A resource book on

High Speed Rail Technology

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Government of India
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FOREWORD

High-speed rail (HSR) brings clear and significant economic benefits to the communities they serve not only in terms of rise in GDP, but also in terms of its environmental impact. HSR uses much less energy per mile than auto or air travel. HSR transit is thus quickly gaining popularity as a key alternative in transportation policy planning. HSR also presents significant technological challenges as it requires synergy amongst a number of engineering disciplines.

It is heartening to see the book "*High Speed Rail Technology*" by Mr. Gaurav Agarwal, Director(E&R)/ME, Railway Board which is a sincere effort towards collating all the relevant information relating to HSR at one place. The book shall serve as a valuable reference point to the Research & Design staff of RDSO, Railwaymen, Research scholars, etc. who can use it as a launching pad for further exploration in the field of HSR.

(V. RAMACHANDRAN)
Director General

Dated: 05.05.2011

Government of India
Ministry of Railways
(Research, Design & Standards Organisation, Lucknow)

FOREWORD

Every major industrialized nation has recognized that high-speed rail is the key to economic growth and mobility. Indian Railways also needs to look ahead and plan for a new future with High Speed Rail (HSR). HSR clearly has the potential to unlock an immense hidden value considering IR's vast network and the desire of people to commute at a faster pace. The Vision 2020 document of Indian Railways also envisages the implementation of regional high-speed rail projects to provide services at 250-350 KMPH. HSR represents the kind of long-term infrastructure investment that will pay back in multiple ways for decades. It will not only change the way we travel but will also change the way we work and live.

The book titled-"*High Speed Rail Technology*" that has been compiled by Mr. Gaurav Agarwal, Director, Efficiency & Research(ME) covers all the important aspects of HSR including a brief history, design issues and a comparison of high speed rail development in various parts of the world. I am sure it would be of immense value to the railwaymen, research scholars and everyone who is interested in this field as they can use the book as a source of information and ready-reckoner for HSR.

Rajesh

(RAJESH KUMAR)
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Date: 05.05.2011

Government of India
Ministry of Railways
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Prologue

Modern society is gripped with many transportation challenges in the form of traffic congestion, long delays for commuters between destinations, and increasing pollution. Existing transportation schemes are not proving adequate to address these challenges. High Speed Rails (HSR) provide a viable solution to the transportation and economic needs of the country.

International technology in HSR is undergoing rapid transformation. Ranging from the wheel based solutions of TGV(SNCF) of France, Shinkansen of Japan, CRH of China to the alternative models of the HS tilting train of UK and the radically different solution of Maglev in Japan and China, HSR technology and models have undergone generational changes in just a few years. With our society aiming at greater efficiency, speed and productivity, and the constraints of time and space being conquered in all aspects of our lives, HSR is shaping to be the transportation solution of the future.

While researching some technological aspects of HSR, I found that the information relating to this subject, although available at various locations (print as well as electronic), is scattered and incoherent. This book is simply an effort to compile all the available information on HSR at one place.

Every effort has been taken to cover all the fundamental aspects of high speed rail technology, in preparation of this book. However, there is always scope of improvement. Any suggestion for the betterment of this book is welcome and may be sent at the email ID: gauravagar@yahoo.com

The assistance provided by Shri Hitesh Goswami and Shri Sunil Prabhat of the E&R Directorate of Railway Board in preparation of book is also appreciated.

गौरव

(Gaurav Agarwal)
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Date: 05.05.2011

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Chapter- 1

WHAT IS HIGH SPEED RAIL?

High speed rail (HSR) is a type of passenger rail transport that operates significantly faster than the normal speed of rail traffic.

The use of the term "maximum speed" in the context of High Speed Rail has many meanings. It can reflect:

- Maximum average speed between two scheduled stops based on the running times in timetables - daily operation.
- Maximum speed at which a train is allowed to run safely as set by law or policy on a straight section in daily service with minimal constraints.
- The maximum speed at which an unmodified train is proved to be capable of running
- The maximum speed at which a specially modified train is proved to be capable of running.

Although, there is no internationally agreed definition of HSR, yet, HSR can be defined as:

- Intercity or inter regional travel at > 250KMPH, typically 300 to 350 KMPH.
- High frequency; capacity 10 trains per hour per direction.
- High density; 500-750 seats per train.

EC Directive 96/58 defines high speed rail as a system of rolling stock and infrastructure which regularly operates at or above 250KMPH on new tracks or 200 KMPH on existing tracks.

A definitive aspect of high speed rail is the use of continuous welded rail which reduces track vibrations and discrepancies between rail segments, enough to allow trains to pass at speeds in excess of 200 km/h (120 mph). Depending on design speed, banking and the forces deemed acceptable to the passengers, curves radius is above 4.5 kilometers and for lines capable for 350 km/h running, typically at 7 to 9 kilometers.

The U.S. definition of a minimum speed for high-speed rail is at a lower figure than that used in Europe of 200 km/h (120 mph). The Federal Railroad Administration (FRA) defines "high-speed rail" in three different ways:

- **High-Speed Rail – Express:** Frequent, express service between major populations centres 200–600 miles (320–965 km) apart, with few intermediate stops. Top speeds of at least 150 mph (240 km/h) on completely grade-separated, dedicated rights-of-way (with the possible exception of some shared track in terminal areas). Intended to relieve air and highway capacity constraints.
- **High-Speed Rail – Regional:** Relatively frequent service between major and moderate population centres 100–500 miles (160–800 km) apart, with some intermediate stops. Top speeds of 110–150 mph (177–240 km/h), grade-separated, with some dedicated and some shared track (using positive train control technology). Intended to relieve highway and, to some extent, air capacity constraints.
- **Emerging High-Speed Rail:** Developing corridors of 100–500 miles (160–800 km), with strong potential for future HSR Regional and/or Express service. Top speeds of up to 90–110 mph (145–177 km/h) on primarily shared track (eventually using positive train control technology), with advanced grade crossing protection or separation. Intended to develop the passenger rail market, and provide some relief to other modes.

Common characteristics of HSR:

- New or substantially upgraded infra-structure.
- Wide minimum track radiuses to allow high speeds, curves often exceed a 5 Km radius.
- Wide spacing between tracks to reduce air-pressure between passing trains.
- No level crossings.

- Standard Gauge rail technology
- Continuous welded rail.

- Electrical driven via overhead lines.
- In-cab Signalling.

Customer Profile of High Speed Trains

- Passengers who otherwise use conventional trains
- Passengers who otherwise had been using aeroplane or car or luxury buses
- Passengers who did not travel otherwise are attracted towards attractiveness & comfort
- Passengers due to demographic shift & spread of population & work-centres due to introduction of High Speed Trains.

UIC: High Speed Principles and Advantages

There are **two important principles** for any high speed rail system:

1 High Speed Railway is not element, but systems. They are in fact very complex systems, comprising of the following state of the art components:

- Infrastructure
- Station emplacement
- Rolling Stock
- Operation rules
- Signalling systems
- Marketing
- Maintenance systems
- Financing
- Management
- Legal aspects

2 High speed is not unique and can be adapted to all the countries and circumstances. Like other railway systems, high speed can be considered under different conceptions, regarding commercial aspects, operation aspects, etc.

High speed service is not restricted to reduce journey time alone. Its success is also due to following quality service attributes

- Frequency of service
- High level of comfort
- On-board & station services
- Level of safety & punctuality

Advantages of High Speed Rail are:

- High capacity
- Environmental respect
- High safety
- Shorter journey times

The performance which supports high speed for customers are:

- Commercial speed - travel with high speed
- Total time of travel - short travel time from door to door
- Frequency - higher availability of transport, due to increased frequency and shorter travel time
- Reliability - a reliable system of transport, which works independent of all types of weather
- Accessibility - one can enter a train spontaneously without long check-in times, which supports high level of flexibility
- Comfort - a higher level of comfort (in terms of space, accelerations, noise, light, etc.) compared to plane, bus, or an average car
- Safety - High speed trains are the safest transport medium
- Freedom - during the trip, one has freedom to move inside the train. Seatbelts are not necessary and electronic devices aren't restricted.

HS advantages for Society:

- Offers high capacity of transport - Up to 400,000 passengers per day - Reduces traffic congestion
- Respects the environment - Efficient use of land (1/3 motorway)

  - Energy efficiency (x 9 planes / x 4 cars)
- Helps economic development
- High Speed Rail promotes logical territory structure and helps contain urban sprawl

HS Safety:

- Till today, there has been no accident with injured passenger(s) at more than 200 km/h.
- In Japan, high speed Shinkansen lines use standard gauge track rather than narrow gauge track used on other Japanese lines. These travel at speeds in excess of 260 KMPH without at-grade crossings.
- In China there are two grades of high speed lines. Firstly, slower lines those run at speeds of between 200 and 250 km/h and have freight as well as passenger trains. Secondly, passenger dedicated high speed rail lines operate at top speeds of up to 350 km/h.
- While high-speed rail is usually designed for passenger travel, some high-speed systems also carry some kind of freight service. For instance, the French mail service La Poste owns a few special TGV trains for carrying postal freight.

Chapter-2

VARIOUS MODES OF TRANSPORT & EMERGENCE OF HIGH SPEED RAIL

A good HSR system has capacity for both non-stop and local services and has good connectivity with other transport systems. HSR, like any other transport system, is not inherently convenient, fast, clean, nor comfortable. All of this depends on design, implementation, maintenance, operation and funding. Operational smoothness is often more indicative of organizational discipline than technological prowess.

Due to current infrastructure designs in many nations, there are constraints on the growth of the highway and air travel systems. A key factor promoting HSR is that airports and highways have no room to expand and are often overloaded. High-speed rail has the potential for high capacity on its fixed corridors (double decked E4 Series Shinkansen can carry 1,634 seated passengers, double that of an Airbus A380 in all economy class, and even more if standing passengers are allowed), and has the potential to relieve congestion on the other systems. Well-established high speed rail systems in use today are more environmental friendly than air or road travel.

Automobiles

High-speed rail has obvious advantage over automobiles in that it can move passengers at faster speeds than those allowed by cars in most countries. The lower limit for HSR (200 km/h, 125 mph) is substantially faster than the highest road speed limit in most countries. Ignoring the few countries without a general speed limit, the speed limit is rarely higher than 130 km/h (80 mph). For journeys that connect city centre to city centre, HSR's advantage is increased due to the lower speed limits within most urban areas. Generally, the longer the journey, the better the time advantage of rail over road if going to the same destination.

Moreover, train tracks permit a far higher throughput of passengers per hour than a road of the same width. A high speed rail needs just a double track railway, one track for each direction. A typical capacity is 15 trains per hour and 800 passengers per train (as for the Eurostar sets), which implies a capacity of 12,000 passengers per hour in each direction. A typical passenger rail carries 2.83 times as many passengers per hour per meter (width) compared to road transport. Some passenger rail systems, such as the Tokaido Shinkansen line in Japan, have much higher ratios (with as many as 20,000 passengers per hour per direction).

ETR 500 "Frecciarossa" of the Italian Railways. Maximum speed: 365 km/h (226 mph). It takes 1 hour from downtown Milan to the centre of Bologna, while a plane + taxi takes an hour and a half to do the same distance.

HSR is also competitive with cars on shorter distances, like 50–150 km e.g. for work commuting if there is road congestion or for people who have expensive parking fees at their work place which is common in large cities. Introduction of HSR also enlarges the labour market around a large city.

Aircraft

While commercial high-speed trains have maximum operating speeds much slower than jet aircraft, they have advantages over air travel mostly for relatively short distances, and can be an integral part of a transportation system. They also connect city centre rail stations to multiple other city centre rail stations (with an intermediate stop passenger loading/unloading time of one or two minutes), while air transport necessarily connects airports outside city centres to other airports outside city centres (with a stop time for intermediate destinations of 30 minutes to 1 hour.) Both systems complement each other if they are well designed and maintained.

HSR is best suited for journeys of 2 to 3 hours (250–900 km or about 150–550 miles), for which the train can beat both air and car in this range. When travelling less than about 650 km (400 mi), the process of checking in and going through security screening at airports as well as the journey to the airport itself makes the total air journey time no faster than HSR.

However, unless air travel is severely congested, merely providing a comparable service is often not a compelling financial basis for building an HSR system from scratch. As a rule of thumb, rail journeys need to be four hours or thereabouts to be competitive with air travel on journey time. One factor which may have a further bearing on HSR's competitiveness is the general lack of inconvenience when using HSR, e.g. the lack of a requirement to check baggage, or repeated queuing for check in, security and boarding as well as the typically high on-time reliability as compared to air. Separately, from a business traveller's perspective, HSR can offer amenities such as cellular phone network availability, booth tables, more elaborate power outlets (AC mains outlet vs. DC outlet), more elaborate food service, no low altitude electronics ban, self service baggage storage area at the end of the car (eliminating checked baggage), and on-line facilities e.g. Franco-German TGV-Est wireless internet broadband.

There are routes where high-speed trains have totally overtaken air transport, so that there are no air connections anymore. Examples are Paris-Brussels and Cologne-Frankfurt. If the train stops at a big airport, like Paris and Frankfurt, these short distance airplanes lose an extra advantage for the many travellers who want to go to the airport for a long-distance journey. Airplane tickets can include a train segment for the journey, with guaranteed rebooking if the connection is missed, like normal air travel.

China Southern Airlines, China's largest airline, expects the construction of China's high speed railway network to impact on 25% of its route network in the coming years.

Other considerations

Although air travel has higher speeds, more time is needed for taxiing, boarding (fewer doors), security check, luggage drop, ticket check and more. Also rail stations are usually located nearer to urban centres than airports. These factors often offset the speed advantage of air travel for mid-distance trips.

Weather

Rail travel has less weather dependency than air travel. If the rail system is well-designed and well-operated, severe weather conditions such as heavy snow, heavy fog, and storms do not affect the journeys; whereas flights are generally cancelled or delayed under these conditions. Nevertheless snow and falling trees because of wind often delay trains.

Comfort

Although comfort over air travel is often believed to be a trait of high speed rail, it is not inherent; it depends on the specific implementation. For example, high speed trains, which are not subject to compulsory reservation, may carry some standing passengers. Airplanes do not allow standing passengers, so excess passengers are denied boarding. Train passengers can have the choice between standing and waiting for a bookable connection.

Larger number of target areas

From the operator's point of view, a single train can call at multiple stations, often far more stops than aircraft, and each stop takes much less down time. One train stopping pattern can allow a multitude of possible journeys, increasing the potential market. This increase in potential market allows the operator to schedule more frequent departures than the aircraft, and hence create another good reason for preference.

Safety

From the point of view of required traffic control systems and infrastructure, high-speed rail has the added advantage of being much simpler to control due to its predictable course, even at very high passenger loads. This issue is becoming more relevant as air traffic reaches its safe limit in busy airspaces over London, New York, and other large centres. However, it must be noted that high speed rail systems eliminate the possibility of traffic collisions with automobiles (adding cost, simplicity, and safety), while other lower speed rail systems that a high speed train uses to reach high speed tracks, may have grade crossings.

Chapter- 3

SPEED RECORDS OF HIGH SPEED RAILS

MLX01 maglev train 581 km/h (current world record holder)

The term "maximum speed" has many meanings here. It can reflect:

- Maximum average speed between two scheduled stops based on the running times in timetables - daily operation.
- Maximum speed at which a train is allowed to run safely as set by law or policy on a straight section in daily service with minimal constraints (MOR)
- The maximum speed at which an unmodified train is proved to be capable of running
- The maximum speed a specially modified train is proved to be capable of running.

The world record for conventional high-speed rail is held by V150, a specially configured version of Alstom's TGV which clocked 574.8 KMPH on a test run.

The record for railed vehicles is 10,325 km/h (6,416 mph) by an unmanned rocket sled by the United States Air Force.

The maximum speed an unmodified train is capable of running was set by the non-wheeled 581 km/h JR-Maglev MLX01 run in 2003. However, even this is not necessarily suitable for passenger operation as there can be concerns such as noise, cost, and deceleration time in an emergency, etc.

The Shanghai Maglev Train reaches 431 km/h during its daily service between Longyang Road and Pudong International Airport, holds the speed record of any commercial train services. Besides maglev, the fastest maximum operating speed (MOR) of any segment of any high speed rail line is currently 350 km/h (217 mph), a record held by China. It is Beijing–Tianjin Intercity Rail which links Beijing to neighbouring Tianjin (117 km in 30 minutes). The trains have shown an unmodified capability of running 394 km/h in tests, and thus have been set to run 350 km/h in normal operation. That rail line went into operation on August 1, 2008.

The highest scheduled average speed between two scheduled stops is held by China Railway High-speed service on Wuhan-Guangzhou High-Speed Railway. Non-stop trains on this line cover the 922-km journey in 2 hours, 57 minutes, at an average speed of 312.5 km/h from Wuhan to Guangzhou South.

World speed record holding (574.8 km/h/357mph) TGV - the V150

Records in trial runs

1963 - Japan - Shinkansen - 256 km/h (First country to develop HSR technology)

1965 - West Germany - Class 103 locomotives - 200 km/h (Second country to develop HSR technology)

1967 - France - TGV 001 - 318 km/h (Third country to develop HSR technology)

1972 - Japan - Shinkansen - 286 km/h

1974 - West Germany - EET-01 – 230 km/h

1974 - France - Aérotrain - 430.2 km/h (high speed monorail train)

1975 - West Germany - Comet - 401.3 km/h (steam rocket propulsion)

1978 - Japan - HSST-01 - 307.8 km/h (Auxiliary rocket propulsion)

1978 - Japan - HSST-02 – 110 km/h

1979 - Japan - Shinkansen - 319 km/h

1979 - Japan - ML-500R (unmanned) - 504 km/h

1979 - Japan - ML-500R (unmanned) - 517 km/h

1981 - France - TGV - 380 km/h

1985 - West Germany – Inter City Experimental - 324 km/h

1987 - Japan - MLU001 (manned) - 400.8 km/h

1988 - West Germany – Inter City Experimental - 406 km/h

1988 - Italy - ETR 500-X - 319 km/h (Fourth country to develop HSR technology)

1988 - West Germany - TR-06 - 412.6 km/h

1989 - West Germany - TR-07 - 436 km/h

1990 - France - TGV - 515.3 km/h

1992 - Japan - Shinkansen - 350 km/h

1993 - Japan - Shinkansen - 425 km/h

1993 - Germany - TR-07 - 450 km/h

1994 - Japan - MLU002N - 431 km/h

1996 - Japan - Shinkansen - 446 km/h

1997 - Japan - MLX01 - 550 km/h

1999 - Japan - MLX01 - 552 km/h

2002 - Spain - AVE Class 330 - 362 km/h (Fifth country to develop HSR technology)

2002 - China - China Star - 321 km/h (Sixth country to develop HSR technology)

2003 - China - Siemens Transrapid 08 – 501 km/h

2003 - Japan - MLX01 - 581 km/h (current world record holder)

2004 - South Korea - HSR-350x - 352.4 km/h (Seventh country to develop HSR technology)

2006 - Germany - Siemens Velaro - 404 km/h (unmodified commercial trainset)

2007 - France - V150 - 574.8 km/h

2007 - Taiwan - 700T series train - 350 km/h

2008 - China - CRH3 - 394.3 km/h

2010 - China - CRH380A - 416 km/h

Chapter- 4

SUCCESS STORIES OF HIGH SPEED RAILS IN VARIOUS PARTS OF THE WORLD

HISTORICAL LANDMARKS: HIGH SPEED RAIL

Railways were the first form of mass transportation on land and until the development of the motorcar in the early 20th century had an effective monopoly on land transport.

Railway companies in Europe and the United States used streamlined trains since 1933 for high speed services with an average speed of up to 130 km/h (81 mph) and top speed of more than 160 km/h (99 mph). Both streamlined steam locomotives and high-speed EMUs were used for high speed services.

The Italian ETR 200 in 1939 was the first high speed service train. It achieved the world mean speed record in 1939, reaching 203 km/h near Milan.

In 1957, the Odakyu Electric Railway in Greater Tokyo launched its Romancecar 3000 SE. This set a world record for narrow gauge lines at 145 KMPH.

The world's first contemporary high volume capable (initially 12 car maximum) "high speed train" was Japan's Tokaido Shinkansen, which officially opened in October 1964 and started with maximum passenger service speeds of 210 KMPH on the Tokyo-Nagoya- Kyoto-Osaka route.

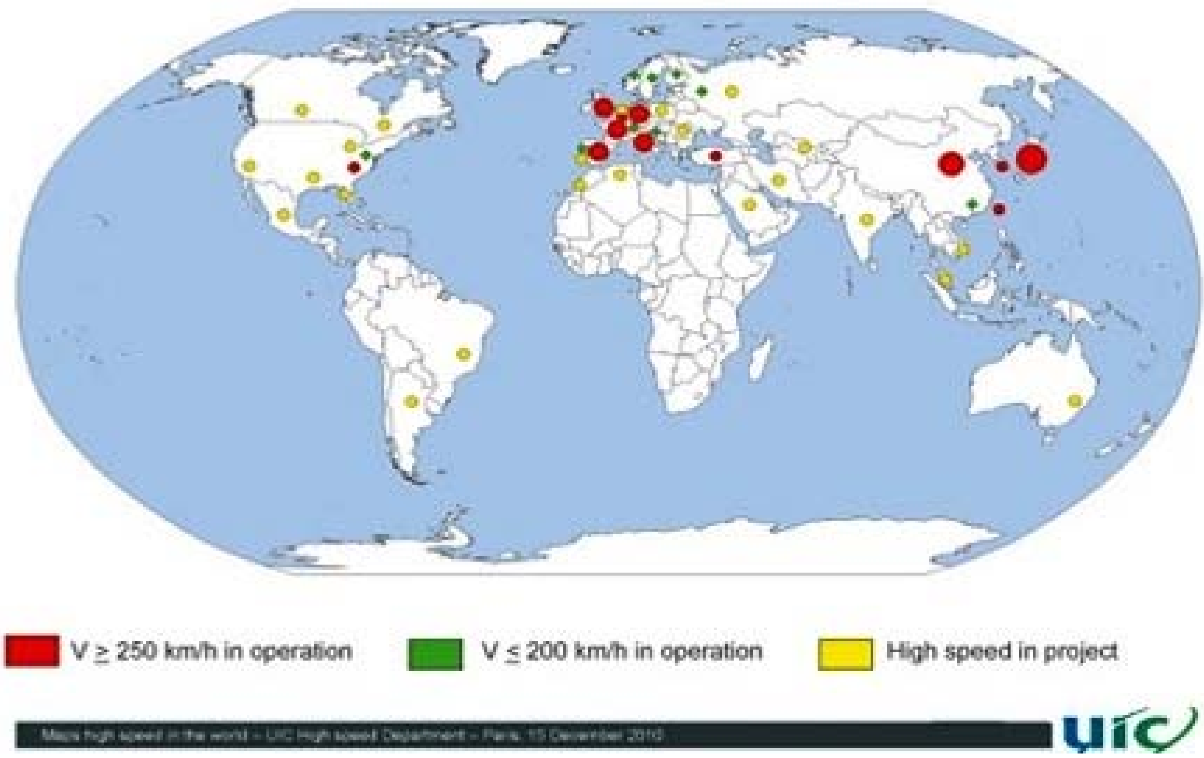
Shinkansen first high speed train design in 1964. The first Shinkansen trains ran at speeds of up to 210 km/h (130 mph), soon after increased to 220 km/h (140 mph).

In Europe, high speed rail started during the International Transport Fair in Munich in June 1965, when DB class 103 hauled a total of 347 demonstration trains at 200 KMPH between Munich and Augsburg.

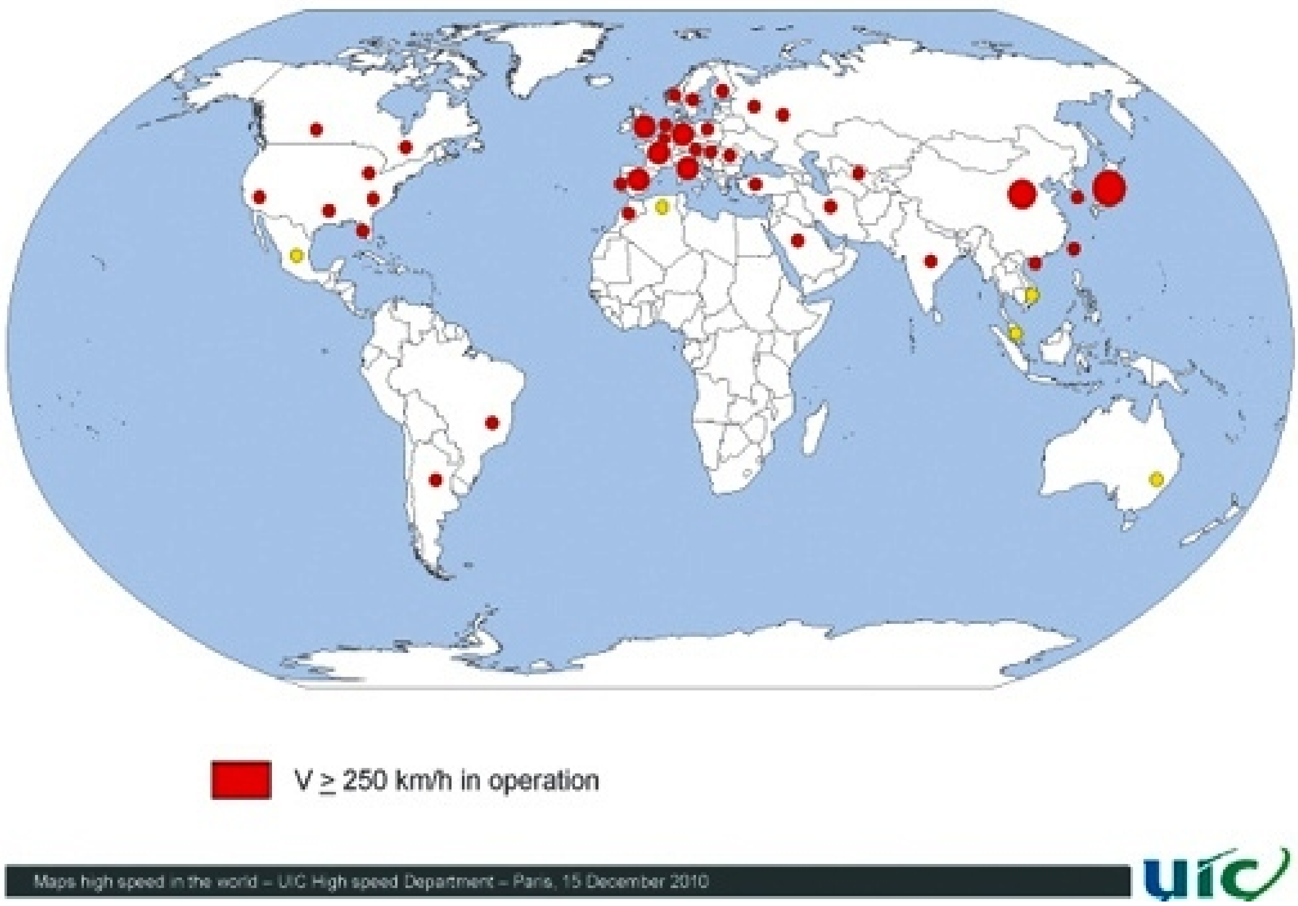
For the purposes of this table, high speed rail is defined as passenger rail running at a top speed of 200 KMPH (124 mph) or higher.

Country	Total network length (km)	Scheduled trains (in KMPH)	Test run speed record (in KMPH)	Average speed of fastest scheduled train (in KMPH)
China	6552	431 (maglev) 350, 330, 300 & 200-250 (conventional)	502 (maglev) 394 (conventional)	313
France	1700	320, 300, 280 & 210	574	272
Japan	2459	300, 275 & 260 (conventional)	581 (maglev) 443 (conventional)	256
Taiwan	335.5	300 & 240	315	245
Belgium	214	300 & 250	347	237
Spain	1272.3	300 & 250	404	236
Germany	1290	300, 280, 250 & 230 (conventional)	550 (maglev) 406 (conventional)	226
United Kingdom	109	300 , 225 & 201	335	219
South Korea	240.4	300 & 240	355	200
Italy	814.5	300, 260 & 200	368	178
Sweden	-	200	303	173
Russia	-	250	290	172
United States	-	241 & 201	296 (jet) 264 (conventional)	161
Austria	-	230	275	153
Finland	-	220	255	152
Norway	-	210	260	151
Netherlands	100	300, 250 & 140	336.2	140
Portugal	-	220	275	140
Switzerland	79	250 & 200	280	140
Turkey	245	250	303	140

High speed rail systems around the world – 2009



High speed rail systems forecast in 2025



4.1 Japan

- 300 KMPH SHINKANSEN train sets since 1990.
- 350 KMPH train sets consisting of 6 motor cars since 1995.
- Japan opened the world's first HSR in 1964, the Tokyo to Osaka Shinkansen, which has since been expanded (now over 2400 KMs).

Shinkansen: The true HSR breakthrough started in Japan. In this densely populated country, especially the 45-million-people area between Tokyo and Osaka, the traffic during the 1950s congested to reach maximum capacity. Both the roads and the narrow-gauge railways were jammed. In 1957, the Odakyu Electric Railway in Greater Tokyo area had launched its Romancecar 3000 SE. Again the train designers were inspired by the U.S. interurban, in this case the last of them – the Electroliners. The Romancecar set a world record for narrow gauge trains at 145 km/h (90 mph), giving Japanese designers confidence they could safely and reliably build even faster trains at standard gauge. The idea of high speed rail was born. Yet a new, dedicated high-speed line was calculated to be very expensive – and so it was. But it would be even more expensive not to build it. The construction started in April 1959, and test runs in 1963 hit top speeds at 256 km/h. And in October 1964, just in time for the Olympics, they opened the first Shinkansen, Tokaido Shinkansen, between the two cities.

The first Shinkansen trains, the 0 Series Shinkansen, built by Kawasaki Heavy Industries – in English often called ''Bullet'' Trains – outclassed the earlier fast trains in commercial service. They ran the 515 km distance with a top speed at 210 km/h and an average speed at 162.8 km/h with stops at Nagoya and Kyoto; the records before Shinkansen were 161 and 132.8 km/h, respectively. But the speed was only a part of the Shinkansen revolution. The earlier high-speed or proto-high-speed trains and railcars were few and far between (ten Red Devils, 15 Brill Bullets, a few Zephyrs with different forenames, two Elelectro-liners, one Morning Hiawatha, one Fliegender Hamburger, etc., each with 150 seats at best). While these services were very limited (in the U.S., express trains were often called just so), Shinkansen offered HSR for the masses. The first Bullet trains had 12 cars; later versions have up to 16, and there are double-deck trains too, to increase the capacity.

After three years, more than 100 million passengers had used the trains, and the first billion was passed in 1976. Later, the Shinkansen system has grown to a 2459 km network, and the Tokaido Shinkansen still is the world's busiest high-speed rail line. Up to ten trains per hour with 16 cars each (Net seat capacity of the train: 1300) run in each direction with a minimum of 3 minutes between trains. Though largely a long-distance transport system, the Shinkansen also serves commuters who travel to work in metropolitan areas from outlying cities. But it doesn’t only substitute a lot of car travelling; it also substitutes much of the air traffic.

4.2 China

Shanghai Transrapid: In the middle of 1990s', China's trains used to travel at top speed of around 60 km/h. To increase railway transportation speed and capacity, The Ministry of Railways (MOR) has continuously increased the speed of its commercial train service on existing lines. From 1997 to 2007, the speed of China's railways increased six times, boosting passenger train speed on 22,000 km of tracks to 120 km/h, on 14,000 km of tracks to 160 km/hr, on 2,876 km of tracks to 200 km/h and on 846 km of tracks to 250km/h.

State plan to develop high speed railway in China first began in the early 1990s. The Ministry of Railways submitted a proposal to build the Beijing - Shanghai high speed railway to the National People's Congress in December 1990. In 1995, Premier Li Peng announced that preparatory work on the Beijing Shanghai HSR would begin in the 9th Five Year Plan (1996–2000). The MORs' initial design for the Jinghu high-speed line was completed & a suggestion report was produced for state approval in June 1998. The construction plan was finally determined in the beginning of 2004 after five years' debate on whether to use rail track or the maglev technology.

On January 7, 2004, at a regular meeting of the State Council chaired by Premier Wen Jiabao, the nation's "medium-and-long term plan of railway network" was discussed and passed in principle. The plan indicates a high-speed railway network consisting of four north-south lines and four west-east lines, with the Beijing-Shanghai railway placed at the top.

When China initially decided to develop high speed rail, it adopted a methodology to research and develop domestic technology to reach world standard. In 1998, China started the construction of its first high speed rail, the Qinhuangdao-Shenyang Passenger Dedicated line (Qinshen PDL), this PDL was opened in 2003, with designed speed of 200km/h, and several manufacturers' prototypes meant to reach 300 km/h were tested here. They are "China Star" "Pioneer" & latterly "Changbai Mountain". However, the faster operating speed achieved by "Changbai Mountain" is only 180 km/h.

The development of the domestic technology was not that successful as was initially expected. In order to realize the high speed railway service as soon as possible, the MOR decided to import HSR trains and technology from Europe and Japan, which are currently known as CRH (China Railway High speed) Trains. However, most of the train-sets are manufactured by Chinese companies as technology transfer agreements are contracted as part of the deals with foreign companies.

In April 2007, China launched the sixth "speed up" campaigns. CRH service firstly opened at some 6,003 km of tracks. 52 CRH train-sets (CRH1, CRH2 and CRH5) were put into operational service as 280 train numbers.

By 2007 the top speed of Qinshen PDL was increased to 250 km/h. On 19 April, 2008 China opened its second High Speed Rail, the Hening (Hefei-Nanjing) PDL, also with a top speed of 250km/h. On 1 August 2008, the Beijing-Tianjin Intercity line (Jingjin ICL) was opened and new train-set, CRH2C & CRH3C, designed with top operating speed of 350km/h were put into commercial service for the first time. On 26 December 2009, the Wuguang (Wuhan-Guangzhou) PDL was opened, which travels 968 kilometres (601 mi) in 3 hours, reaching top speeds of 350 kilometers per hour (220 mph) and averaging 310 kilometers per hour (190 mph).

China has opened its 15th High speed rail, the Huhang (Shanghai-Hangzhou) PDL on 26 October, 2010 which uses the CRH380A train-set manufactured by CSR Sifang. It covers the 200-km distance in only 45 minutes, reducing the travelling time from 78 minutes at an average speed of 350 KMPH.

China's high speed rail lines consist of upgraded conventional rail lines, newly-built high-speed passenger designated lines (PDLs), and the world's first high-speed commercial magnetic levitation (maglev) line. The country is undergoing an HSR building boom.

China unveils world's fastest train

China's high-speed rail network now stretches over 7,431 km. The government plans to expand the network to over 16,000 km by 2020.

A CRH380A train sets out from a terminal of the Shanghai-Hangzhou High-Speed railway, in Shanghai.

Investment on High Speed Rail in China

Investment in the high-speed rail network has gathered pace since the first line, connecting Beijing with the port city Tianjin, opened in 2008.

Following the $586-billion stimulus plan that was announced in November 2008, spending on infrastructure projects has increased substantially.

China is investing an estimated $300 billion on its high-speed rail network.

The investment has divided opinion — some planners have cautioned that local governments will struggle to recoup the investment. Others have argued the rail network will spur economic development by boosting connectivity.

It is felt that the operation of the Shanghai-Hangzhou high-speed rail line will help alleviate traffic pressure in the Yangtze River Delta region, which is in China's manufacturing heartland.

China has also begun work on a 1,318-km high-speed rail line linking the country's two most important cities — Beijing and Shanghai. The $33-billion line will open in 2012, reducing the travel time between the capital and the financial centre to half, to just five hours.

4.3 Taiwan

Taiwan High Speed Rail (THSR) is a high-speed rail network that runs along the west coast of Taiwan. It is approximately 345 km (214 mi) long and runs from Taipei to Kaohsiung. THSR began service on January 5, 2007. The project had a total cost of US$18 billion and is one of the largest privately-managed and funded transport schemes to date.

THSR's technology is based mainly on Japan's Shinkansen system, mixed with European standards and system components. The Taiwan High Speed 700T train is a variant of the 700 Series Shinkansen and was built by a consortium of Japanese rolling stock builders, most notably Kawasaki Heavy Industries. Trains with a service top speed of 300 km/h (186 mph) from Taipei to Kaohsiung takes 90 minutes, compared to over four hours for a train on the conventional Western Line of the Taiwan Railway Administration (TRA). THSR is operated by the Taiwan High Speed Rail Corporation (THSRC).

4.4 South Korea

South Korean KTX high-speed rail, which runs on a dedicated line, became operational in April 2004, and was the third nation outside Western Europe to have high speed intercity service, after Japan and the US. (China still didn't have service between major cities) The maximum speed of the KTX, which derives its technology directly from France's Alstom TGV, is 300 km/h. A journey from Seoul to Daejeon, that previously took around 90 to 120 minutes, now takes only 49, and the time from Daejeon to Daegu (Dongdaegu St.) has been similarly reduced. Passengers can save up to 2 hours on journeys from Seoul to Busan. Since service began, there have been many complaints about the train sets, citing general discomfort, together with seating that faces opposite the direction of travel. However, rail demand rose by

25% in the second three months of service (April–June 2004). Rail revenue in general increased by more than 91% from the previous year with 33% more seats offered. Recent observations indicate a growth in trend and increase in public acceptance of the service. Daily ridership is now in the range of 85,000 passengers. Diversions from other modes show wide variability, according to customer surveys. KTX enticed 56% from existing rail services, 17% from air, 15% from express buses, and 12% from highways.

South Korea's KTX II, based on its self-developed HSR-350x (also known as Korean G7), reaches maximum speed of 352.4 km/h

With the development of the HSR-350x, South Korean media argue that Korea came to be the fourth nation to develop high-speed rail independently, and the seventh nation to acquire the technology. However, the statistics should vary according to the multiple definitions of a high speed rail. The "High Speed Rail 350X" went under development by South Korean engineers several years before the French technology-transfer program. The train is a product of nearly 10 years of research and development by the Korean company Rotem and the National Rail Technology Institute of Korea. Called the "Korean G-7" (a direct reference to Korea's ambitions of joining the technological prowess of G-7 nations), this technology is in its test-run phase. The proposed train would run faster than the TGV, at 350 km/h as opposed to 300 km/h. The Korean G-7 incorporates several technologies the French TGV doesn't, including an aluminium body, digital traffic control, and a pressure compensation system. When operational, the Korean G-7 will also allow passengers to rotate their seats, giving them the choice of a forward facing or a rear facing seat, in response to the many complaints about the fixed one-directional seating arrangements on the KTX.

Meanwhile, the South Korean government announced their plan to develop an upgraded version of HSR-350X, KHST or NG-KTX alternatively called G-7 HEMU (Highspeed Electric Multiple Unit-400 Km/h experiment), and later officially renamed Hanvit-350. The train system will be introduced in 2011.

Rotem, a member of the Hyundai group, also manufactures magnetic levitation trains. They were first introduced in the 1993 Daejon International Expo.

4.5 Europe

Japan's Shinkansen success contributed to a revival for the HSR idea in Europe – together with rising oil prices, a growing environmental interest, and rising traffic congestions on the roads.

In Europe, high-speed rail started during the International Transport Fair in Munich in June 1965, when DB Class 103 hauled a total of 347 demonstration trains at 200 km/h between Munich and Augsburg. The first regular service at this speed was the TEE "Le Capitole" between Paris and Toulouse with specially adapted SNCF Class BB 9200 locomotives.

DB class 103 trains

Great Britain introduced Europe's first regular above-200 km/h-service, albeit with a small margin, and with-out building new lines. In the years 1976-82, they made 95 diesel-electric train sets of the type Inter-City 125 – called so because of their maximum speed at 125 mph (201 km/h), compared to 100 mph (161 km/h) for their forerunners. Their acceleration was better, too. Thus journey times were reduced, e.g. by an hour on the East Coast Main Line, and the passenger numbers soared. The IC 125 was planned to be followed by a tilting train, APT, to maximize the speed on twisted lines from the Victorian times – but the tilting mechanism brought on nausea in some of the passengers, and the APT project was shelved. This prolonged the IC 125's lifetime, and even today they serve the non-electrified mainlines.

In the Continental Europe, several countries started to build new high-speed lines during the 1970s – Italy's ''Direttissima'' between Rome and Florence, Western Germany's Hannover–Würzburg and Stuttgart–Mannheim lines, and France's Paris–Lyon TGV line (LGV Sud-Est). The latter was the world's fastest when it was fulfilled in 1983 (the Paris–Dijon partition was opened in 1981), with a maximum speed at 260 km/h and average at 214 km/h. In addition, the tickets weren't expensive and the man in the street could afford them. The line became immensely successful, and the air route between the cities was practically de-invented when the trains' journey times shrunk from about 3½ to two hours. France became Europe's leading HSR nation. They started to build a high-speed network which also expanded into the neighbouring countries and, via the Channel Tunnel, even into London (England). France's eastern neighbour, Germany, followed up with its own high-speed network, and after Germany was re-united in 1990, the Hamburg–Berlin line again became a mainline.

Spain's first high speed line opened in 1992 between Madrid and Seville. In 2005 the Spanish Government elaborated an ambitious plan of infrastructures (PEIT 2005-2020) - it is envisioned that by 2020, 90 percent of the population will live within 50 km of a station served by AVE-. Spain is thenceforth leading the construction of HSR in Europe: four new lines have been opened (Madrid-Zaragoza-Lleida-Tarragona-Barcelona, Córdoba- Malaga, Madrid-Toledo, Madrid-Segovia-Valladolid) and another 2219 km are currently under construction to be finished between 2010 and 2012.

In Europe, High speed travel has grown 5 times in last 15 years

France

- TGV-R 300 KMPH (1992)
- TGV-325 V2.0 515.3 KMPH (under trial)
- France has over 1500 KMs of HSR route serving 9 major cities.

SNCF (Société Nationale des Chemins de fer français)

Locale	France
Track gauge	1,435 mm (4 ft 8 1⁄2 in)
Length	32,000 km (20,000 mi)
Headquarters	Montparnasse and 14th arrondissement, Paris

SNCF (Société Nationale des Chemins de fer français), is France's national state-owned railway company. SNCF operates the country's national rail services including the TGV, France's high-speed rail network. SNCF is a driving force behind Europe’s high speed rail industry and a global leader in design, construction and operation of high speed rail systems throughout the world. Its functions include operation of rail services for passengers and freight, and maintenance and signalling of rail infrastructure owned by Réseau Ferré de France (RFF).

SNCF employs more than 180,000 people in 120 countries across the globe. The rail network consists of about 32,000 km (20,000 mi) of route, of which 1,800 km (1,100 mi) are high-speed lines and 14,500 km (9,000 mi) electrified. About 14,000 trains are operated daily.

A 2nd-generation TGV Réseau train at Marseilles St-Charles station

SNCF operates almost all of France's railway system, including the TGV (Train à Grande Vitesse, meaning "High-Speed Train"), In the 1970s; SNCF began the TGV high speed train program with the intention of creating the world's fastest railway network. It came to fruition in 1981, when the first TGV service, from Paris to Lyon, was inaugurated. Today, SNCF operates more than 1,100 miles of designated high-speed track that accommodates more than 800 high-speed trains per day. SNCF's TGV trains carry more than 100 million passengers a year. TGV lines and TGV technology are now spread across several European countries in addition to South Korea.

In the past SNCF also owned the European tracks, but this has changed due to EU Directive 91/440. Since 1997 the tracks and other rail infrastructure have belonged to a separate government establishment, Réseau Ferré de France; this change was intended to open the market to independent train operating companies, although few have yet appeared.

SNCF's TGV has set many world speed records, the most recent on April 3, 2007, when a new version of the TGV dubbed the V150 with larger wheels than the usual TGV, was able to cover more ground with each rotation and had a stronger 25,000 hp (18,600 kW) engine, broke the world speed record for conventional rail trains, reaching 574.8 km/h (357.2 mph).

SNCF has a remarkable safety record. After nearly 30-years in operation, SNCF's TGV system has never experienced a fatal accident.

SNCF operations

Since the 1990s, SNCF has been selling railway carriages to regional governments, with the creation of the Train Express Regional brand. SNCF also maintains a broad scope of international business that includes work on freight lines, inter-city lines and commute lines. SNCF experts provide logistics, design, construction, operations and maintenance services. SNCF operates the international ticketing agency, Rail Europe.

An SNCF Transport Express Regional train

SNCF has employees in 120 countries offering extensive overseas and cross border consulting. Those projects include:

- **Israel:** Assistance and Training. SNCF International provides assistance to Israel Railways in every area of rail operations including projects to upgrade the network's general safety regulations. Other assistance and training programs involve Infrastructure and the Traction Division.
- **Taiwan:** Operations Training. SNCF supervised the prime contractor responsible for construction of the Taiwan Railways Administration’s main high-speed rail line. It also trained rail traffic controllers, drivers, and crew members. On behalf of the Government of Taiwan, SNCF managed the high-speed rail Command Control Centre.
- **United Kingdom:** Maintenance. In 2007-2008, SNCF-International consultants audited the maintenance practices applied to the track, signalling and overhead electric power line on British high-speed rail lines connecting London to the Channel Tunnel. In addition, it conducted an audit of the maintainer’s performance from the service quality and cost control standpoint, made recommendations for improvements, and proposed a three-year Business Plan.
- **South Korea:** HSR Electrification Design. SNCF advised Korean Railroad on the electrification of track between Daegu and Busan and on linking existing conventional track to the new high-speed line. SNCF also assisted in selecting and inspecting high-speed rolling stock and trained 400 senior manager, engineers, and executives in a broad range of skills, including signalling, catenaries, track, rolling stock maintenance, HSR operation, safety management, marketing, and passenger information systems. SNCF have assisted Korea in maintaining its high-speed.

- **Spain:** Signalling System. SNCF partnered with the Spanish railroad infrastructure manager in the study, supply, installation, and maintenance of the standard EU rail signalling system along the Madrid-Lerida high-speed rail line. On behalf of the Spanish Government, SNCF designed and led maintenance operations on this line over a two year period.
- **France:** Lead Infrastructure and Rolling Stock Maintainer – The scope of SNCF's maintenance duties is staggering: it maintains 31,000 miles of track, 26,500 main sets of points and crossings, 2,300 signal boxes, 80,000 track circuits, over 1 million relays, etc. On the rolling stock side, SNCF maintains 3,900 locomotives and 500 high-speed trains. Each of SNCF's TGV trains travels more than 24,000 miles a month – enough to circle the globe. Each year SNCF's Human Resources Department provides over 1.2 million hours of training to it's over 25,000 employees.

SNCF was formed in 1938 on the nationalisation of France's five main railways (Chemin de Fer in English means railway, literally, 'path of iron').

The French state originally took 51% ownership of SNCF and invested large amounts of public subsidies into the system. Today, SNCF is 100% owned by the French government.

SNCF's High Speed Train –TGV 3302

SNCF is a recognized leader in eco-mobility with a commitment to become the world's first operator to offer carbon neutral travel at no extra cost to travellers. SNCF has cut emissions on its cross-channel Paris to London route by 31% in two years by using more electricity from non-fossil fuel sources. SNCF's 39 manufacturing facilities are in the process of "going green" and 9 sites are already ISO 14000 certified. SNCF developed an interactive website to help travellers calculate the environmental impact of their travel choices.

SNCF has its head office in the Montparnasse area of the 14th arrondissement of Paris, in the Rue du Commandant Mouchotte, located near the Gare Montparnasse.

SNCF used to have its head office in the Saint-Lazare area of the 9th arrondissement. In 1996 the president of SNCF, Louis Gallois, announced that SNCF would move its headquarters to a new location during the middle of 1997.

United Kingdom

The UK's "Channel Tunnel Rail Link (now known as High Speed 1)" consists of 109 KMs long new high speed route with 3 major tunnel sections totalling 25 KMs. The first purpose-built high-speed rail line within the United Kingdom was the Channel Tunnel Rail Link, of which the first section opened in 2003. A mixture of 300 km/h (186 mph) Eurostar international services and 225 km/h South-eastern domestic passenger services use High Speed 1. Attempts to increase speeds to 140 mph (225 km/h) on the East Coast Main Line (ECML) and West Coast Main Line (WCML) have both failed, partly because trains that travel above 125 mph (201 km/h) are considered to require in-cab signalling for safety reasons. The term High Speed Train is currently used to refer to the British fleet of diesel-powered 125 mph (201 km/h) Inter-City trains currently in use.

High Speed 1 (HS1)

The Channel Tunnel Rail Link (CTRL), now known as High Speed 1 (HS1), was the first new mainline railway to be built in the UK for a century and was constructed by London and Continental Railways. After a lengthy process of route selection and public enquiries in the second half of the 1990s, work got under way on Section 1 from the Channel Tunnel to west of the Medway in 1998 and the line opened in 2003. Section 2, continuing the line to London St Pancras, started soon after Section 1 and was opened to the public on 14 November 2007.

The HS1 line was finished on time and under budget. The reduction in journey times and increase in reliability achieved through the opening of Section 1 enabled Eurostar to capture 71% of the total London-Paris market and over 80% of the leisure market and Section 2 has increased these figures further. Additionally, the connections provided to the WCML, MML and ECML by Section 2 may see growth of hitherto marginal markets, by finally allowing Regional Eurostar to operate, at least on the electrified ECML and WCML.

The construction of High Speed 1 also permitted the introduction of a new domestic high-speed service when in 2009 Southeastern launched its high-speed route between London St Pancras and Ashford International. Operated with a fleet of British Rail Class 395 trains, the service reaches a top speed of 140 mph (225 km/h). Southeastern High-Speed is currently the only British domestic high-speed service allowed to run above 125 mph (201 km/h)

High Speed Two (HS2)

High Speed Two (HS2) is a proposed high speed railway in the United Kingdom serving London, Birmingham, Sheffield and Leeds or alternatively London, Manchester, Liverpool, Preston, Glasgow and Edinburgh. The UK Government launched a formal high speed rail project in January 2009 and high speed rail has the support from all three main political parties. The UK Government has now approved construction, due to begin in 2017, with the first trains running by 2025. Subject to consultation, the London terminus for the high-speed line would be Euston, the Birmingham city centre station would be at Curzon Street, and there would be interchange stations with Crossrail west of Paddington and near Birmingham airport.

HS2's proposal is a network between London and England's major regional cities serving Manchester, Birmingham, Leeds, East Midlands and Newcastle, with connections onto the West Coast and East Coast mainline to allow through services to Scotland. The total route length including the connections to the existing network and High Speed One, is 150 miles (240 km).

Germany

- ICE-2 280 KMPH (1996)
- ICE-3 350 KMPH (under trial)
- Germany has 4 HSR routes covering almost 900 KMs with 3 further routes planned.

Italy

Italy opened the first high-speed rail route, the Direttissima, which from 1978 connected Rome with Florence (254 km/158 mi). The maximum speed of the Italian line was 250 km/h (160 mph), giving an end-to-end journey time of just over 90 minutes with an average speed of 200 km/h (120 mph).

Since then, Italy's high speed network has grown substantially. Services are provided by Trenitalia using both Eurostar Italia (ETR 4xx, better known as Pendolino, which was developed by Fiat Ferroviaria), and more recent ETR 500 series trains (Italian "Eurostar trains" are unrelated to the Eurostar trains operating between the United Kingdom, France and Belgium).

Treno Alta Velocità SpA (a subsidiary of state-owned Rete Ferroviaria Italiana which manages the Italian railways) is building a new high speed network on the two main axes Milan-Bologna-Florence-Rome-Naples-Salerno; and Turin-Milan-Padua-Venice-Trieste. Some lines have already opened while others are under construction. International connections with France, Switzerland, Austria and Slovenia are underway, though most of these will use conventional lines.

Rolling stock:

Eurostar Italia is a system of trains operated by Trenitalia on the routes connecting the main Italian cities and towns. Several types of high-speed trains, belonging to three major families, carry out the service:

- ETR 500 (Elettro Treno 500 - non-tilting, speeds up to 362 km/h/225 mph) used as the Frecciarossa.
- ETR 600 ETR 610 Frecciargento (tilting, speeds up to 250 km/h/160 mph)
- ETR 480 (tilting, speeds up to 250 km/h/160 mph) for other services used as the Tbiz a business class-only train.

Secondary stock:

- ETR 450, ETR 460, ETR 485 (tilting, speeds up to 250 km/h/160 mph) for other services used as the Eurostar Italia.
- ETR 470 (tilting, speeds up to 250 km/h/160 mph) operated by Cisalpino AG Company on services between Italy and Switzerland.

New Pendolino (ETR 610) are being introduced to the Italy-Switzerland route. In addition, TGV trains run on the service Paris – Turin - Milan and in the future possibly between Paris and Rome.

Belgium

Belgium's rail network is served by four high-speed train operators: Thalys, Eurostar, ICE and TGV trains. All of them serve Brussels South station, Belgium's largest train station. Thalys trains operate between Belgium, Germany (Cologne), the Netherlands (Amsterdam) and France (Paris). Thalys trains are a variant of the French TGV. Since 2007 Eurostar has connected Brussels to London St Pancras. Before that date trains connected to London Waterloo. The German ICE operates between Brussels, Liège and Frankfurt Hbf.

The HSL 1 is a Belgian high speed railway line which connects Brussels with the French border. 88 km long (71 km dedicated high-speed tracks, 17 km modernised lines), it began service on 14 December 1997. The line has appreciably shortened rail journeys, the journey from Paris to Brussels now taking 1:22. In combination with the LGV Nord, it has also impacted international journeys to France and London, ensuring high-speed through-running by Eurostar, TGV, Thalys PBA and Thalys PBKA train sets. The total construction cost was €1.42 billion.

The HSL 2 is a Belgian high-speed rail line between Brussels and Liège, 95 km long (61 km dedicated high-speed tracks between Leuven and Ans, 34 km modernised lines between Brussels and Leuven and between Ans and Liège) it began service on 15 December 2002. Its extension to the German border (the HSL 3) is now in use, the combined eastward high speed line greatly accelerates journeys between Brussels, Paris and Germany. HSL 2 is currently used by Thalys and ICE trains as well as fast internal Inter-City services.

The HSL 3 is a Belgian high-speed railway line which connects Liège to the German border, 56 km long (42 km dedicated high-speed tracks, 14 km modernised lines), it began service on 13 December 2009. HSL 3 is used by international Thalys and ICE trains only, as opposed to HSL 2 which is also used for fast internal InterCity services.

The HSL 4 is a Belgian high-speed railway line which connects Brussels to the Dutch border. 87 km long (40 km dedicated high speed tracks, 57 km modernised lines). HSL 4 is used by Thalys trains since 13 December 2009 and it will be used starting 2010 by fast internal Inter-City trains. Between Brussels and Antwerp (47 km), trains travel at 160 km/h on the upgraded existing line (with the exception of a few segments where a speed limit of 120 km/h is imposed). At the E19/A12 motorway junction, trains leave the regular line to run on new dedicated high-speed tracks to the Dutch border (40 km) at 300 km/h.

The completion of the Channel Tunnel rail link (High Speed 1) and the completion of the lines from Brussels to Amsterdam and Cologne led to news reports in November 2007 that both Eurostar and Deutsche Bahn were pursuing direct services from London to Amsterdam and Cologne. Both trips would be under 4 hours, the length generally considered competitive with air travel.

Sweden

Sweden today runs many trains at 200 km/h, including the X2 tilting trains, wide-body and double-decker regional trains, and the Arlanda Airport Express X3. Since both the X2 and X3 are allowed to run at 205 in case of delay, they can technically be considered as high-speed trains. The X2 runs between many cities in Sweden including Stockholm, Gothenburg, Malmo. The Arlanda Express trains connect Stockholm and Stockholm-Arlanda Airport.

Parts of the network can be relatively easily upgraded to 250 km/h. This requires new signalling system, catenary, removal of level crossings and new trains. There are plans to upgrade specific railways to allow this speed. They have been delayed to after 2015. A number of upgrades from single to double track or new railway have been built since 1990. They have been built with curves capable for 250 km/h (some requiring tilting trains for that). However neither the signalling system, nor the trains allow more than 205 km/h before upto 2010. The Botniabanan was ready and allowed for 250 km/h trains in 2010, but no such trains will run there for the first years, partly because the manufacturers have no experience of this in such cold climate. A research project ("Gröna tåget") aims to get experience of it, to make such trains available before 2015. SJ plans to order such trains, in traffic in 2014.

There are plans for a long completely new high-speed railway for 250–320 km/h, Stockholm-Linköping-Jönköping-Borås-Gothenburg, since the existing railways are relatively congested. An informal date suggestion by the Banverket is operation by year 2030. For two parts (Södertälje-Linköping and Mölnlycke-Bollebygd) detailed planning is done, and they are expected to have construction start by around 2017 (opposed by the minister of finance) and be in operation by around 2025.

Further HSR development in Europe is underway in Holland, Austria, Switzerland and several other countries.

4.6 United States

High-speed rail in the United States currently consists of one rail line described by the US Department of Transportation as a high-speed line: Amtrak's Acela Express service, which runs the Northeast Corridor—from Boston via New York, Philadelphia, and Baltimore, to Washington, D.C.—at speeds averaging 68 mph (109 km/h) for the entire distance but intermittently reaching 150 mph (240 km/h) at times. A federal allocation of $8 billion for high-speed rail projects has prompted U.S. federal and state planners to establish high-speed service along ten more rail corridors. Some US states (such as California and Florida) are considering HSR links between major cities.

Acela Express

Increasing airport congestion led to a renewed interest in high-speed rail, and in 2001 the Acela Express was inaugurated. Tilting technology allows Acela Express, to negotiate tight curves on the New York to Boston route while maintaining relatively fast speeds. While the trains themselves are capable of 150 mph (240 km/h), improvements to the track have proceeded in a piecemeal manner, and actual speeds are significantly slower. Presently the New York–Washington segment (formerly PRR) is the faster of the two, and only a small portion of the line allows 135 mph (217 km/h) running. The New York–Boston segment contains extensive segments with speeds as low as 90 mph (140 km/h); consequently, most of the recent improvements have focused on this corridor, thus the 150 mph (240 km/h) segments is also found here.

Acela travel time between Washington and New York is 2 hours and 53 minutes (compared to 2 hours and 30 minutes for PRR's nonstop Metroliner in 1969), or an average speed of 79 mph (130 km/h). Schedule between New York and Boston is 3 hours 34 minutes, an average speed of only 63 mph (80 km/h). With a 15-minute layover in New York, the entire end-to-end trip averages 68 mph (110 km/h).

Amtrak's Acela Express at Union Station in New Haven, Connecticut, currently the only line used for high-speed rail in the U.S

In recent years high fuel prices, congested airports and highways, and tight airport security rules regarding baggage checks have made high-speed rail options more attractive. A study conducted by the International Union of Railways indicated that high-speed trains produce five times less CO2 than automobiles and jet aircrafts. Most high-speed rail systems use electricity for power, which is available from renewable energy sources, or by nuclear power such as in Japan and France. There has been a resurgence of interest in recent decades, with many plans being examined for high-speed rail across the country, but current service remains relatively limited.

Chapter- 5

DESIGN REQUIREMENTS FOR HIGH SPEED RAILS

Much of the technology behind high speed rail is an improved application of mature standard gauge rail technology using OHE. By eliminating level crossings, frequent stops, a succession of curves and reverse curves, and not sharing the track with freight or slower passenger trains; higher speeds (250-320 KMPH) are maintained. Total cost of ownership of HSR systems is generally lower than the total costs of competing alternatives (new highway or air capacity). Japanese systems are often more expensive than their counterparts but more comprehensive because they have their own dedicated elevated gateway, no traffic crossings, and disaster monitoring systems. The technological and other requirements for HSR, in various facets of Railway System are given below:

Areas of attention for designing High Speed Railway systems:

- Track
- Bridges and Structures
- Traction
- Coaches
- Overhead equipment
- Signal & Telecommunication system
- Testing & proofing of prototypes
- Human Resource Development
- Suitable formation
- Specification-ballast, rail & sleepers
- Upgradation of turnouts
- Track maintenance parameters
- Grade separation
- Fencing of track

Track, Bridges & Formation

- Continuously welded rail
- Resilient track
- Viaducts, tunnels common
- Substantially straight
- Fairly large gradients
- System of track monitoring
- Type of bridges and structures suitable for high-speed
- New loading standards for bridges & structures
- Upgradation of formations & ballast specifications

Motive Power

- 50KV autotransformer OLE
- Nuclear powered….in France
- Mode of Traction

  (i) End Loco Concept

  (ii) Multiple Unit Concept

Coach Design

- Pressure sealed (Al extrusion shell)
- Aerodynamic profile
- Noise reduction
- Modular concepts
- High speed bogie, brake systems
- Safety devices
- Automatic wheel inspection
- Hanging part and Hot Box detector
- Aesthetic furnishings
- Sealed gang way
- Vacuum or Controlled Discharge toilet system
- Air Conditioning
- Public address

Bogie Design

- Light Weight
- Wheel Profile
- Axles: either Solid or Hollow
- Springs: Steel and Rubber
- Air Suspension

Overhead Equipment

Development of new design of:

- Overhead equipment
- Suitable power supply and distribution system
- Improved fault monitoring system

Signalling and Communications

(i) In cab signalling, transmission from track to train and/or
(ii) Moving block, high capacity: 3 to 5 min headways and/or
(iii) Automatic train control/ protection
(iv) Interlocking system for wayside station
(v) Inter signal distance based on braking distance
(vi) Mobile communication among crew members, station and control.
(vii) Public address system inside coaches
(viii) PCO Facilities e.g. ISD, STD, Fax, E-Mail, Internet etc.

Testing and proofing of Prototypes

- Computer simulation for study of vehicle dynamics
- Instrumented runs to establish design values of ride index, noise level and dynamic loads
- Proving of braking distance, cab signalling and operation of safety systems like advance warning systems

Human Resource Development

Selection, training and positioning of

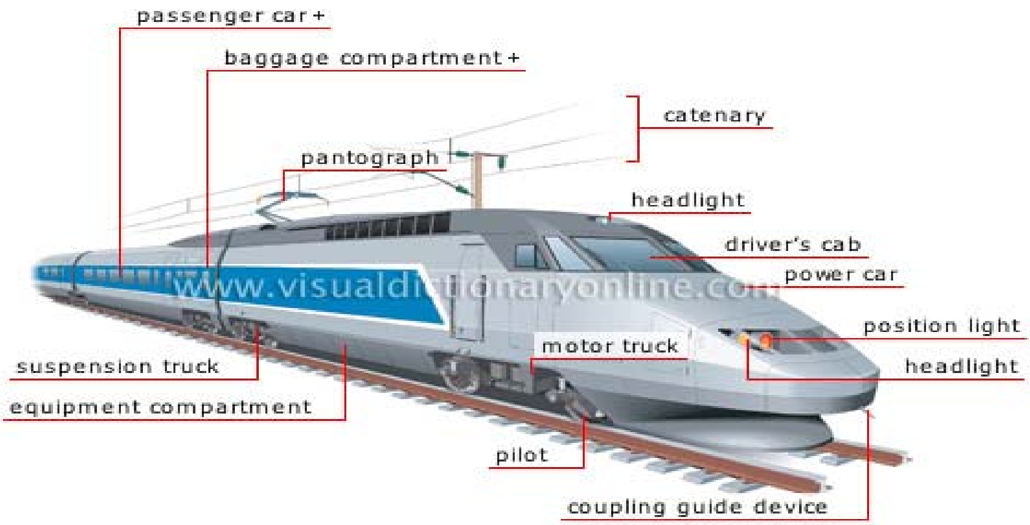
- Officers
- Supervisors
- Operating Crew
- Maintenance Staff

Traffic

- Dedicated- train types, little or no freight

Locomotive Design

- Aerodynamic Profiling
- Pantograph
- Automatic Train Control
- Noise Reduction Measures



Pressure Tightness

Pressure tightness is required in design of:

- Shell design
- Toilet system
- Doors
- AC system
- Windows
- Gangways

Other Design Requirements

- Brake System

  (i) Disc Type, or

  (ii) Magnetic, or

  (iii) EP Brake

- Seat Design

  (i) Comfortable

  (ii) Light Weight

- Emergency Exit
- Passenger Alarm system
- Draft and Buffing Gear
- Air Conditioning
- Noise Reduction

  (i) Noise Control measures

  (ii) Floor & Bogie Interface to reduce noise

  (iii) Low Noise Wheel

Chapter- 6

VARIOUS TECHNOLOGICAL MODELS OF HIGH SPEED RAILS

6.1 Aérotrain

Aérotrain (GM) prototype

The Aérotrain was a hovercraft train developed in France from 1965 to 1977. The lead engineer was Jean Bertin. The goal of the Aérotrain was similar to that of the magnetic levitation train: "to suspend the train above the tracks so the only resistance is that of air resistance." Consequently, the Aérotrain could travel at very high speeds with reasonable energy consumption and noise levels, but without the technical complexity and expensive tracks of magnetic levitation.

This project was abandoned in 1977 due to lack of funding, the death of Jean Bertin, and the adoption of TGV by the French government as its high-speed ground transport solution.

Advantages of Aérotrain

- Less pressure on track, with possible lower construction and maintenance costs.
- Less friction, with possible lower energy requirements.
- Less noise, because it had no wheels and transmitted less vibration to the track.

The Aérotrain was abandoned by the French government in favour of TGV.

Advantages of TGV over Aérotrain

- Unlike Aérotrain, TGV could use existing rail lines in metropolitan areas. Aérotrain would have required new lines, easements and stations in metropolitan areas.
- As developed, the Aérotrain had much lower capacity.
- After the first oil shock, the chemical propulsion used by the Aérotrain I80 would be too costly, thus requiring propulsion by electric linear motor. This may have been much more expensive than the wheel based propulsion used by TGV.
- The rail world was totally unfamiliar with the technology used by the Aérotrain.

6.2 TGV

The TGV (French: Train à Grande Vitesse, meaning high-speed train) is France's high-speed rail service, currently operated by SNCF Voyages, the long-distance rail branch of SNCF, the French national rail operator. It was developed during the 1970s by GEC-Alsthom (now Alstom) and SNCF. Although originally designed to be powered by gas turbines, the TGV prototypes evolved into electric trains. Following the inaugural TGV service between Paris and Lyon in 1981, the TGV network, centred on Paris, has expanded to connect cities across France and in adjacent countries. A TGV test train driven by Eric Pieczak set the record for the fastest wheeled train, reaching 574.8 km/h (357.2 mph) on 3 April 2007. A TGV service previously held the record for the fastest scheduled rail journey with a start to stop average speed of 279.4 km/h (173.6 mph), which was surpassed by the Chinese CRH service Harmony express on the Wuhan–Guangzhou High-Speed Railway in 2009.

History

The idea of the TGV was first proposed in the 1960s, after Japan had begun construction of the Shinkansen (also known as the bullet train) in 1959. At the time the French government favoured new technologies, exploring the production of hovercraft and the Aérotrain air-cushion vehicle. Simultaneously, SNCF began researching high speed trains that would operate on conventional track.

Development

It was originally planned that the TGV, then standing for très grande vitesse ("very high speed") or turbine grande vitesse ("high-speed turbine") would be propelled by gas turbine-electric locomotives. Gas turbines were selected for their small size, good power-to-weight ratio and ability to deliver high power over an extended period. The first prototype, TGV 001, was the only TGV constructed with this engine: following the increase in the price of oil during the 1973 energy crisis, gas turbines were deemed uneconomic and the project turned to electricity from overhead lines. The electricity was to be generated by France's new nuclear power stations.

The TGV opened to the public between Paris and Lyon on 27 September 1981. The TGV was considerably faster than normal trains, cars, or aeroplanes. The trains became widely popular, the public welcoming fast and practical travel.

A *TGV Duplex trainset*

Milestones

The TGV was the world's fourth commercial high speed train service and third standard gauge high speed train service, after Japan's Shinkansen.

6.3 Maglev

Maglev, or magnetic levitation, is a system of transportation that suspends guides and propels vehicles, predominantly trains, using magnetic levitation from a very large number of magnets for lift and propulsion. This method has the potential to be faster, quieter and smoother than wheeled mass transit systems. The power needed for levitation is usually not a particularly large percentage of the overall consumption; most of the power used is needed to overcome air drag, as with any other high speed train.

The first commercial Maglev "people-mover" was officially opened in 1984 in Birmingham, England. It operated on an elevated 600-metre (2,000 ft) section of monorail track between Birmingham International Airport and Birmingham International railway station, running at speeds up to 42 km/h; the system was eventually closed in 1995 due to reliability and design problems.

Maglev train

The highest recorded speed of a Maglev train is 581 KMPH achieved in Japan in 2003, 6 kilometres per hour (3.7 mph) faster than the conventional TGV speed record.

Superconducting magnet Bogie

Perhaps the most well known implementation of high-speed maglev technology currently operating commercially is the IOS (initial operating segment) demonstration line of the German-built Transrapid train in Shanghai, China that transports people 30 km to the airport in just 7 minutes 20 seconds, achieving a top speed of 431 km/h (268 mph), averaging 250 km/h (160 mph).

6.4 Shinkansen

The Shinkansen (new main line) also known as the bullet train is a network of high-speed railway lines in Japan operated by four Japan Railways Group companies. The Tokaido Shinkansen is the world's busiest high-speed rail line.

Shinkansen train

Routing

- It uses tunnels and viaducts to go through and over obstacles rather than around them, with a minimum curve radius of 4,000 meters (2,500 meters on the oldest Tokaido Shinkansen).
- The Shinkansen system is built without road crossings at grade.
- Tracks are strictly off-limits with penalties against trespassing strictly regulated by law.

Track

- The Shinkansen uses standard gauge in contrast to the 1,067 mm narrow gauge of older lines.
- Continuous welded rail is exclusively used.
- Swing nose crossing are employed, eliminating gaps at turnouts and crossings.
- Long rails are used, joined by expansion joints to minimize gauge fluctuation due to thermal elongation and shrinkage.

Signal system

- It employs an ATC (Automatic Train Control) system, eliminating the need for trackside signals.
- Centralized traffic control manages all trains operation, and all tasks relating Shinkansen train, track, station and schedule are highly systemized by computer.

Electricity

Shinkansen uses a 25,000 V AC overhead power supply (20,000 V AC on Mini-Shinkansen lines).

Trains

Shinkansen 700T train on a test run on the Taiwan High Speed Rail in June 2006 (Left). Class 395 in the United Kingdom, September 2009(Right)

- Shinkansen trains are electric multiple unit style, offering high acceleration and deceleration, and reduced damage to the track because of lighter vehicles.
- Shinkansen cars are air-sealed to ensure stable air pressure when entering tunnels at high speed.

Safety record

During the Shinkansen's 45-year, nearly 7 billion-passenger history, there have been no passenger fatalities due to derailments or collisions, despite frequent earthquakes and typhoons.

Challenges encountered

Noise pollution: Shinkansen noise is regulated less than 70 dB in residential area. Improvement and reduction of pantograph, weight saving of cars, and construction of noise barriers and other measures have been implemented.

Earthquake: Because of the risk of earthquakes, Urgent Earthquake Detection and Alarm System (UrEDAS) (earthquake warning system) was introduced in 1992. It enables automatic braking of bullet trains in the case of large earthquakes.

6.5 Transrapid

Transrapid is a German high-speed monorail train using magnetic levitation. Its current application-ready version, the Transrapid 09, has been designed for 500 KMPH cruising speed and allows acceleration and deceleration of approx. 1 m/s2.

In 2004, the first commercial implementation was completed. The Shanghai Maglev Train connects the rapid transit network 30.5 km (19.0 mi) to the Shanghai Pudong International Airport. The Transrapid system has not yet been deployed on a long-distance intercity line.

The system is developed and marketed by Transrapid International, a joint venture of Siemens and ThyssenKrupp.

Transrapid's technology is more expensive per mile to construct than conventional train systems, but uses less energy once installed, and has much lower maintenance costs.

6.6 High speed tilting train

A high speed tilting train is a train that combines high speed and tilting technology. At high speeds, the train tilts around curves to help keep speed while not flying off the track. This technology is useful in areas where there are many curves, as a conventional high speed train would be forced to slow at each curve.

The first tilting train regularly put into public service was the ETR 401 run by Italian State Railways, which became operational on 2 July 1976 on the Rome-Ancona (later extended to Rimini) line. The first tilting train was the Spanish Talgo Pendular which was operational since 1980. This technology was not fully implemented world-wide as the marginally increased curve speeds did not justify the extra expense and technology in many cases. The British Advanced Passenger Train (being operational from 1984 to 1985) was the first to successfully implement active tilt increasing speeds significantly on tight rail curves. Active tilting is the mechanism most widely used today.

The most successful active tilt trains of note in operation is the Italian Pendolino (built and produced by Fiat), partially based on the Advanced Passenger Train. The most successful passive tilting train is the Spanish Talgo.

Virgin Pendolino High Speed tilting train, UK

Chapter- 7

DEVELOPMENTS IN HIGH SPEED RAILS ON INDIAN RAILWAYS – A CHRONOLOGY

- **1987:** At the instance of Ministry of Railways, Japan International Co-operation Agency (JICA) submitted a feasibility study report in 1987 for introducing speed of 250 KMPH between Delhi - Agra - Kanpur section. Study was based on principle of setting up new corridor terminal stations at Delhi, Agra & Kanpur.. JICA suggested two types of services:

  1. Super express train at maximum speed of 250 KMPH on new corridor of Delhi - Agra - Kanpur
  2. Long distances express trains operating at 160 KMPH to utilize dedicated track by getting in and out of new corridor at Agra and Kanpur.

  Some of the important features of JICA report are as follows:

  - New alignment for high speed with maximum grade should be 1 in 1000 or less.
  - Minimum radius of curve required is 4000 meters
  - Every crossing with conventional railway line and roads should be separated with a grade separation.
  - Suitable new rolling stock is required.
  - OHE and track needs to be upgraded.
  - Dedicated workshops for maintenance of rolling stock are required.
  - Matching maintenance depots for track and OHE at about every 50 km
  - Use of automatic train control system
  - Train operation with CTC system
  - Setting up of High speed terminals at New Delhi, Agra and Kanpur.

  The following three alternative corridors were examined

  - Mumbai - Vadodara – Ahmedabad (Distance - 492 KMS)
  - New Delhi - Kanpur – Lucknow (Distance - 507 KMS)
  - New Delhi - Agra (Distance - 199 KMS)

Cost estimates

In the feasibility study, RDSO and JICA estimated the construction cost to be Rs 49 million per km, for a line dedicated to 250-300 KMPH trains. In 2010, that 1987-estimated cost, inflated at 10% a year, would be Rs 439 million per km (US$ 9.5 million/km). Therefore the route of 500 km will cost Rs 220 billion (US$ 4.76 billion) to build. At US$ 9.5 million per km, cost estimates are in line with US$ 18 million per km of the recently completed Wu-Guang HSR line in China.

Potential High Speed Rail lines

In India, trains in the future with speed of 250-350 KMPH, are envisaged to run on elevated corridors, to prevent trespassing by animals and people. This is an excellent way to isolate high-speed train tracks. The TGV tracks are completely fenced in and have no road crossing them at the same level. Wu-Guang's 2-tracks line is laid, 468 km on bridges, 177 km in tunnels, and 323 km on embankments. The 336 km THSR tracks are 91% on bridges, flyover, or tunnels.

- **Aug.' 1988:** In 1988, first Governing Council Meeting (GCM) was held at Research Design and standards Organisation (RDSO), Lucknow, the R&D wing of Indian Railways. In the meeting, it was decided to improve passenger train speeds, reduce travel time and increase transport facility. As part of the strategy for Railway Technology development, a Mission termed as Mission-II was assigned. Aim of this Mission was to develop technology for operation of passenger services upto 160 KMPH on mixed traffic routes and 200 KMPH on dedicated routes. The Mission as instituted envisaged import of the rolling stock and locomotives.

- **April' 1991:** In 5th GCM, Ministry of Railways had asked RDSO/Lucknow to develop indigenous technology for coaches and locomotives for operation of trains at 160 KMPH. A number of projects were undertaken in different disciplines to achieve this mission. Projects were undertaken by RDSO and inputs for train operation at 160 kmph on selected sections were identified.

- **Oct.' 1994:** An action plan for introduction of a train at a speed of 160 KMPH between New Delhi and Allahabad was drawn.

- **Feb.' 1995:** A 'Technology Mission' was initiated for identifying the inputs required for upgrading existing Rajdhani/Shatabdi routes for introducing 160 KMPH speed trains. The sections recommended were: (i) New Delhi – Kanpur (ii) New Delhi – Jhansi (iii) Delhi – Jhansi – Bhopal (iv) Delhi – Ambala – Ludhiana (v) Delhi – Kanpur – Allahabad – Varanasi (vi) Delhi – Jaipur and (vii) Howrah – Rourkela.

- **Feb.' 1996:** A Board Memorandum on the above subject was submitted to the Ministry of Railways for deciding the time frame and sequencing for introduction of 160 KMPH high speed trains. A Committee was also constituted to go into all the aspects involved and submit a report. It was further observed by the Board that dedicated separate corridors would have to be developed for high speeds and it would be necessary/desirable to think in terms of a maximum permissible speed of 250/300 KMPH for such corridors.

- **March' 1997:** It was decided to increase the number of trains running at the maximum speed of 120 KMPH and Zonal Railways were advised accordingly.

- **May'1998:** In the 15th Governing Council Meeting (GCM) held in May'1998, it was decided that before finally closing Mission-II, a consolidated list of the inputs required for 130 kmph, 140 kmph and 150 kmph should also be issued to zonal railways as had been done for 120 KMPH. During the meeting, commenting on the new mission for high-speed technology members stated that Board will decide on the separate corridor for the high-speed in the region 250-300 KMPH. It was decided to take up the project as mission 16 of RDSO.They also felt that consultants should be associated right from the beginning.

- **Oct.' 1998:** A new Mission-16 for "High-speed technology for running passenger trains at 250-300 KMPH on dedicated track" was approved by the Ministry of Railways.

- **1998-99:** IRY coaches with IR-20 bogies were designed indigenously. These coaches were introduced in New Delhi- Amritsar Swarna Shatabdi Express on trial basis. This is the only running rake with IRY coaches. Design of shell and bogies were entirely different from existing ICF all coil bogies.

- **1999-2000:** A global tender was invited for modern design coaches and order was given to M/s Alstom-LHB/Germany. 24 high speed LHB coaches were imported and introduced in New Delhi-Lucknow Shatabdi trains which are capable to run at the maximum speed of 180 KMPH.

- **2003:** LHB coaches were built in RCF/Kapurthala on the basis of technology transferred by M/s Alstom-LHB and introduced in New Delhi- Mumbai Rajdhani Express. A trial run at the maximum speed of 160 KMPH was done in Delhi-Mathura section.

High-Speed Rails in India in 2lst Century

India has one of the largest rail networks in the world. The fastest train in India is the Bhopal Shatabdi, a Shatabdi Express train, with a maximum speed of 160 KMPH (100 mph) and an average speed of 93 KMPH (58 mph), excluding stops. Rajdhani Express which connects New Delhi with other destinations in India was introduced in 1969, has speed up to 140 KMPH. The Duronto Express trains introduced in 2009, run without stop between major cities, are the fastest train in India, and are as fast as a Rajdhani or Shatabdi on the same route.

Rajdhani Express

Tracks

Duronto, Shatabdi, and Rajdhani trains run on Indian broad-gauge which is 5 ft 6 in (1,676 mm). These tracks are multi-purpose supporting all passenger and freight traffic, and are not made exclusively for lighter load fast-express passenger trains. The Rajdhani, Shatabdi and the Duronto adhere to a speed limit of 140 km/h. They run on tracks with classification Group A, permitting speed up to 160 km/h, and Group B for speed up to 130 km/h. Lower speed limits apply when they are on tracks or railway switches, which have lower speed limits. The design of the railway switches, with a speed limit of 15-75 km/h, is the major bottleneck to higher speed. Another constraint is the need to accommodate freight trains at the current maximum speed of 70 km/h. These constraints to speed are consequences of sharing tracks with freight and lower speed suburban passenger trains. But currently, a separate freight corridor construction work is in progress with land acquisitions and other hurdles being slowly overcome. Other Mail/Express trains on the same route are only slightly slower, since the locomotives hauling them are same.

HSR tracks versus conventional tracks

Sl. No.	Description	Tracks for High Speed Railway network	Conventional tracks
1.	Track Radius	Wide enough to allow high speeds, curves often exceeds a 5 Km radius	Not so wide curves are required (218 meters without checkrail for Broad Gauge and 175 meter minimum with check rail)
2.	Spacing between tracks	Wide spacing between tracks to reduce air-pressure between passing trains	Comparatively lesser space between tracks is also O.K.
3.	Level Crossings	No level crossings are permitted	There are provisions for level crossings
4.	Gauge	Standard Gauge rail technology	Broad Gauge/Meter Gauge/Narrow Gauge
5.	Rail	Continuous welded rail	Rails with fishplates Joints
6.	Sleepers	RCC sleepers	RCC/Wooden/Metallic sleepers
7.	Use of tracks	Dedicated passenger tracks	Mixed use of tracks- passengers as well as goods trains
8.	Track path	Either elevated or suitably isolated. Viaducts and tunnels are common	Generally tracks are at gradient without any isolation

Locomotives

Duronto, Shatabdi, and Rajdhani trains are hauled by powerful electric locomotives built at CLW, such as WAP-4, WAP-5, or WAP-7, each with an output of more than 5,000 HP. WAP-5 design originated from Bombardier-Adtranz-ABB, and WAP-7 is a powerful locomotive and can haul trains with higher load and at higher speeds.

3-Phase Locomotives versus Conventional (DC motor) Locomotives

Sl. No.	Description	3-Phase Locomotives	Conventional (DC motor) Locomotives
1.	Drive used	3 Phase Squirrel-Cage Induction Traction Motor	DC Traction Motor
2.	Power output (continuous HP)	Much higher (6120 HP - WAP7)	Less (5000 HP – WAP4)
3.	Models in production	WAP5, WAP7, WAG9, WAG9H	WAP4, WAG7
4.	Maximum Speed	Higher speed (Though presently, WAP5 has been certified for 160 KMPH operation, the locomotive has been designed to give a service speed of 200KMPH with test speed potential of 225KMPH)	130 KMPH (WAP4)
5.	Gear Ratio	20:72 (WAP7) 67:35:17 (WAP5)- 3 stage gears	23:59 (WAP4)
6.	Braking	Air and Re-generating brakes	Air Brakes and Rheostatic Brakes
7.	Axle Load	20.5 t (WAP7)	18.8 t (WAP4)
8.	Tractive Effort	36.0 t (WAP7)	30.8 t (WAP4)
9.	Reliability	Reliability of 3-phase locos is higher due to robust size of induction motors and modern micro-processor based technology.	Reliability is less
10.	Overall Efficiency of Operation	Re-generating braking effort is available from the full speed till dead stop. Consequently, the overall efficiency of operation is higher.	The overall efficiency of operation is less.
11.	Maintenance Cost	Maintenance cost is less due to absence of brush-gear/commuter in the traction motors and switchgears in the power circuit.	Maintenance cost is high
12.	Overload capabilities	Overall capabilities in 3-phase locos are more liberal	Less liberal
13.	Size of Traction Motor	The size of traction motor (i.e. 2100 Kgs for WAP7) for the same output power is much less in case of 3-phase motor. Therefore, with the permissible axle load and available space in a bogie, realization of a much higher-powered locomotive is possible	For the same output power, traction motor size (i.e. 3500 Kgs for WAP4) is larger
14.	Un-sprung masses	Due to lesser weight of the traction motors, the un-sprung masses are low. This reduces track forces and consequently minimizes wear on rails and disturbance to track geometry.	The un-sprung masses are high

Similarly, old conventional 2600HP WDM2 Diesel locos are being upgraded to 3100HP/3300HP on a war footing at DMW/Patiala. Indigenous production of new technology 4000HP/4500HP has also started at DLW.

GM (EMD) Locomotives versus WDM 2 (ALCO) Diesel Locomotives

Sl. No.	Description	GM (EMD) Locomotives	WDM 2 (ALCO) Locomotives
1.	Power output	4,000 HP (3,000 kW)/4500 HP(WDP-4B)/4500 HP with dual cabs (WDP-4D)	2400 HP
2.	Type of engine	2 stroke, V-16 (results in better power stroke)	4 stroke, V-16
3.	Axle Load (Tonnes)	21.42	18.8
4.	Gear Ratio (Pinion : Bull Gear)	17:90	18:65/ 18:74
5.	Brake	Computerized Controlled Brake (CCB)	Indian Railway Air Brake (IRAB)
6.	Minimum radius of Curvature (Meters)	64.92	73.2
7.	Transition	No transition	3 with field shunting
8.	Excitation	Micro-processor based	E-type
9.	Governor	Micro-processor based	Electrical/Hydraulic type
10.	Electrical Transmission Type	AC-AC	AC-DC
11.	Cranking done by	Two Starter Motors (AC)	Generator working as Motor
12.	Bogie	Fabricated	Cast/Fabricated
13.	Expressor/Compressor cooling	Water cooled	Air cooled
14.	Cooling water system	Two water pumps gear driven to radiator fans by computer controlled electrical motors	One water pump, gear driven one radiator fan and drive from engine through ECC
15.	Weight transfer to wheels through	Side rubber resilient pads-100%	Centre pivot-60%, side bearer-40%
16.	Type of Truck	Side load pads, Centre pivot, Co-Co type	Tri-mount Co-Co type
17.	LOC per every 100 litres of Fuel Oil Consumption	0.5 litres	1.5 litres
18.	Minimum Radius of Curvature (Meters)	69.42	73.2

Coaches

The coaches in these trains are of crash-worthy design from Alstom-LHB, built at RCF, Kapurthala. These Alstom-LHB coaches can be pulled to higher speeds without any modification. Stainless steel construction of coaches is primarily motivated by lower maintenance and also reduces empty weight, enabling more passengers per coach. The bogies, design from FIAT, has 2 disk brakes per axle, essential for safe operations especially at the speed of fast-express trains.

LHB coaches versus conventional ICF coaches:

Sl. No.	Description	LHB Coaches	Conventional ICF Coaches
1.	Braking system	Axle Mounted Disc Brakes	Body/Bogie Mounted Brake cylinders
2.	Wheel slide protection	Brake system with wheel slide protection	No provision for wheel slide protection
3.	Design of Bogies	EUROFIMA/FIAT	ICF All coil
4.	Test speed potential	*180 kmph (No major changes required for 200 kmph)*	140 kmph
5.	Shell Body	Stainless steel	Corten Steel
6.	Coupler	Tight Lock Centre Buffer Coupler (CBC)	Screw coupling/CBC
7.	Dampers	Use of lateral, yaw and vertical dampers	Only vertical dampers are used
8.	Coach Weight	Coach weight reduced for better hauling speed (AC chair car weight brought down by around 5 Ton)	Heavier coach
9.	Ride index	More comfort with better riding index of 2.5	Comparatively poor riding index i.e. 3

Speed

FASTEST TRAINS ON IR

Train	Source, Destination	No. of Stops	Total stop time, (hr:m)	Distance, (in km)	Total time (hr:m)	Speed excluding stop time, KMPH (mph)	Remarks
2002 Bhopal Shatabdi	New Delhi, Bhopal	5	0:18	701	7:50	93.1 (58.1)	Fastest Shatabdi

2259 Sealdah Duronto	Sealdah, New Delhi	non-stop	-	1454	16:20	89.0 (55.6)	Fastest Duronto
2951 Mumbai Rajdhani	Mumbai Central, New Delhi	4	0:32	1384	15:50	90.5 (56.5)	Fastest Rajdhani
2313 Sealdah Rajdhani	Sealdah, New Delhi	6	0:32	1454	17:30	85.7 (53.6)	Slower than Sealdah Duronto by 3 KMPH
2431 Trivandrum Rajdhani	Trivandrum Central, H Nizamuddin	15	1:21	3149	41:25	78.6 (49.1)	Longest distance
2030 Swarna Shatabdi	Amritsar Junction, New Delhi	5	0:11	448	6:05	75.9 (47.5)	Northern region
2028 Shatabdi Express	Bangalore City, Chennai Central	2	0:04	362	5:00	73.4 (45.9)	Southern region
2267 Ahmedabad Duronto	Mumbai Central, Ahmedabad Junction	non-stop	-	491	6:45	72.7 (45.5)	Western region
2019 Shatabdi Express	Howrah Junction, Ranchi	7	0:19	423	7:05	62.5 (39.1)	Eastern region
2436 Dibrugarh Rajdhani	New Delhi, Dibrugarh Town	21	3:16	2463	44:55	59.1 (37.0)	Slowest. Also has most stops

The average speed of fast trains (excluding stop time) range from 59 to 93 KMPH. Other Mail/Express trains on the same route are only slightly slower, since the locomotives hauling them are same.

Stops

Frequent stops reduce the average running speed of a train greatly by preventing it from gaining higher speed. Duronto, Shatabdi, and Rajdhani express trains have very few stops. Distance between stops is as short as 16 km between Chandrapura-Bokaro Steel City on Howrah-Ranchi Shatabdi, and as long as 528 km between Vadodara-kota on the Trivandrum Rajdhani.

Duranto train

Current efforts to increase speed to 160-200 KMPH

Indian Railways' current effort to provide fast non-stop train services under the brand of Duronto continues in the decade of 2010-19. In addition, it is aimed at raising the speed of passenger trains to 160-200 KMPH on dedicated conventional tracks. Train journey between Delhi-Mumbai and Delhi-Kolkata will become an overnight service compared with the present 15-16 hours.

Approach to high-speed

Indian Railways' approach to high-speed is of incremental improvement on existing conventional lines for up to 200 KMPH, with a forward vision of speed above 250 KMPH on new tracks with state-of-the-art technology, such as Shinkansen/TGV/etc.

Dedicate corridors

By building dedicated corridors for freight trains, and separate network for busy suburban traffic in Mumbai and other cities where traffic is equally busy, network on existing trunk lines will be more or less dedicated to passenger trains. It will also result in faster freight and suburban traffic, fast-express trains that can run at the speed limit of rolling stock, the track or railroad switch, whichever is lowest among those that will apply.

Upgrade tracks for 160-200 KMPH

Upgrade the dedicated passenger tracks with heavier rails, and build the tracks to a close tolerance geometry fit for 160-200 KMPH. High-speed tracks are required to be maintained and inspected using automation to ensure required track geometry. Design, manufacture and deploy railroad switches, with thick web construction and movable crossings that permit 50 KMPH to alleviate this bottleneck of speed.

Upgrade locomotives and coaches

Upgrade coaches, which can support 200 KMPH, with stainless steel bodies and crash-worthy designs, incorporating passenger and crew protection, and fire-retardant materials. Equip coaches with electro-pneumatic brake systems to enhance safe operations at 160-200 KMPH. Develop locomotives with output of 9000 to 12000 hp for hauling of 24-26 coach long passenger trains to 160-200 KMPH.

New Improved Rapid Transit Railway Skybus at Goa (Inventor Mr. B. Raja Ram)

Chapter- 8

FUTURE OF HIGH SPEED RAILS IN INDIA

India has one of the largest rail networks in the world. As of 2010, India does not have any high-speed rail lines capable of supporting speeds of 200 km/h or more, and none is under construction or subject to definite plans.

The fastest train in India is the Bhopal Shatabdi, a Shatabdi Express train, with a maximum speed of 160 km/h (100 mph) and an average speed of 93 km/h (58 mph), excluding stops. The Duronto Express trains introduced in 2009, runs without stop between major cities, is projected the fastest train in India, when new services are introduced with a higher speed limit of 130 km/h. Despite limited to a much lower speed limit, it is as fast as a Rajdhani or Shatabdi on the same route. Rajdhani Express which connects New Delhi with other destinations in India was introduced in 1969, has speed up to 140 km/h. These trains are not comparable in speed to the Shinkansen of Japan (and running in Taiwan), TGV of France, Intercity Express of Germany, the ETR 500 of Italy, the KTX of South Korea, AVE of Spain, the Wuhan-Guangzhou High-Speed Railway trains in China, or the HS 1 of the UK (although the Acela Express of the US is classified there as high speed, its average running speed is too low to be truly called high speed.)

During a high level delegation visit to Tokyo in December 2006, Japan assured cooperation to India in creating a high speed link between New Delhi and Mumbai. In January 2009, the then Railway Minister had expressed keen interest in introducing bullet-trains in India, after getting a first-hand feel of the superfast trains travelling from Tokyo to Kyoto at a speed of about 300 KMPH. On a visit to India in December 2009, Japanese Prime Minister offered bullet-train technology to India.

On December 18, 2009 Vision 2020 document was submitted in the parliament which envisages the implementation of regional high-speed rail projects to provide services at 250-350 KMPH, and planning for Dedicated Corridors resulting in superior technology and high speeds.

Some of the extracts of the Vision 2020 are indicated below:

- (*Vision 2020,* Page no.VI, High-Speed Rail Travel) *"In the coming decade, Indian Railways must catch up with the developed railways of the world in the matter of speed of trains. The current effort to provide fast non-stop train services under the new brand of Duronto will continue. In addition,* ***the Vision aims at raising the speed of regular passenger trains to 160-200 kmph on segregated routes, which will bring about a major transformation in train travel.*** *For example, train journey between Delhi-Mumbai and Delhi-Kolkata will become an overnight service.*

  The Vision 2020 also envisages the implementation of ***at least 4 high-speed rail projects to provide bullet train services at 250-350 KMPH****, one in each of the regions of the nation and planning for at least 8 more corridors connecting commercial, tourist and pilgrimage hubs.*

  Six corridors have already been identified for technical studies on setting up of High Speed Rail Corridors. These are:
  i. Delhi-Chandigarh-Amritsar;
  ii. Pune-Mumbai-Ahmedabad;
  iii. Hyderabad-Dornakal-Vijayawada-Chennai;
  iv. Howrah-Haldia;
  v. Chennai-Bangalore-Coimbatore-Ernakulam;
  vi. Delhi-Agra-Lucknow-Varanasi-Patna

  These could be built as elevated corridors in keeping with the pattern of habitation and the constraint of land. *The Railways will use the PPP mode for investment and execution, and draw on frontier technologies incorporating the highest standards of safety and service quality"*

- (Vision 2020, Page-9, item no- 3.1 (d) Slow Speeds) "The speed of freight trains on IR has stagnated at around 25 kmph for a long time. Passenger services are also slow by international standards. The maximum permissible speed on Indian Railways is 130 kmph for Rajdhani/Shatabdi trains and 110 kmph for other mail/express trains compared to a maximum permissible speed of 200 kmph on several European Railways on conventional networks and more than 300 kmph on high speed corridors in Europe and Japan. Chinese Railways are presently engaged in construction of 12,000 Kms of dedicated passenger corridors with speeds of 250-350 kmph.

  Currently, eastern and western routes of dedicated freight corridors (DFCs) totalling 3400 Kms from JNPT (Mumbai) to Delhi and Ludhiana to Dankuni have been sanctioned. Pre-feasibility studies for other dedicated freight corridors for North-South (Delhi to Chennai), East-West (Howrah to Mumbai), Southern (Chennai to Goa) and East-Coast (Kharagpur to Vijaywada) have also been carried out. The DFCs are being planned with high axle-load and modern technology. These would provide the opportunity to achieve substantial segregation of freight and passenger traffic on the trunk routes and improve the speed and reliability of both services. The key challenge is to find and devote adequate financial and human resources to execute these projects in time.

Segregation of freight and passenger services, creation of adequate capacity and rising of speeds of both services would be a key challenge if Indian Railways are to retain their market share and improve upon it."

- (Vision 2020, Page-14, item no- 3.3 (e) Raising of Speed) "Improvement of speed to 160-200 kmph on segregated passenger corridors would be necessary to meet the requirement of fast intercity travel between major cities. In the long run, however, genuine high speed trains with travel speeds exceeding 300 kmph would be needed to keep pace with developments in other parts of the world."

- (Vision 2020, Page-14, item no- 3.3 (f) High-speed trains) *"Construction and operation of high speed lines is, however, very expensive and would require capital infusion and passenger patronage of a very high order. Massive capital investment would necessitate running of trains at frequent intervals of 5-10 minutes with sufficient load factors. Farebox revenues may not be sufficient to cover cost of infrastructure and operation for a long time.* ***This would, therefore, call for innovative approaches; a mix of viability gap funding from government - both at central and state levels- and leveraging of real estate would be necessary to attract successful PPP interest in these projects."***

- (Vision 2020, Page-32, item no- 6.7 High Speed Corridors) *"India is unique and alone among the major countries of the world in not having a single high-speed rail corridor capable of running trains at speeds of over 250 kmph. High speed corridors have played a major role in revitalization of Railways in Japan and Europe. Of late, high speed-rail networks are also getting built in China, Taiwan and USA. Indian Railways would follow a two-pronged approach in this respect. The first approach would be to raise the speed of segregated passenger corridors on trunk routes using conventional technology to 160 to 200 kmph. The second approach would be to identify a number of intercity routes, depending on viability, and build state-of-the-art high-speed corridors for speeds up to 350 kmph through on PPP mode in partnerships with the State Governments. Partnerships with the State Governments would be crucial as real-estate development would be a key element of viability of these high-cost projects. By 2020, at least four corridors of 2000 Kms would be developed and planning for 8 other corridors would be in different stages of progress."*

Research initiative in Indian Railway

Indian Railways had signed an MoU with Indian Institute of Technology, Kharagpur, India in February 2010, to set up a "Centre for Railway Research (CRR)". 'High Speed' is one of the key area on which research would be carried out at this centre. 'High speed' is one of the key area on which research is being carried out at IIT. In continuation to various ongoing projects, following projects have been sanctioned for high speed related research works at CRR or otherwise in 2011-12:

- Aerodynamic design of traction rolling stock with speed potential of 250 km/h, upgradeable to 350 km/h
- Suspension and bogies technology for high speed trains
- Design and development of Cab Signalling system

- Development of provision for design of steel concrete composite Railway bridges for normal speed and special provision for high speed passenger traffic
- Railway Bridge Health Monitoring System with Wireless Sensor Networks
- Development of thermo mechanically processed high strength bainitic steel rails for Indian Railways

Other modes of transport

Like elsewhere, railways in India compete with air travel and road transport. The advantages of travelling by air between cities are the greater frequency of flights, and shorter travel time. Rail travel, with few exceptions, offers lower cost.

Rail transport also faces competition from the use of roads improved under National Highways Development Project. People owning cars can, for short distances, benefit in terms of shorter travel time, given the lack of commute to and fro a railway station at both ends of a journey. This is also balanced against the need to maintain one's vehicle and its security during such trips.

Potential ridership

As of July 2010, there are currently 49 train services on the 968 km Wuhan-Guangzhou HSR line in China, with fares from US$ 70-115 (Rs 3220-5290), or US$ 0.07-0.12 per km (Rs 3.33-5.46/km). Amritsar-New Delhi line has 22 daily services, with fares range from Rs 552-1434 (US$ 12-31). Ahmedabad-Mumbai has 32 daily services with fares from Rs 514-1475 (US$ 11-32). On the 2 Indian lines travelling cost Rs 1.14-3.19 per km (US$ 0.025-0.069/km).

Project execution

To put the construction in perspective, in the period 2005-09 Indian Railways took on construction of 42 completely new conventional lines, a total of 4060 km at a cost of Rs 167 billion (US$ 3.63 billion), or Rs 41 million per km (US$ 0.89 million/km). A public-private-partnership mode of investment and execution is envisaged for such expensive 250-350 km/h high-speed rail project.

Unit cost for setting up of HSR in various countries:

Country	Data available for calculation for HSR	Cost per KM (in US $)
India	Rs.439 Mn per KM (US $ 9.5 Mn per KM) *(As per feasibility study published in 1987, RDSO and JICA estimated the construction cost to be Rs 49 million per km, for a line dedicated to 250-300 KMPH trains. In 2010, that 1987-estimated cost, inflated at 10% a year.)*	9.5 Mn
Wu-Guang HSR (China)	US $ 18 Mn per KM	18.0 Mn
LGV Est (France)	€ 10Mn per KM (US $ 15.1 Mn per KM)	15.1 Mn
Madrid to Lerida HSR	£ 7 Mn per KM	10.3 Mn

(Spain)		
The Channel Tunnel Rail Link (CTRL, also known as high Speed 1) (UK)	£ 50 Mn per KM *(High cost due to high proportion of tunnels. Other reasons include the cost of land, labour costs, regulatory/ approved procedures)*	73.4 Mn
London to Birmingham (UK)	Total cost-£ 9 Bn Distance-118.86 miles *(as per yahoo map)*	69.2Mn
London to Leeds (UK)	Total cost-£ 12 Bn Distance-194.77 miles *(as per yahoo map)*	56.3 Mn
London to Edinburgh & Glasgow (UK)	Total cost-£ 31 Bn Distance- 405.23miles *(as per yahoo map)*	69.8 Mn
Taiwan High Speed Rail (abbreviated as THSR)	Total cost-US $ 18 Bn *(including station, building & other construction costs)* Total route length- 335.50 KMs	53.65 Mn
California HSR (USA) (To be begin by 2012)	Total cost-US $ 42.6 Bn Total route length- 1100+ KMs *(including station, building & other construction costs)*	38.7 Mn

Above figures are calculated on the basis of data available on the internet and are indicative only.

Road map for execution of High Speed Rail in India

Primarily, following steps may be taken towards introduction of High Speed Trains in India:

- **Formation of Expert Panel on HSR–** A long term expert panel may be formed comprising officials of multi-disciplines at Railway Board and RDSO. Sufficient exposure at various leading high speed railways and industries may be imparted to the members of this expert panel, in order to have hands on experience of High Speed Rail.

- **Construction of Dedicated Passenger Corridors –** Like Dedicated Freight Corridors (DFC), separate elevated/tunnel tracks should be constructed for the purpose of high speed rail. These Dedicated Passenger Corridors will be useful to avoid mixed use traffic or other conventional slow passenger traffic.

- **Fund raising –** A Public-Private-Partnership (PPP) model or Built-Operate-Lease-Transfer (BOLT) model may be adopted for raising the necessary funds for HSR.

- **HSR development –** Following options are available for HSR development:

- Outright import of equipment including rolling stock and track
- Transfer of Technology with three alternatives:

1. Foreign turnkey consultancy

2. Study overseas and implementation
3. For operating speeds above 160 KMPH, technology may have to be imported and adapted

- Indigenous developments

In this context, Indian Railways has to choose from a number of competing options in the areas of Train speeds, traction technology, design of coaches, frequency of trains etc. For instance:

- Should Indian Railways go in for quantum jump in train speed like 450 KMPH or adopt cautious approach and go in for gradual increase in train speed, initiating from 200 KMPH and then to 250 KMPH, 300KMPH, 350 KMPH and more.
- Should the traction technology be wheel on rail or Maglev?
- Should the design of coaches be single deck or double deck?
- Should there be trains of less number of coaches with more frequency or longer trains with less frequent service?

On the way to High Speed Railway