# High-speed Railways: The Last 10 Years

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## Introduction

1 October 2004 is the 40th anniversary of the opening of the Tokaido Shinkansen, the world's first high-speed railway that marked the start of the era of high-speed rail travel.  Ten years ago, the October issue of *JRTR* 3 published a special feature entitled 30 Years of High Speed Railways. This article summarizes the events in high-speed railways in the last 10 years and discusses their future prospects.

## Speed Increase—History and Recent Trends

*Railway Gazette International,* the leading journal on world railways, publishes a World Speed Survey every 2 years.  The main part of this survey is a league table that ranks countries based on the fastest average speed between intermediate stops of regularly scheduled revenue-service trains.  Figure 1 is based on these surveys and shows past trends from 1975 for 11 countries ranked as trains operating at more than 150 km/h in the latest 2003 survey.  The Japanese shinkansen held the lead until 1981 when France opened the TGV Sud-Est with operations at a maximum speed of 270 km/h.  France and Japan then indulged in friendly competition with each other through the 1980s and early 90s (see *JRTR* 3, pp. 45–48), resulting in rapid improvements in their operating speeds.  France was the first to achieve operations at 300 km/h in 1989, but this was followed by a long interval with no further increases until 2003 when speeds reached 320 km/h over a limited section of the TGV Méditeranée.  This relatively small speed increase had little general impact and is not reflected in *Railway Gazette International's* latest survey.

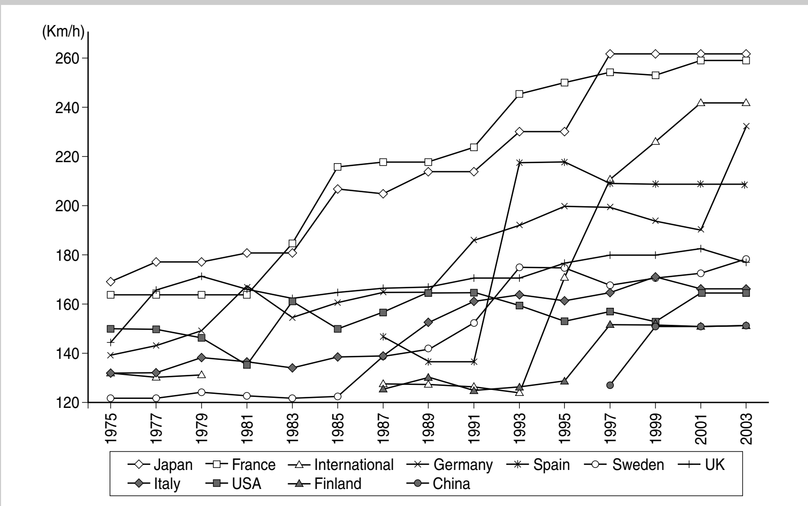
In Japan, after JR Central introduced the Series 300 *Nozomi* flagship services operating at a maximum speed of 270 km/h on the Tokaido Shinkansen in 1992, the two other shinkansen operators (JR East and JR West) joined the competition to develop new high-speed rolling stock.  In 1997, JR West began operating their Series 500 *Nozomi* at 300 km/h between Shin Osaka and Hakata on the San'yo Shinkansen, marking Japan's return to the leading position in the World Speed Survey. However, average speeds in both Japan and France have since shown signs of reaching a 'saturation' level and some flagship services in Japan are actually becoming slower due to increases in the number of intermediate stops.

High-speed operations are becoming increasingly widespread in countries other than Japan and France; Spain jumped from well behind to third position in the 1993 survey after the start of their AVE high-speed railway, which is largely an imported version of the French TGV. Another example is the improved speeds of some international services; in 1995, *Eurostar* services between London and Paris reached 171.5 km/h; in 1997, *Thalys* services from and to Brussels recorded speeds exceeding 200 km/h.  In the latest 2003 survey, Germany leapfrogged into third position with the opening of the Cologne–Rhein/Main high-speed line (NBS).  High-speed lines are expected to open in more European countries, because the EU is planning to expand its Trans-European high-speed Network (TEN) initiative eastwards following the addition of 10 new member states.

In April 2004, Korea Railroad (Korail), the former Korean National Railroad, opened its KTX between Seoul and Busan, using technology based on the TGV.  Korea is now the 8th country with trains operating at 300 km/h and only the second in the Far East after Japan.  However, this will change when the Taiwan High Speed Rail Corporation opens the Taiwanese high-speed railway between Taipei and Kaohsiung in 2005, becoming the first operator outside Japan to adopt shinkansen technology.  Not only will Korea and Taiwan both be joining future league tables, but China will soon be a player when the planned high-speed line between Beijing and Shanghai materializes.

To summarize, high-speed railways are

**Fastest Start-to-Stop Average Railway Speed for 11 Countries**




Source:  *Railway Gazette International*, World Speed Survey

JR West's Series 700 *Rail Star* running on San'yo Shinkansen (JR West)

spreading around the world where they are widely recognized as a safe, environment-friendly and efficient mode of transport. However, speed saturation is starting to appear at the top of the table. There are two major reasons why speeds increases are flattening out. First, the proportionally smaller speed increases no longer cut journey times by more than a minute or two so the impact on attractiveness to passengers and concomitant increases in passenger numbers are too small to justify the additional costs. Second, privatization and other rail industry shake-ups have seen increasing emphasis on encouraging people to travel by rail for its convenience rather than just on speed for its own sake.

## Rail Loses Environmental Advantage?

Today, the fastest speed of any scheduled service on conventional railways using steel wheels on steel rails is 330 km/h (for recovering from timetable disruptions) on the Cologne–Rhein/Main NBS. France also has a limited section of the TGV Mèditerranèe where 320 km/h is permitted, but the TGV Est is being built to a design speed of 350 km/h, as is the Barcelona–Madrid AVE line in Spain. In Japan, JR East has unveiled plans to develop shinkansen trains capable of reaching 360 km/h on the existing Tohoku Shinkansen (see article on pp. 14–17).

However, although these facts suggest that there will be further gradual increases in maximum speed, the EU European Research website says that, 'Although there are, no doubt, some who dream of trains achieving even higher speeds, this is not a realistic prospect. Noise, vibration, the cost of maintaining the track and rolling stock, and energy consumption (up by 50% for an increase in train speed from 300 km/h to 360 km/h) would all increase excessively for just a marginal time-saving.'

Recently, some critics have argued that railways are losing the environmental advantage they are said to have enjoyed previously. For example, Roger Ford quotes Professor Roger Kemp of Lancaster University in the UK and states that if a north-of-London *Eurostar* train set is used on a hypothetical 350 km/h high-speed line between London and Edinburgh (600 km), the energy consumption (estimated at 57 kWh/seat) converted to a crude-oil equivalent is more than that of an Airbus A321 short-haul aircraft flying between the same two cities. The author believes that Ford's conclusion that railways have lost their environmental advantage is not generally true at the moment, but it must be accepted that increases in maximum speed over 300 km/h will result in a sharp increase in consumed energy, mainly because of increased aerodynamic drag. This certainly leads to the conclusion that any further great increase in train operating speed is now very unlikely.

Apart from the problem of the global environment, high-speed railways also face problems regarding trackside noise. Although European high-speed railways enjoy lower trackside population densities than Japan, increasing lengths of high sound barriers along the tracks prevent passengers enjoying the scenery. In Korea, it has been reported that the initial intention of imposing the same strict noise limits used in Japan on the KTX was dropped because the new TGV-based rolling stock simply could not meet the limits.

These facts suggest that reducing energy consumption and trackside noise will be the next major advances in high-speed rail—areas where Japanese shinkansen are leading the way.

## Privatization and Competitive Transport Market

Following the successful privatization and division of Japanese National Railways (JNR) in 1987, many EU countries privatized their railways in the 1990s. The new organizational structures and effects varied from country to country. Although some delays in construction of new high-speed lines might be attributed to privatization, the overall impact of privatization on this type of investment is generally hard to quantify.

So-called low-cost airlines are becoming increasingly popular in Europe because they offer exceptionally low fares through various cost-cutting measures, such as narrower seats, shorter airport turnaround times, internet booking, use of small airports on the outskirts of larger cities like London, Paris, etc. High-speed railways now have to compete with these new

DB AG's ICE 3 standing at Cologne Station (Author)

market players, undoubtedly requiring cost reductions.

In Japan, flagship high-speed services are becoming 'slower' because of more intermediate stops. The initial concept of the *Nozomi* on the Tokaido Shinkansen was that it should link Tokyo Station and Shin Osaka in 2 hours and 30 minutes. However, following the opening of the new Shinagawa Station south of Tokyo Station, the journey time actually increased to 2 hours and 36 minutes, and new stops, such as Shin Kobe, also increase the journey time west of Osaka. But despite the slightly longer journey times, these new stops are contributing to increased ridership by offering passengers more opportunities to 'catch the train.' This demonstrates that passengers view a reduction in total door-to-door journey time as being much more important than just travelling at high speed between two stations on a shinkansen line. A valuable lesson can be learned from Switzerland where public transport operates to a regular-interval timetable and Swiss Federal Railway's Rail 2000 project aims at further improvements by investing in better connections at transport 'hubs.'

Obviously intermediate stops are undesirable for passengers not wanting to embark or disembark, and in addition to increasing travel time, they also increase train energy consumption. Information technologies (IT) offer the possibility of developing systems that strike a better balance between riding opportunities and speed and there are a number of proposals in Japan, including CyberRail (*JRTR* 32, pp. 28–34) and Intelligent Passenger Assistance for Public Transport (IPASS) in which IT is used to provide passengers with intelligent guidance while making it possible for the railway system to collect detailed information about passengers (*JRTR* 36, pp. 37–41).

These new technologies will permit more efficient operation of railway systems but to be successful, they must be highly reliable. In terms of punctuality (which is a reflection of reliability), Japanese railways have achieved outstanding levels. For example, the shinkansen has an average delay of only 6 s, which is especially significant in combination with its top position as the world's fastest train. However, Japanese punctuality comes with some lack of flexibility. For example, all train sets introduced after 1992 for the Tokaido Shinkansen have exactly the same number of seats (1323); this may have made it easier to deal with disruptions at Tokyo Station, which has limited capacity compared to the huge transport demand, but made it impossible to provide the variety of services offered by many main-line railways, making the Tokaido Shinkansen more like 'a high-speed metro.'

## Ongoing R&D

The Series 300 shinkansen entered revenue service in 1992 and achieved significant weight reduction compared to its predecessor Series 0 and Series 100 bullet trains. The major contributors to the lower weight were a new distributed traction system, as well as combining AC asynchronous traction motors and a Variable Voltage Variable Frequency (VVVF) control system with a lightweight aluminium-alloy monocoque body and bolsterless bogies.

Although the distributed traction system has two great merits of offering more payload space because there is no need for power cars, and better adhesion because more axles are powered, it is the regenerative braking at high speeds that gives distributed traction it overwhelming advantage. During regenerative braking, the traction motors are used as generators and the generated energy is returned to the catenary via the pantographs. The system is lightweight; all electric equipment—including the AC asynchronous traction motors—require almost no maintenance; brake pads and discs suffer reduced wear, leading to less maintenance; and the system is safer because no component gets very hot.

The successful Series 300 demonstrated these advantages and was soon followed by the German ICE 3. Even the design of the next-generation French AGV is expected to follow suit by adopting distributed traction.

Despite these new competitors, the Japanese shinkansen still has significant advantages, such as lightweight design, low trackside noise, and superior reliability. Even the major long-time weakness of current collection has been modified; the early 16-car Series 0 shinkansen had eight pantographs but now there are just two per train interconnected by a high-voltage onboard bus (The French TGV has only one pantograph.) Initially, the Series 300 suffered from poor ride characteristics, including high in-carriage noise, but the problems were fixed and the newest Series 700 is probably one of the best in the world. JR Central claims that the Series 700 energy consumption is just 14.7 kWh/seat when running between Tokyo and Shin Osaka at 270 km/h compared to 17.5 kWh/seat for the oldest Series 0 running at 220 km/h. Despite the increased operating speeds on the Tokaido Shinkansen, the total energy consumption has decreased over the past 10 years, while reliability has increased. For example, the frequency of incidents causing delays of 10 minutes or more is 0.01 per million car-km, which compares to the TGV's record of 8 per million train-km. (Note train-km and car-km are different units. Also, TGV 'incidents' cause delays of 15 minutes or more.)

There is no doubt that competitive development of high-speed railways will continue, but since the rate of increase in top speed is tailing off, competition based on energy saving, higher productivity, lower trackside noise, lower life-cycle costs, and other multi-dimensional comparisons will become more important. 'Soft' technologies will also contribute to better management of railways, through provision of improved passenger services.

Such developments will see speed increases up to 330–360 km/h.

## Maglev—The Next Step?

Apart from conventional railways, Shanghai in China has the Shanghai Maglev operating since 2003 between Shanghai International Airport and the city centre using technology from Transrapid, a German company. After some initial teething problems, it is now operating successfully at a top speed of 430 km/h—the fastest revenue service in the world. However, due to the initial problems and high construction costs, the Chinese government is believed to have abandoned use of this technology for the planned Beijing–Shanghai high-speed railway, although the Shanghai Maglev was built as showcase technology for this new route. There are currently no plans to use the Transrapid technology on any rail corridors in Germany.

In Japan, JR Central is leading the development of JR Maglev, which uses superconducting magnet technology. In December 2003, the test train established a world record of 581 km/h on the Yamanashi Test Line. Current development is focused on further verification of reliability and durability, cost reduction and improvement of aerodynamics. JR Central has improved the old Tokaido Shinkansen to its limit, and maintains a position of promoting maglev technology for the next generation high-speed rail link between Tokyo and Osaka. However, they claim that public funding is vital for the success of the project.

As is well known, Japan is buried under a mountain of public debt, preventing the government from moving on construction of a maglev shinkansen. However, the Tokyo–Osaka corridor is the only realistic possibility for maglev because its impact on a corridor with such huge transport demand would be far-reaching. Therefore, a major issue in the development of high-speed rail during the next 10 years will be whether Japan gives a green light to the maglev system. ■


### Further Reading

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