribute to at least calculating the actual costs of transport and helping to take adequate decisions.

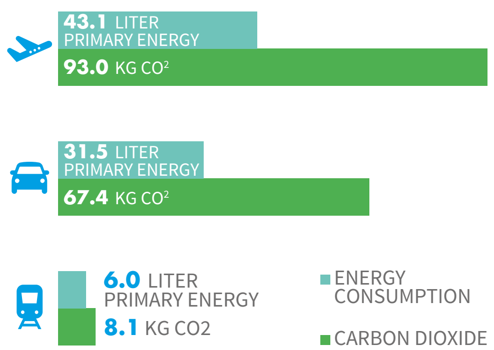
AVERAGE EXTERNAL COSTS 2008 FOR EU



PROVIDING ENVIRONMENTAL INFORMATION

Many passenger high-speed railway operators provide environmental comparison information on their website and tickets. In Italy, FS - Trenitalia prints a comparison of average CO_2 emitted for the same journey by train, car and plane on its long-distance tickets. The UIC EcoPassenger website provides potential travellers with an environmental footprint calculation for international rail journeys in Europe (www.ecopassenger.org), compared to the main competitor modes (plane and car) and showing customers of the main rail services the advantages in terms of CO_2 emissions.

CARBON DIOXIDE & ENERGY RESOURCE CONSUMPTION, FROM MADRID TO BARCELONA



RENEWABLE ENERGIES IN HIGH SPEED RAIL OPERATION

HSR, as a 100% electrified rail system is immediately compatible with renewable energies without further technological improvements. Nowadays, HSR is the unique mode consuming renewable energies in a relevant share in the intercity and long-distance transport market.

Decarbonisation of electricity mix is the main driver in reducing CO_2 emissions: the higher the percentage of electricity from renewable sources is used for traction in transport, the lower the CO_2 emissions produced.

One of the advantages of the use of electricity is the possibility for HSR undertakings to easily resort (in comparison with other transport modes) to the main forms of use of renewable energy such as on site renewable power plants or by the purchasing of Green Certificates through the procurement of Renewable Energy Certificates (GO or REC), market tools defined by European Directives, promoting the investment in green energies power plants.

In this frame with the aim of increasing the share of renewable electricity, some rail companies have started recently to procure "green electricity". Just as an example, Scandinavia, Switzerland, and Austria owns entire rail networks in where the electricity used is almost entirely carbon free. Accordingly with a contract signed, by 2018 Dutch railways will get all energy from renewable energy sources.

A GOOD EXAMPLE OF FRIENDSHIP BETWEEN HSR AND THE ENVIRONMENT

Some HSR infrastructure and services produce and consume their own renewable energy. An innovative example is the Schoten Rail Tunnel in Belgium, primarily designed for the protection of wildlife in a forest area and to reduce noise from the rail and highway. There, the infrastructure manager Infrabel installed 16 000 solar panels on the roof of the railway tunnel of the high speed line Antwerp – Amsterdam, covering a total length of 3.4 kilometres on an overall surface of 50,000 m² (approximately 8 football pitches), with a total installed power of nearly 4 MW and generating each year 3.3 GWh of electricity.

The energy is used to power both fixed infrastructure (e.g. railway stations, lighting, heating and signaling) and the traction of trains. The electricity produced by the solar panels feed about 4,000 trains per year. The equivalent of a full day's worth of Belgian rail traffic will be able to run entirely on solar power generated by the installation.

COMBINING CARBON OFFSET AND MODAL SHIFT IN THE CALIFORNIA HIGH SPEED LINE

A free project carbon has been developed on the new California high speed line. The project will have an impact in terms of GHG emissions of 170,000 CO_2 tons. But once the rail project will be concluded the high speed line will reduce GHG emissions by 520,000 tons through carbon offset by planting 4,600 trees and donating 20 million US dollars for the replacement of old school buses.

In addition, the modal shift will reduce the corridor's carbon footprint. Calculations of the California High-Speed Rail Authority show that including all the carbon correction measures for high speed line, planes produces 57 times more GHG pollution, and cars 43 times more.

REPORTS, FACTS AND FIGURES ON SUSTAINABILITY FOR RAILWAYS

UIC reports on "High speed rail and Sustainability" and "Carbon Footprint of high speed rail" can be found on the UIC-High Speed website: **www.uic.org/highspeed**.

UIC and IEA report on "Energy consumption and CO_2 emissions 2014" can be found on the UIC-High Speed website: **http://www.uic.org/IMG/pdf/iea-uic_railway_handbook_2014_web.pdf**.

Updated average externalities in Europe for different modes of transport (CEDelft, Infras, Fraunhofer ISI, November 2011,) can be found at: **http://ecocalc-test.ecotransit.org/CE_Delft_4215_External_Costs_of_Transport_in_Europe_def.pdf**.

INFRASTRUCTURE

SPECIFIC NEEDS OF HIGH SPEED DEVELOPMENT

The world network of high-performance railway is dramatically increasing.

- **High speed rail infrastructure** must be designed, inspected and maintained in optimum quality conditions
- **Layout** requires large radius curves and limited gradients and broad 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.

TRACK FORM OPTIONS SUITABILITY ASSESSMENT GUIDE

Technological progress has been very intense on the track field for decades. Under a continued evolution trend, the ballasted track has been largely improving its efficiency. In parallel, new solutions without the ballast as a component have appeared as new technical options.

As a result of this innovation process there are currently a number of available alternative track forms to be implemented on future construction of High Speed lines. Each of them with or without ballast as component presents similar performance levels from the point of view of passenger trains operation. However they show significant differences from an economic perspective. The balance for a long-term view not only the capital costs but the maintenance and materials renewal costs, have to be considered. Selecting the most suitable track form for a particular new line is a complex task as it involves a wide number of variables that have to be taken into account from a long-term perspective.

The most relevant of them can be classified into:

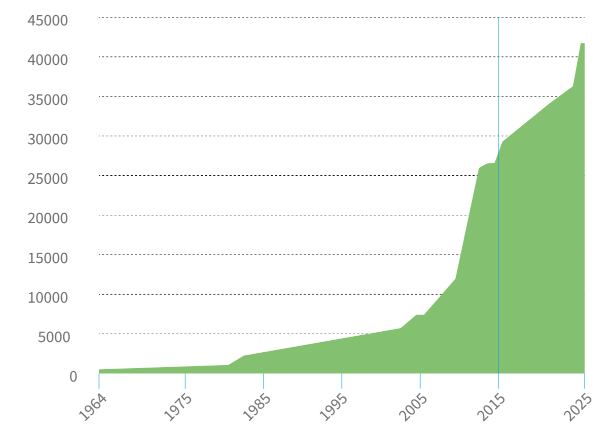
- **Functional/operational conditions:** traffic characteristics, track possession availability, operational conditions evolution, combination of different types of tracks, …
- **Infrastructure technical features:** viaducts, tunnels and earthworks sizes, track geometry stability requirements, geotechnical local features, …
- **Environmental conditions:** noise emissions levels, vibrations emissions levels, CO_2 footprint,…

All of them need to be analysed to provide a robust support to the decision process.

The purpose of this guide is to provide a methodology to rationally assess the most suitable track typology for a line under study considering all the parameters involved. Some of these parameters are intrinsic to the track characteristics but some others are related to particular features of the line and the local conditions where it´s located. All of them together have to be analysed systematically in the frame of the line life cycle cost approach.

UIC report on "Track technical options" on the UIC-High Speed website: **www.uic.org/highspeed**.

DEVELOPMENT OF THE WORLD HIGH SPEED NETWORK



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 freight and passenger traffic:** up to 12/15mm/m
- **Track centre distance:**
  For 200km/h: 4m
  For 300km/h: 4.5/5m
- **Maximum cant:**
  150/170mm
- **Minimum curve radius:**

Minimum	Ideal	Recommended
200km/h	2,500m	3,500m
300km/h	5,500m	7,000m

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. Technological current limit: maximum speed on deviated track is 220 km/h
- **Electrification:** Single phase. The most common voltages are 25kV, 50 or 60Hz or 15kV, 16 2/3Hz
- **Signalling, communications and other fix equipments:** 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 trainsets in operation for a single line depends on the level of the expected demand and offer, 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 quantity and quality of trains to be produced and the corresponding technological developments to be achieved so as to fit with the service to provide in terms of both quality and quantity.
So far manufacture and maintenance of rolling stock were often activities handled by separate actors. However, **partnerships between industrial bodies and operators for manufacturing and maintaining high speed trains have already been successfully experimented.**

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 300 km/h)
- **High traction power** (approx. 11 to 24kW per ton)
- **Power electronic equipment**: GTO, IGBT > **Control circuits. Computer network. Automatic diagnostic system**
- **Optimised aerodynamic shape**
- **In-cab signalling system/s**
- **Several complementary braking systems**
- **Improved commercial performances**
- **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**
- **Dual power trains** (electric and diesel engines).

ROLLING STOCK MAINTENANCE

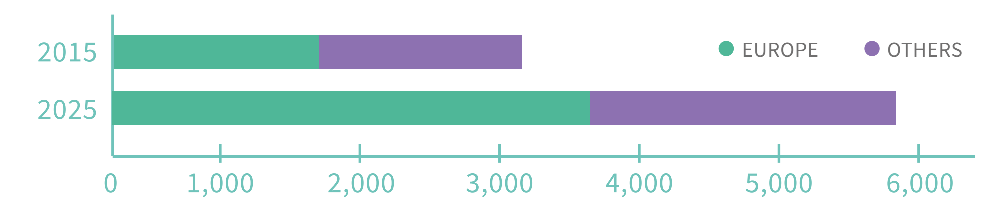
Maintenance on high speed rolling stock is essential to guarantee the safety and reliability of the entire system.

- **Fixed inspection time interval** for preventive maintenance is broadly applied
- **Several graded maintenance levels**, from daily inspection to overhaul, are planned according to various steps of use.

FORECAST FOR THE NUMBER OF TRAINSETS IN 2025

The total number of trainsets required to operate on ahigh speed line is highly variable, depending of the level of total and stationary traffic, type and density of services, type and size of trains and possible operation also on conventional lines.
Just as a magnitude, an average of 13 to 15 trainsets per 100 kilometres can be considered as reasonable.
Taking into account these figures and the expectations for the evolution of the world network on high speed, an estimation of the global market in the near future could be as shown in the appended graphic.
In 2015, more than 3,600 high speed train sets (able to circulate at least at 250km/h) were in operation across the world :

ASIA **2,095**
OTHERS **20**
EUROPE **1,488**
TOTAL **3,603**



The time necessary to design and test a new high speed train (new technical development, incorporation of innovations, design)can be estimated at 3 to 5 years for the development of the technology and 2 to 5 years for test and approval.

14 NUMBER OF HIGH SPEED ROLLING STOCK MANUFACTURERS IN THE WORLD

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**
- **Compatibility with maintenance, upgrade and repair works.**

The maintenance and renewal of all the components and their interfaces involved in a high speed system is essential to ensure the main operational parameters at the optimum level, at any moment and under any condition. Monitoring, inspection, current maintenance and major renewal must be compatible with current operations.

SOME MAGNITUDES TO REALISE WHAT OPERATION ON HIGH SPEED LINES REQUIRES

MAGNITUDE OF USUAL BRAKING DISTANCE

FROM 200 KMH/ TO 0
1,900 M

FROM 250 KMH/ TO 0
3,100 M

FROM 300 KMH/ TO 0
4,700 M

FROM 320 KMH/ TO 0
5,800 M

FROM 350 KMH/ TO 0
6,700 M

OPERATING AT 300 KM/H

1 KM: 12 SEC
5 KM: 1 MN

HEADWAY 5 MINUTES AT 300 KM/H

25 KM

DISTANCE TO ACCELERATE FROM 0 TO 300 KM/H :

10-20 KM/H

OPTIMUM SPEED OPERATING ANY HIGH SPEED LINE

- **Concept**

A constant feature in the world of transport is the desire of passengers to arrive earlier (accordingly with the idea of the increased value of time). From the point of view of the operators, going faster and faster means being more competitive.

The process of increased speed in all modes has led, however, in each of them to a situation of stabilising around a level at which they become stuck permanently, or at least for a long period of time until a trend breaking technological leap forward occurs. This level around which speed stabilises in a unanimous process is **the optimum speed for each transport mode.**

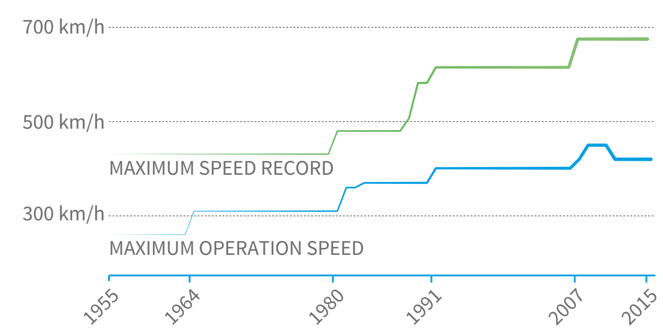
Due to several reasons, all long-distance passenger transport modes have maximum operating speeds stabilised over years that correspond to the optimum speed of each system (120 km/h in the case of the routes and around 900 km/h in the case of the aviation). The railway is the exception because the maximum operating speed continues to increase as technological improvements arise.

The maximum operating speeds for high speed rail has increased steadily since the 1960's and continues to increase today. The «the optimum speed of the system» is not yet reached but some limits are imposed by physical phenomena, technological barriers or criteria of a social nature.

After analysing the various phenomena surrounding train operations at increasing speeds and according to experts, it is considered that the main factor with regard to limiting speed increases is of aerodynamic origin, with its associated noise component. Factors overlapping between line geometry requirements, rolling stock restrictions, growing needs for acoustic attenuation measurements and the aerodynamic phenomenon, point to the optimum speed in the high speed system appearing in the 500-550 km/h range.

This optimum speed of the system is close to the record speeds achieved to date for the two families of railway technologies - wheel-rail running and magnetic levitation - which have reached 570 km/h and 600 km/h.

MAXIMUM SPEED IN OPERATION



WORLD SPEED RECORD

574.8 KM/H

On 3 April 2007, the world speed record for rail transport was set at 574.8 km/h by a special TGV train on the French TGV East high speed line.

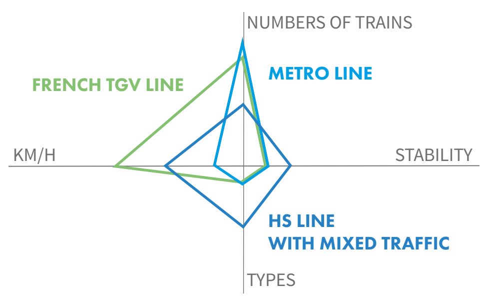
MAXIMUM DENSITY OF OPERATION

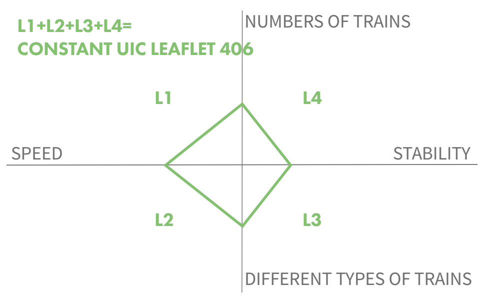
15 TRAINS/HOURS

CAPACITY

The maximum capacity conditions in the operation of any railway line is obtained when all the trains operate under similar conditions, at the same maximum speed and stopping at the same places. These conditions are not always the case on mostly of high speed lines and consequently analysing the conditions converging to **the capacity**, one of the main characteristics of railways, is essential.

Balancing capacity when operating in mixed traffic needs considering four basic parameters: number of trains per hour, maximum speed, number of different types of trains and regularity, this measured in terms of “stability” (the impact of one minute of delay in one train, to the rest of the trains).





TRAFFIC MANAGEMENT

- **Missions of control - command centre :**
  - **Operational time table**
  - **Real time calculation** of difference between scheduled/actual times
  - **Display as distance/time graph or station survey.**
- **Also controlling:**
  - **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.**

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 any other trains/vehicles/obstacles.
- **Means:** automatic systems, manual procedures, specific rules or a combination of the above.

SIGNALLING SYSTEMS

Operating any high speed line requires a special signalling system, incorporating, among other characteristics, onboard signalling devices. Many different systems exist at the present moment.

Europe ERTMS (European Rail Traffic Management System) In fact, ERTMS is a full management system, composed by:

- **ECTS** (European Train Control System)
- **GSM-R** (Global System for Mobile Communications - Railways)
- **TRAFFIC MANAGEMENT LAYER** (and Automatic Centralised Traffic Control)

ERTMS was created to reach seven main goals for :

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

ETCS exists on levels I, II and III (not yet in revenue operation).

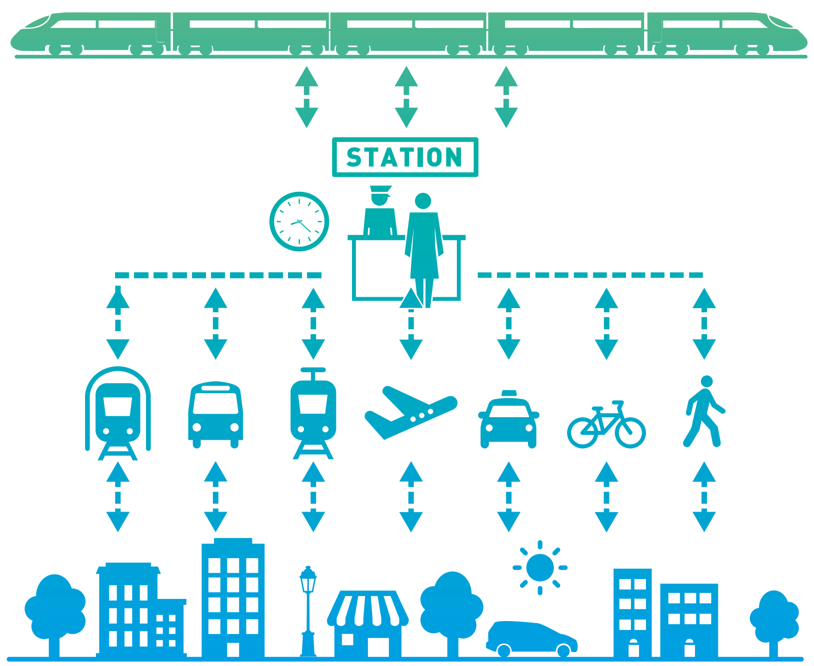
- **Japan ATC (Automatic Train Control)**

- **China CTCS (Chinese Train Control System)**

SAFETY RECORD

No fatal accidents at more than 200 km/h on high speed lines since the beginning of high speed history.

STRATEGIC VALUE OF STATIONS



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

● **Their location has to be optimised** so as to take advantage of the reduced travel times. They also have to be well connected to airports, mass transit and light systems as well as to private transport.

● In the big cities or big urban areas, the criteria for having one or more stations and the exact emplacement, must take into consideration the requirements of the city, the citizens and their intermodality and accessibility, as well as the technical constraints of the railway system in itself.

● **A preliminary functional design factoring the result of marketing surveys is absolutely essential.** In addition, in house no rail business activities are a common feature of high speed stations, due to the important volume of customers visiting daily.

HIGH SPEED ALSO MEANS HIGH CAPACITY

Having capacity as a basic characteristic of high speed, stations are expected to handle high traffic volume. “Volume” must be understood in terms of trains, customers, private cars, taxis, and public transport means.

Commercial operations in stations require information, ticketing, vending, in some cases access controlling, after travel services, etc. These operations must be planned and calculated by thinking in the functionality of the services: volume of passengers, high value-add for the travel, accessibility and its coherence with the reduction of time travel, etc.
Most often, stations and their nearby surroundings are the place where railway operators do certain operations: replacing crews, cleaning and inspecting trains, water refilling, turning around seats, refurbish catering, etc.
These industrial activities usually share the available (reduced) space with passenger’s flows. Planning what, where, why and who is to do these operations will be an essential input for the functional design of any high speed station. And, if possible, removing these activities out of the big terminals and out of the city centres where land is at a lower cost may be a good economic and land use policy, as well as an optimisation of the quality of operations and service.

Finally the fundamental values of railways applied in stations (environment, energy, safety, security, civil protection, etc.) are to be taken into account accordingly with the volume and characteristics of the traffic.

ARCHITECTURE AND URBANISM

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.

In high speed stations, the **governance** (this means, “who decides what”) and the **financial approach** (this means “who pays, who finances, who does what”) are essential concepts.

“High speed and the City 1 & 2”, are two UIC studies on benchmarking on the relationship of several big cities and their respective high speed and transit system. Available on the UIC high speed website: **www.uic.org/highspeed**

DESIGN CONCEPTS FOR HIGH SPEED SERVICES

At the beginning of this brochure, it says that the "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 components. 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".

But **all these elements are compiled and coordinated just for one objective: transporting passengers.** Consequently, this is the main focus to keep in mind at any stage of the process to build or operate any high speed system

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 CUSTOMERS

- **Commercial speed**
- **Frequency**
- **Accessibility**
- **Comfort**
- **Attractive travel time** (door-to-door)
- **Reliability**
- **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.

PRICING SYSTEMS

High speed railway undertakings increasingly use variable prices for different types of service. Depending on travel purposes (business or private), travel periods or other circumstances influencing demand, including the conditions of purchase, the loyalty and the risk taken (possibility to be refunded in case of a change, prices can vary considerably).

Various procedures, some imported from the airlines like "yield management" (which aims to maximise the income per train, when reservation is mandatory for all trains), widespread use of Internet, for information and dematerialisation of tickets as well as the introduction of innovative ideas (like iD TGV and Ouigo 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 ticket purchase.

MARKET SHARE

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

Traffic growth can be boosted by mobility gains and shifts from other transport modes. Increasing the rail network also contributes to traffic expansion. The "network effect" is such that the passenger traffic can grow proportionally more than the total length of the network.

DESIGN FOR CUSTOMERS

New customer requirements require 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 expected.

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

THE COST OF HIGH SPEED RAIL SYSTEM

FUNDING/CALCULATION COSTS

High speed requires **significant investment** requiring public funding. Consequently, **detailed studies** traffic forecasts, costs and benefits encompassing all the positive and negative impacts of a project, including in comparison with the doing nothing scenario are needed.

- The cost 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**
- 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 funds obtains Return On Investment (ROI)
- Public funds ensures social benefits.

(see external costs page 9)

Several UIC studies on “Infracharges” and report on “Relationship between rail service operating direct costs and speed” are available on the UIC-High Speed website: www.uic.org/highspeed

MAGNITUDE OF COSTS OF HIGH SPEED SYSTEMS

Average costs in Europe

€ 15-40 M	CONSTRUCTION OF 1 KM OF NEW HIGH SPEED LINE
€ 90,000	MAINTENANCE OF 1 KM OF NEW HIGH SPEED LINE (PER YEAR)
€ 30-35 M	COST OF A HIGH SPEED TRAIN (350 PLACES)
€ 1 M PER YEAR	MAINTENANCE OF A HIGH SPEED TRAIN (2€/KM-500,000 KM/TRAIN & YEAR)

KEY ELEMENTS TO REDUCE COSTS

OPTIMAL HIGH SPEED RAIL SYSTEM, fed by:

- KNOWLEDGE OF HIGH SPEED SYSTEMS & ELEMENTS
- MARKET PROCEDURES
- DEFINITION OF MAX SPEED & PERFORMANCE
- STANDARDISATION
- FINANCING

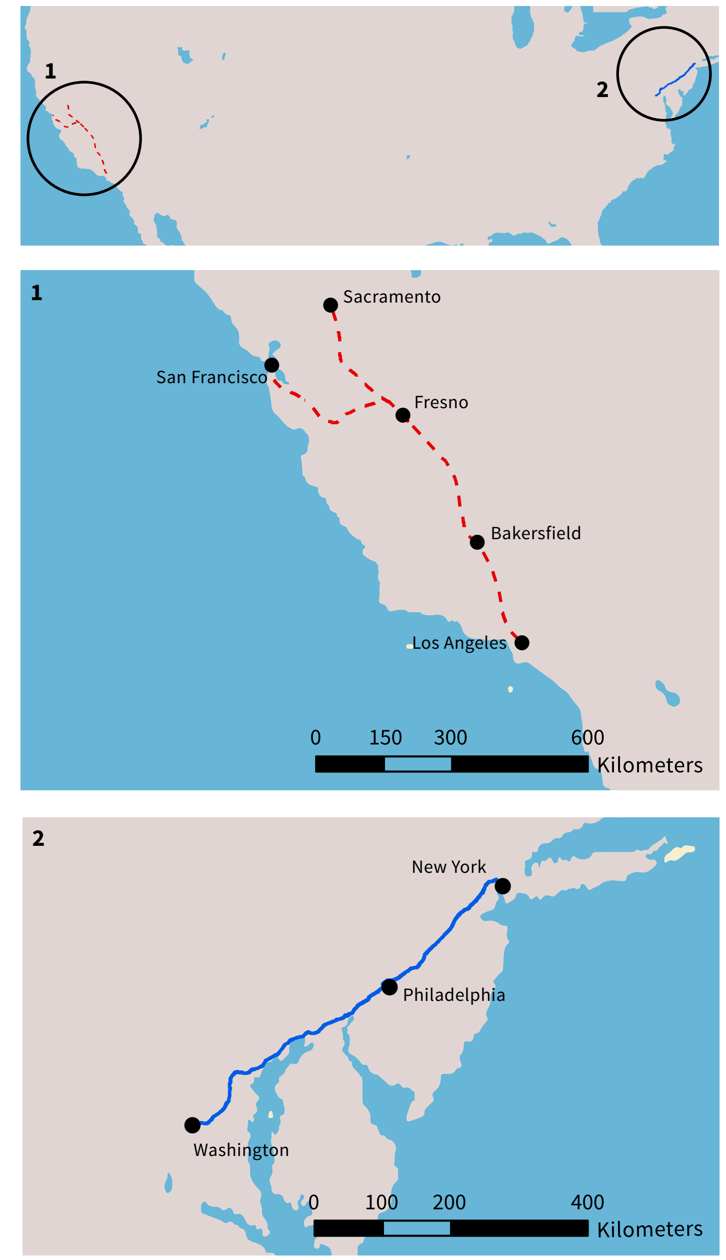
HIGH SPEED SYSTEM IN THE WORLD

EUROPEAN AREA

ASIA


Ürümqi
Lanzhou
Harbin
Changchun
Shenyang
Hohhot
Beijing
Tianjin
Shijiazhuang
Taiyuan
Jinan
Zhengzhou
Xi'an
Nanjing
Hefei
Shanghai
Hangzhou
Wuhan
Chengdu
Chongqing
Nanchang
Changsha
Guiyang
Kunming
Fuzhou
Taipei
Kaohsiung
Nanning
Guangzhou
Haikou
Seoul
Gwangju
Busan
Sapporo
Hakodate-Hokuto
Shin-Aomori
Morioka
Sendai
Niigata
Kanazawa
Tsuruga
Tokyo
Nagoya
Osaka
Fukuoka
Nagasaki
Kagoshima
Medina
Jeddah
Mecca
0 75 150 300
Kilometers
Legend
Commercial operation over 250 km/h
Under Construction or planned over 250 km/h
Commercial operation less 250 km/h
Under Construction or planned less 250km/h
Input UIC Members
0 300 600 1200
Kilometers

USA


1
2
1
Sacramento
San Francisco
Fresno
Bakersfield
Los Angeles
0 150 300 600
Kilometers
2
New York
Philadelphia
Washington
0 100 200 400
Kilometers

COMPREHENSIVE PROTECTION

High speed rail related people (customers, workers, outsiders) equipment and premises in particular need protection.
The high volume of passengers carried and their expectations as customers (they expect a high level quality of service), the number of staff involved, the value of the required investments, in both infrastructure and rolling stock, the operation speed, much higher than other transport modes, the operational performance, etc., makes it necessary to consider protection against any kind of risk. Customers and business partners are confident in how the railway is run and what is being done to secure the railways. This is the origin of the concept of "Comprehensive protection" for high speed rail systems, which is the addition of safety, security, civil defence and natural risk protection. Even if in certain languages there is no difference between them, **there is a big difference between the concepts of "safety" and "security".**

SAFETY & SECURITY

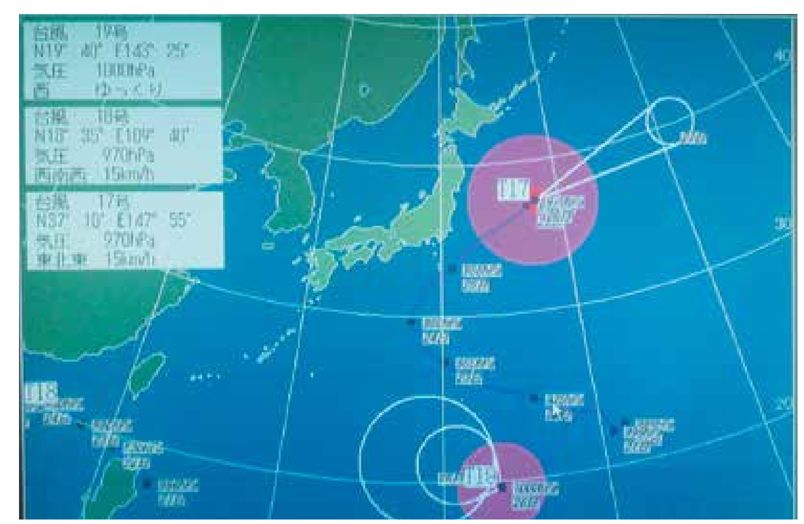
Safety is the protection against "technical" failures and can be related with many different elements (signalling, operations, maintenance quality, training, etc.). The protection is an almost exclusive responsibility of railway companies and is independent of any human desire (even in the most negligent behaviour, nobody wants a derailment). Statistic and historical series can be established and through assessing and managing the inherent railway system risks it is possible to ensure that the rail transport system is safe and reliable.

In contrast to the previous concept, **security is the protection against any kind of attack or malicious intent**, from graffiti to robbery, vandalism or terrorist acts. These acts correspond to someone's will and must be coordinated by authorities. As these are unpredictable, it is not always useful to look at statistics or historical records. Security events affect the population and have a heavy impact on governments, regulating bodies, etc.
Security management must go beyond the most obvious of scenarios and a true understanding of the cultural, social and economic environment where railways are implemented and operating, is the first step towards the high speed rail comprehensive protection and the consequent consideration as an attractive mode of transport.
In order to ensure the civil defence and the resilience of railway systems, the role of emergency services and crisis management is essential, with the aim of mitigating the consequences.
To complete the previous protection concepts, it is necessary consider that rail transport is vulnerable in the face of natural disasters, extreme climate conditions and particular geographic situations. A significant part of high speed lines in the world are subject to strong weather conditions and the impacts on the railway systems and the operation can be numerous.
Advanced technologies allow some situations to be anticipated and to propose some tools to eliminate or just limit the risks generated by the environment.
In any case, **the first step in order to ensure the protection is to identify, for each risk, the potential dangerous events that could happen**, involving just one of the subsystems integrating the entire railway system (track, catenary, equipment, substations, signalling and telecommunications), or a combination of several of them.

UIC study on "Extreme natural conditions for high speed systems" is available on the UIC-High Speed website: www.uic.org/highspeed

The second step is to identify, for each potential event, the existing measures that deal with the effects (prediction of effects, detection and forecast measures, prevention of effects during the operation, eventually mitigation by fixed measures and eventually curative measures when the potential event occurred.

Beyond certain thresholds, natural risks are:
- High temperature
- Low temperature
- Snow
- Frost
- Change of humidity or high humidity
- Strong sunshine
- Strong wind
- Sand and dust
- Heavy rain
- Flood
- Thunderstorms
- Embankment collapse
- Fallen rocks
- Seismic events
- Slope fire
- Fog smoke
- Fallen leaves



STANDARDS FOR HIGH SPEED RAIL SYSTEMS

High speed rail standards improve the system integration of the railway services and contribute to achieving the necessary interoperability.

The UIC High Speed specific standards are focus on the coordination of sets of documents addressed to standardise the pre-competitive items of a railway application.

For a given railway application (e.g. High Speed) the standards consider the level of service requested, the boundary conditions, the expected functionalities and the KPIs together to the complete sets of standards so allowing immediate spendable solutions and confirmations from the market.

IRS, International Railway Standards, High Speed Cluster, are currently under preparation by UIC. Information on the UIC website: www.uic.org

RESEARCH & DEVELOPMENT

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

- **Business & technical management**
Development-procurement-approval-deployment, LCC*, RAMS*, standardisation and modularity, etc.

- **Basic dimension & 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**
CO_2 , other gas, and energy, EMC*, noise, LCA*, extreme climate.

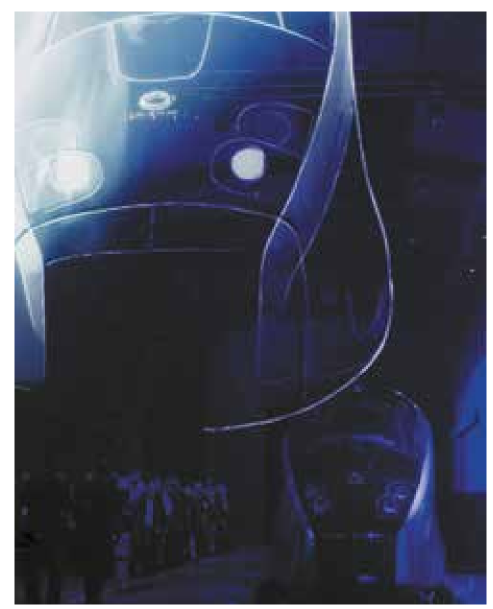
- **Aerodynamics**
Aerodynamic resistance, tunnel micro-pressure wave, flying ballast.

- **Comfort**
Ride comfort, noise abatement, tilting system, airtight structure, air conditioning, passenger service.

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

- **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.



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

TECHNOLOGY FOR THE FUTURE

TODAY'S TECHNOLOGY IS FULLY COMPETITIVE

However it will not continue to be competitive beyond the next 20 years without investments in research and development, because the other transport modes are quickly evolving and compete more strongly with high speed rail.
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 IMPROVEMENTS IN:

- Higher commercial speeds
  - Maximum speeds in the range of 320 -360km/h
  - More availability of 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 rows of seats)
- 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

HIGH SPEED RAIL AT UIC

UIC aims to support its members in various ways. More particularly, its High Speed Committee regularly conducts studies and researches requested by one or several members. All of them are posted on the UIC extranet and are access free. All such works cannot be listed here, however some of them clearly illustrate their typology.

EXCHANGE OF BEST PRACTICES

Operating high speed and conventional trains under difficult natural conditions is a topical issue since the climate warming increases the frequency of peaks in temperature, strengths
of wind, volumes of snow, numbers and gravity of floods, in addition to natural disasters such as earthquakes, typhoons, etc.

- **The "Operations under extreme natural conditions" report lists such kind of events and for each one establishes, according to the various practices of Railway Undertakings and Infrastructure Managers:**
  - Their definition (speed thresholds above which a wind is considered as dangerous, for example) and the frequency of their occurrence
  - The prevention measures to be taken at the design stage (for example, erection of wind screens)
  - The detection means to be provided so as to detect when they begin (for example, anemometers)
  - The simulation models helping to forecast the time, the width and the strength of the event
  - The prevention operation measures to be taken during the event itself (for example, temporary speed reduction)
  - The mitigation measures aiming to mitigate the damages.
- **About 20 different events are considered:** cross winds, very low and very high temperatures, snow, rainfall, floods, typhoons, earthquakes, sand gusts, fires, etc.
- **Manuals also enter this category. Two of them are worth quoting:**
  - Construction of a high speed line
  - Upgrading a conventional line.

Both documents are organised in a very pedagogic way, step by step, from the first idea to the commissioning of the construction or modernisation works. At each stage, the stakeholders are identified as well as what is at stake for them, so as to understand how best to steer the project.

SURVEYS

UIC has conducted a very broad survey in Europe in order to provide its members with **a fair comparison of rail and air transport modes in terms of prices for the customers.** This study shows evidence that in more than 80% of cases, characterised by the purpose of the journey, the group size, the booking anticipation, the OD pair, etc., the train is significantly cheaper. The savings made by the customer when choosing the high speed train is calculated. This survey also encompasses buses as a third mode competing with rail and air. This last mode proves to be cheaper than the train but it offer longer travel times. This survey will be extended so as to give examples of how air companies react to the creation of a high speed line, in terms of fare policy.
Another survey in Europe has been conducted about the level of track access charges both on domestic and international routes. This survey has been made 3 times over a 7-year period. The adopted methodology has been established so as an objective comparison by considering the same train running on the 100 selected routes at the same hours. The five main conclusions are:

- There is no common philosophy for settling track access charges between the Europe Member States
- There is no consistency in the various calculation methods: the marginal costs of one country may be higher than the full cost in another country
- Over the years, most of the countries change their access rules, and generally increase their levels
- Over the years the gap between the countries is widening.
- It is impossible to predict the level of track access charges two years in advance, for trains on domestic and even more on international routes.

The report also gives an insight of track access charges policies in countries outside Europe.

BENCHMARKS

The so-called **"High speed and the City"** study, is typical of the benchmarks carried out so far by UIC. The report has selected, in a first phase, a dozen stations served by high speed trains.
Each station is seen from four viewpoints corresponding to:

- The city (its mayor)
- The Infrastructure Manager
- The Railway Undertakings
- The customer

Much information is provided about the network configuration, access to the station by private car or public transport, services delivered to the customer, track capacity, etc.
Another interesting and typical benchmark, anonymously carried out, is about ***"Key Performance Indicators"*** of companies operating high speed trains.

RESEARCH

Many UIC members do not have the necessary resources and data to carry out research. One of them, for example, is about the **"Optimal Speed for High Speed Trains"**. Another deals with the **"Comparison of Ballasted and Slab tracks",** aiming to help make a choice between them, based on the geographic context.
Other research aims to:

- Measure the impact on the environment of high speed rail. One of them deals with the **"carbon balances"** of high speed rail,
- Compare, from an economic viewpoint, **the do-nothing, upgrading conventional tracks, building a high speed line and at last creating a link using new technology (such as magnetic levitation) scenarios.**

DATABASES

Most of the statistics illustrating this brochure come from UIC databases. Two databases are worth mentioning because they are unique worldwide:

- **List of all high speed lines** with the corresponding characteristics; an atlas of the high speed network is based on this database and provides a good location of these lines.
- **List of high speed rolling stock** owned by the high speed operators across the world.

WORKSHOPS (some examples):
Daejeon (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), Philadelphia (2012), Tockyo (2015).

TRAINING ON HIGH SPEED SYSTEMS:
UIC member 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, in two levels.

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unity, solidarity, universality

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