

# High-speed Railways in Germany

Klaus Ebeling

## High Speed?

When the railway appeared as a new means of transportation in the first half of the 19th century, its top speed of 30 to 40 km/h was considered dangerous. In Germany, where Adler transported two barrels of beer between Nuremberg and Fürth in 1835 as the first German rail freight, physicians warned people against such perilous adventures and farmers were worried that their cows grazing alongside the tracks would 'go mad' at the sight of the 'rushing steel monsters' and that the milk would sour.

Although these worries turned out to be unfounded, there were renewed warnings against further speed increases when railways were already well developed. In *Paris in the Twentieth Century* (written in 1863 but not published in English until 1997), Jules Verne (1828–1905), the famous French author of science fiction literature including *Around the World in Eighty Days*, *Twenty Thousand Leagues under the Sea* described a future fantasy world of shiny skyscrapers made of glass and steel, high-speed trains, gas-driven automobiles, computers, fax machines and a global communications network. Verne's farsighted vision of future technologies is set against the background of the tragic struggle of an idealistic young man searching for happiness in an unmerciful materialistic dystopia. In this gloomy picture, Verne fears the approach of a future in which loss of humanity is the price paid for the unscrupulous application of perfected technology.

Friedrich List (1789–1846), the founder of the German macroeconomic science, had a different attitude toward the new means of transportation. He was a champion of Germany economic unity and had a profound impact on German railways; he established the Leipzig–Dresden Eisenbahngesellschaft in 1834 as the basis

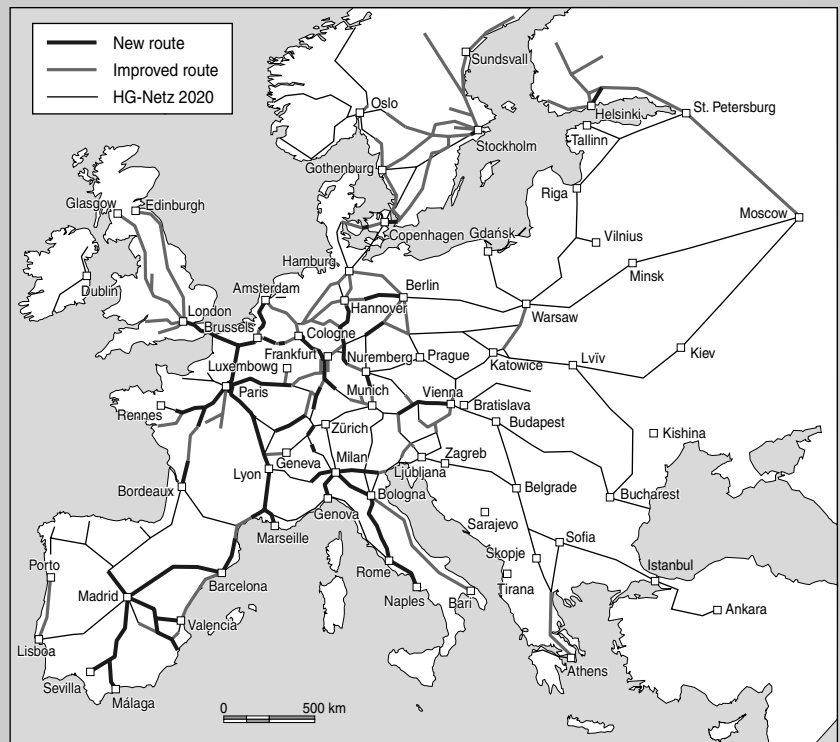
of his planned railway system covering all Germany. In *The National System of Economic Policy* (1841, uncompleted), his main work on economics, he countered Adam Smith's (1723–90) classic doctrine of free trade with a 'theory of productive forces' orientated toward economic practice and describing the impact of a speed increase in transportation on industrial and economic issues. Subsequent modern experience proved his hypothesis of the extraordinary economic development set in motion by shortened travel times and expansion of people's range of action. His appraisal was shared by Goethe (1749–1832) who did not experience rail travel but realized that such an effective means of transport could have political repercussions as well. Goethe said he was not worried about German unity (at that time Germany

consisted of several states) because the railways would solve the problem. History proved him right!

The railway's greater speed compared to previous means of transportation played a major role in the huge industrial boom in Europe and America at the end of the 19th century and railway's pre-eminence was only jeopardized by the later advent of the more-flexible automobile and the faster aeroplane.

The struggle for supremacy in transportation is not a recent phenomenon and railway advocates have long pondered how to compete against air and road. The earliest and obvious solution was found by increasing speed and the early years of the 20th century were marked by successive breakings of various rail speed records. In 1903, Germany set an early record of 200 km/h with an

Planned Trans European Network Transport (TEN-T)



Source: UIC

electric locomotive between Marienfeld and Zossen. A new dimension in commercial high speed on rails was inaugurated by the Deutsche Reichsbahngesellschaft in 1933 when the world-famous *Fliegender Hamburger* (Flying Hamburger) achieved an average speed of 122 km/h and a maximum speed of 160 km/h between Berlin and Hamburg. Japan's railways came to the forefront of attention in 1964 with still higher speeds when the Tokaido Shinkansen opened between Tokyo and Shin Osaka with operations starting at 210 km/h. The French topped this in 1981 with speeds of 270 km/h on the new TGV line between Paris and Lyon. These two mammoth railway achievements were followed by long debate on the relative merits of distributed traction (used by the shinkansen) and centralized traction with a locomotive (used by the TGV), as well as on the value of separation of passengers and freight or use of mixed transport. Germany finally followed the Japanese and French achievements with the development of the InterCity Express (ICE) described in more detail below.

As commercial speeds rose, various railway operators conducted ever-faster trial runs to investigate pushing the commercial speed envelope higher. France set a new world record for electric traction in 1955 with a test run of 331 km/h. This was broken by Germany in 1988 with an ICE test run of 406.8 km/h. This was beaten in turn a few weeks later by France with 408 km/h and then again in 1990 with 482.4 km/h. France still holds the current world speed record for wheels on rails with 513.3 km/h achieved in 1990 using a production TGV. These test runs have helped prove the reliability of rolling stock and infrastructure at high speeds and railway engineers now describe speeds above 200 km/h as 'high speed.' However, actual commercial speeds have gradually been pushed well beyond 200 km/h to



ICE 3 running parallel to the Autobahn A3 between Cologne and Frankfurt

(Bildarchiv DB AG)

reach between 300 and 350 km/h, depending on local topography, and the high-speed records prove that the wheel-rail system still has the technical potential to go beyond present commercial speeds, although noise and energy consumption considerations have prevented this so far. High-speed railways are being planned in other countries too, including Spain, Italy, Korea and Taiwan. In some countries, high-speed trains operate on existing conventional lines by keeping to the 200 km/h maximum limit. For example, Switzerland's mountainous topography allows no other solution that stays within reasonable cost limits. In Sweden, despite very long lines that can only operate at a profit by connecting major conurbations, the low population density makes little sense of going overboard on high-speed transportation. In mountainous countries, a common solution is to use tilting trains permitting up to 30% higher speeds on conventional lines.

### **Separate or Mixed Passenger and Freight Traffic?**

The German preparations for adoption of high-speed services saw a very time-consuming debate between the Ministry

of Transport and railway management centred on the key issue of whether new lines should be dedicated solely to passenger traffic (following the Japanese and French model) or whether mixed passenger and freight traffic would be best. The state railways obtained a large part of their income from freight traffic and were therefore inclined to offset the high investment in new infrastructure by serving freight traffic as well. On the other hand, some top persons advocated separation of passengers and freight. Although the Cologne-Frankfurt line was intended to be the first new high-speed line, the planning schedule has been delayed by this dispute to such an extent that it has fallen behind the Hannover-Würzburg and Mannheim-Stuttgart lines. Although the first decision was to build the Cologne-Frankfurt line as a mixed passenger-freight line, experience from the other lines showed that freight traffic could only be accommodated with severe restrictions. First, it was impossible to create a reasonable timetable for daytime freight due to large speed differences between passenger and freight traffic. Second, the required time slots for night freight traffic could not be allocated because high-speed lines

require high levels of maintenance that can only be done at night. The different weight of passenger and freight trains is another factor favouring separation of passenger and freight traffic; lighter passenger trains can negotiate steeper grades (35 per mil or 35‰) than heavier freight trains (10 per mil or 10‰), permitting more direct alignments with fewer tunnels. The Hannover–Würzburg line was the first to be operated at high speed but the initially planned freight traffic was soon discontinued for the above reasons, only to be subsequently resumed. At present, heavy freight trains run every 6 minutes at night at 120 km/h, while more lightly loaded trains are permitted to run at 160 km/h.

Another dispute that required resolution was the incompatibility between high-speed traffic and short-distance traffic, especially in conurbations. The solution required separation of the two infrastructures and giving priority to high-speed services. But freight traffic is now demanding the same privileges to protect its business quality, which suffers serious delays at some times of day by being ‘pushed aside’ in favour of short-distance commuter traffic, which has absolute priority. To their regret, freight traffic managers cannot overcome this inherent disadvantage of freight through extra payments to the infrastructure manager/owner, because the priority of commuter traffic is based on social necessity.

Another key issue that became an almost ideological debate was about whether future high-speed rolling stock should use distributed traction like the Japanese shinkansen or be hauled by powerful locomotives like the French TGV. Advocates of distributed traction argued that it enables flexible adjustment of capacity to demand. Its opponents argue that in a high-speed world, no time would be available for shunting and flexibility only makes sense if two or three motor units can be coupled together.

Even more fundamental questions were being raised about the necessity for high-speed trains based on economic, social and environmental objections. Undoubtedly, high-speed track, rolling stock, and safety infrastructure are incredibly expensive and state funding tends to leave government coffers with hardly any funds for regional middle-distance traffic. Short-distance commuter traffic tends to be exempt from this problem because politicians realize that public service obligations (PSOs) are a hot potato they ignore at their peril. Critics of high-speed rail argue that there is no good justification for ignoring middle-distance regional traffic, which carries many more ordinary people than the ‘elite’ high-speed traffic used mostly by a relatively small number of business travellers. A second fundamental criticism of high-speed trains is that they consume too much energy and generate too much noise. The energy merits of high-speed trains versus short-distance air travel have been questioned by Professor Roger Kemp of Lancaster University in a recent UK study, but opinion remains divided. Environmental criticisms have been rebuffed so far by taking careful measures to protect wildlife. For example, expensive sound barriers have been built to protect the breeding sites of bustards, etc., and deer can continue following 1000-year old paths through railway underpasses.

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### Rolling Stock

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The German ICE operated today by Deutsche Bahn AG (DB AG) was preceded by the short-lived Class ET403 railcar developed in 1972 by Deutsche Bundesbahn (DB). The German intercity network was inaugurated during the 1971–72 period coupled with a massive timetable revision and the development of the ET403 railcar at the same time that

the state-of-the-art Class 103 electric locomotive came into scheduled service and is a good indicator of the internal disputes described above. The ET403 came into full service with the 1974–75 winter timetable revision and was actually a very advanced concept. It had underfloor motors driving all axles, providing advantages of low axial load, reduced rail wear and good acceleration. Passive tilting technology enabled it to travel at a maximum speed of 200 km/h even on tracks with many curves but technical shortcomings made some passengers travel-sick, resulting in the temporary abandonment of tilting technology. On the other hand, the air-bolster suspension provided a very comfortable ride in combination with a luxurious interior with heated window panes and swivel seats. Although the first-class-only *Star* train continued the *Rheingold* luxury coach tradition, and was very popular with the travelling public, only three sets were built and they remained in service for just 4.5 years until the 1978–79 winter timetable revision. Their operation life was short because lack of suitable tracks mostly prevented them running at their maximum speed. However, economic and ecological reasons prompted the Ministry of Transport to implement a policy of replacing internal domestic flights with railway services and the ET403 was revived in March 1982 as the *Lufthansa Airport Express* service between Düsseldorf and Frankfurt. The concept was expanded using loco-hauled trains between Stuttgart and Frankfurt but was discontinued when the discovery of severe corrosion damage forced the ET403 to be scrapped. This early sensible cooperation between rail and air services was continued by allowing air travellers to reserve seats on regular trains. Undoubtedly, DB’s ET403 was ahead of its time and must take the honour of being the forerunner of German high-speed services.



Driver's cab of ICE 3

(Bildarchiv DB AG)

Despite the problems with the ET403 and the success of the Class 103 locomotive, DB proceeded with designing an EMU taking into consideration aerodynamic requirements at higher speeds. After extensive studies by the Federal Ministry of Research and Technology (FMRT), financing was secured to start building the Series 410-001 InterCity Experimental in September 1982. About 60% of the DM94 million in construction costs was covered by the FMRT with the remainder borne by the manufacturers and DB. The Class 410 entered service on 19 March 1985 soon after leaving the works and became the first train in the history of German railways to pass the 300 km/h mark on a test track between Bielefeld and Hamm on 26 October 1985 when it set a new record of 317 km/h. This record was broken again by the ICE when it set a world record of 406.9 km/h on 1 May 1988.

The InterCity Experimental incorporated various design innovations from the fields of aeronautics and aerospace engineering to achieve excellent aerodynamic performance. The axles used solid monobloc wheels as well as air suspension. The two power units had powered bogies with two three-phase asynchronous motors each for a total rated power of 4.2 MW. The braking system

was especially noteworthy because it consisted of an electrical regenerative brake, mechanical disc brakes and a rail brake using eddy current.

While the InterCity Experimental (sometimes called the ICE-V) was still in development, in the summer of 1988, DB ordered 82 units of the first-generation Class 401 ICE 1. It was designed to reach a maximum speed of 280 km/h on new tracks and 200 km/h on existing tracks. The maximum speed through tunnels was limited to 250 km/h due to large pressure-wave effects in trains closing head-on. The ICE 1 train set consists of two identical motor cars (one at each end) and 12 cars between them. An optical-fibre control cable runs the full 400-m length of the set ensuring that driving and braking commands arrive practically simultaneously at both motor cars. If the optical fibre parts while the train is moving, a fail-safe mechanism activates full service braking (automatic train stop). The ICE 1 has a Scharfenberg coupler that allows an ICE to be towed in an emergency but does not permit double heading of two ICE trains, which only became possible with ICE 2 trains (Class 402).

The two ICE 1 motor cars have independent brake systems. Most service braking uses the regenerative brakes and

the pneumatic disc brakes (two per axle) are only used when additional braking power is needed and to prevent a stopped train rolling. In addition to disc brakes, the passenger cars also have rail brakes but the system is different to the eddy-current based rail brakes of the ICE-V, which had brake problems. The ICE-V suffered from some noise and vibration, especially in the restaurant car, so DB changed from the earlier solid monobloc wheels to resilient wheels. Although this change cut the in-carriage noise and vibration, the disintegration of the tyre of a resilient wheel was a principal factor causing the Eschede accident in June 1998 that killed 101 people. As a result, all trains have been retrofitted with the original solid monobloc wheels.

Compared to the French TGV, the ICE 1 is much more comfortable and more spacious but at DM50 million per train, it is nearly three times more expensive than a TGV Atlantique train. The much higher cost is mainly due to the more complex electronics in the monitoring and diagnostic systems. On the other hand, the TGV has the advantage of Jacobs-type bogies with superior aerodynamics and better stability in a derailment. However, the TGV has disadvantages of narrower car passages and a restricted axle load of 17 tonnes. Although the TGV intermediate cars are shorter than those of the ICE 1, two TGVs can be coupled to provide an adequate number of seats even during peak periods.

The ICE 1 changed the fundamentals of German railways; speeds of 310 km/h were easily reached during test runs in summer 1990. The first 23 trains entered scheduled service at a maximum speed of 250 km/h between Hamburg and Munich in June 1991, considerably shortening travel times between many German cities and cutting 62 minutes off the journey between Hamburg and Frankfurt and up to 115 minutes from Hamburg to Stuttgart.

Services were easily extended into Austria and Switzerland although Swiss services required addition of a narrower pantograph. However, international services to the Netherlands, Belgium and France were blocked by incompatible signalling; France also objected that the ICE trains are too wide and too heavy for the French gauge. On the other hand, an ICE 1 train set even made a transatlantic journey as described in the article by Mr Black on pp. 18–21 in this issue of *JRTR*. Although the ICE 1 set an American speed record of 260 km/h and operated as the Amtrak *Metroliner* for several months, a variant of the French TGV was chosen for budget reasons.

Following the first 60 ICE 1 train sets, DB ordered 44 second-generation ICE 2 train sets in August 1993. They are shorter sets that can run on busy track sections as a combination of two coupled trains and double heading. Some pantograph problems arose because vibration of closely adjacent pantographs causes the trailing pantograph to lose proper wire contact. Tests were run in cooperation with TGV engineers—who have been double heading TGVs for more than 18 years—to solve these problems and for testing the bow flaps for firmness in the opened state. Following the tragic Eschede accident in 1998, DB AG fitted the ICE 2 with an early warning system to detect incipient damage to bogies and wheels. Sensors on each bogie detect the occurrence of cracks or other signs of wear from the bogie vibration profile. Apart from the ICE, only *Eurostar* services through the Channel Tunnel between Europe and the UK have this type of wheel diagnostics. A special problem occurs when the driving trailer of the ICE 2 is running in the lead. Since the driving trailer has no motors or power converter, it is lighter than the driving unit and there is danger of the trailer rising and derailing when there are strong cross-winds on open sections. In the UK, this problem was

solved for the Inter City 225 by using an artificial ballast. In Germany, wind breaks and protective walls have been built along the track and anemometers are installed at known windy locations. When the wind speed exceeds the threshold, a signal is sent directly to the ICE automatic train control system informing the driver to slow to a maximum speed of 200 km/h even on sections with a speed limit of 250 or 280 km/h. This problem does not occur when running with the driving unit in the lead or when double heading with the driving unit at the front, so the speed restriction does not apply in these cases. The ICE 2 started commercial operations in June 1997 on the Cologne–Hannover–Berlin line at maximum speeds of 250 km/h. This limit was later increased to 280 km/h except in tunnels. Initially, ICE 2 trains only served east–west lines but they are now found on most ICE lines except in Austria and Switzerland. A more powerful computer was installed to improve control for double heading as well as for better wheel-slip and wheel-skid prevention. Data are displayed on two monitors, one each in the lead and trailing units. The bogies are fitted with air suspension to improve the running stability over the ICE 1, making it possible to retrofit the low-maintenance time-tested solid monobloc wheels without problems. The ICE 2 exterior is similar to that of the ICE 1 but the domed roof of the restaurant car (which was criticized by the public as being out of harmony with the overall design theme) was eliminated for aerodynamic reasons. The passenger seats weigh only 25 kg, 50% less than ICE 1 seats. Every car has power outlets to support AC operation of laptop computers. However, despite the overall success of the ICE 2, DB AG does not envisage placing another order for more sets because the 40 per mil (40‰) grade on the planned Frankfurt–Cologne high-speed line would overtax the present ICE series.

Following the ICE 2, DB AG faced a major decision about whether to stay with the present system of centralized traction or to develop new distributed-traction EMUs like the Japanese shinkansen. Past French and German experience spoke for keeping centralized traction, but economic considerations favoured a different solution. For example, about 17% of a 200-m long French TGV is occupied by the two motor cars, which do not produce fare revenues from seats. In the case of a shinkansen EMU where traction motors are distributed throughout the train length, passengers can be seated along the full length except in the driver's cab. Moreover, the EMU principle has the advantage of low static axle loads meaning less track wear and tear, etc.

The optimum internal divisions and external design were determined by building a full-scale model in 1996 and ICE 3 production started a year later. Although DB AG had to wait a long time before the ICE became a distributed traction system, the ICE-M is now a reality. Seventeen of the first 50 ICE 3 sets (Class 403) are multiple units (Class 406). Four of the first 17 sets were supplied to Netherlands Railways (NS) due to urgent rolling-stock needs, and December 2000 saw ICE 3 trials in Switzerland. More ICE 3 tests were made in June 2001 between Strasbourg, Nancy, and Mulhouse in France. A train was tested in Belgium in January 2002 and subsequently made test runs between Calais and Lille. The French trials were made to test the compatibility of power systems and brakes with SNCF regulations, as well to investigate the interaction between the pantograph and catenary. The goal is to obtain type approval for operations on the French network. Eleven ICE 3 train sets were incorporated into the timetable for the Hannover EXPO 2000, meeting with success right from the start. ICE 3 services have been operating between Frankfurt (Main) and Cologne every 2 hours since 4 November 2000

with alternate intermediate stops at Limburg, Montabaur, and Siegburg; every train stops at Frankfurt Airport and service frequencies were increased to 1-hour intervals on 15 September 2002. Six new ICE lines are now running on this new infrastructure.

Raising the maximum speed to 300 km/h soon showed up a number of deficiencies in couplings, air-conditioning, rail brakes, disc brakes and motors. The remedies required many meetings between DB AG and the builders, suggesting that the development time was too short and DB AG did not allow sufficient time for operation tests.

ICE 3 services have been running to Amsterdam since June 2000 and three runs per day were added between Frankfurt (Main) and Brussels (Bruxelles-Midi) in time for the 2002 winter timetable. Unfortunately, use on the Belgian high-speed line has yet to be approved, so the ICE 3 services run on the old line, taking 15 minutes longer than would be possible on the high-speed line. When the high-speed tests have been completed, the journey between Frankfurt and Brussels will drop to 3 hours and 32 minutes. The future TGV Est Européen line from Paris via Strasbourg to Munich will be served by both French TGVs and German ICE 3s. Spanish National Railways (RENFE) has decided in favour of the ICE 3 for its service on the new Madrid-Zaragoza-Barcelona line where trains will run at service speeds of 350 km/h—the highest in the world.

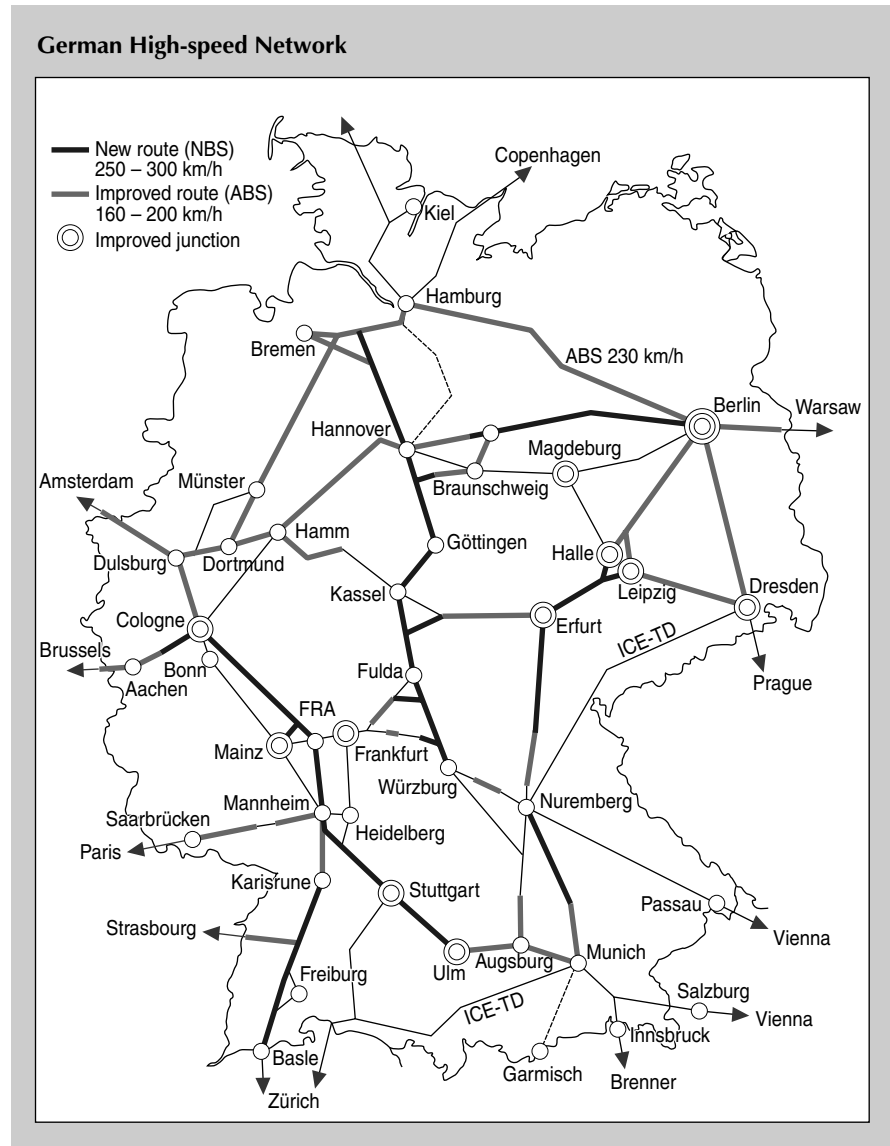
This performance is possible because half of all the ICE 3 bogies are powered, guaranteeing excellent acceleration. Unlike the TGV, centre bogies were not chosen because priority was given to quick bogie replaceability. The new SGP 500 bogie used by the ICE 3 is lighter than the SGP 400 of the ICE 2, and the still older design of the ICE 1. Both the design of the bogie frame and coach body ensure very quiet running. All bogies have disc

brakes while the traction motors serve as regenerative brakes supplying power back to the catenary during service braking. The pneumatic disc brakes are only used at lower speeds. Since some countries do not permit back-supply to the catenary at regenerative braking, brake resistors are installed in the ICE-M units to absorb the regenerated power as heat. Rail braking using eddy current is very effective under all rail conditions but the high magnetic field induced by eddy current

can interfere with signals, so trackside signalling systems must be shielded. The ICE 3 train sets have lavish interiors with an attractive lounge at each end where passengers can get a driver's eye view of the tracks.

### The German Railway Network

Heavy aerial bombing during WWII left the German rail network badly damaged.



Moreover, the political division of Germany into West and East cut the mainly east–west oriented network, forcing a north–south reorientation in what was then West Germany. The West German federal government developed a comprehensive plan for the entire transportation infrastructure including railways. The DB component envisaged 2225 km of new lines supporting speeds up to 300 km/h and development of a further 1250 km for speeds up to 200 km/h. Work on the first new Hannover–Würzburg line (327 km) started in August 1973 and it was opened in sections between 1988 and 1991. Other new lines were envisaged between Cologne and Frankfurt (177 km), and Mannheim and Stuttgart (100 km). The latter line was opened between 1987 and 1991. However, the First Gulf War and subsequent oil crisis forced the plans to be scaled back; the Cologne–Frankfurt line was dropped and less ambitious operations targets were set for the other new lines with mixed passenger and freight traffic running at maximum speeds of 200 and 80 km/h, respectively.

The 1981 opening of the first TGV line between Paris and Lyons and subsequent successful operations inspired DB to formulate a High-speed Transportation Plan for the Nineties in 1984. The three key elements were full utilization of the planned new lines and extensions; development of high-speed trains based on the latest R&D into ‘wheels on steel’; and further development of the Inter City system started in 1979 under the slogan ‘Every hour—Every class’ and now forming the core of passenger traffic on regular lines.

The commercial idea was based on the concept of ‘half as fast as the aeroplane—twice as fast as the car.’ In contrast to the French concept, the proviso was that high-speed trains should only operate to a minor degree on conventional lines, because they could not display their advantages on such lines. On the other hand, Germany’s polycentric structure

made it impossible to operate radially from the centre of the country; the existing IC network formed the shape of a figure ‘8’ with hub stations where passengers could make easy cross-platform connections to another line.

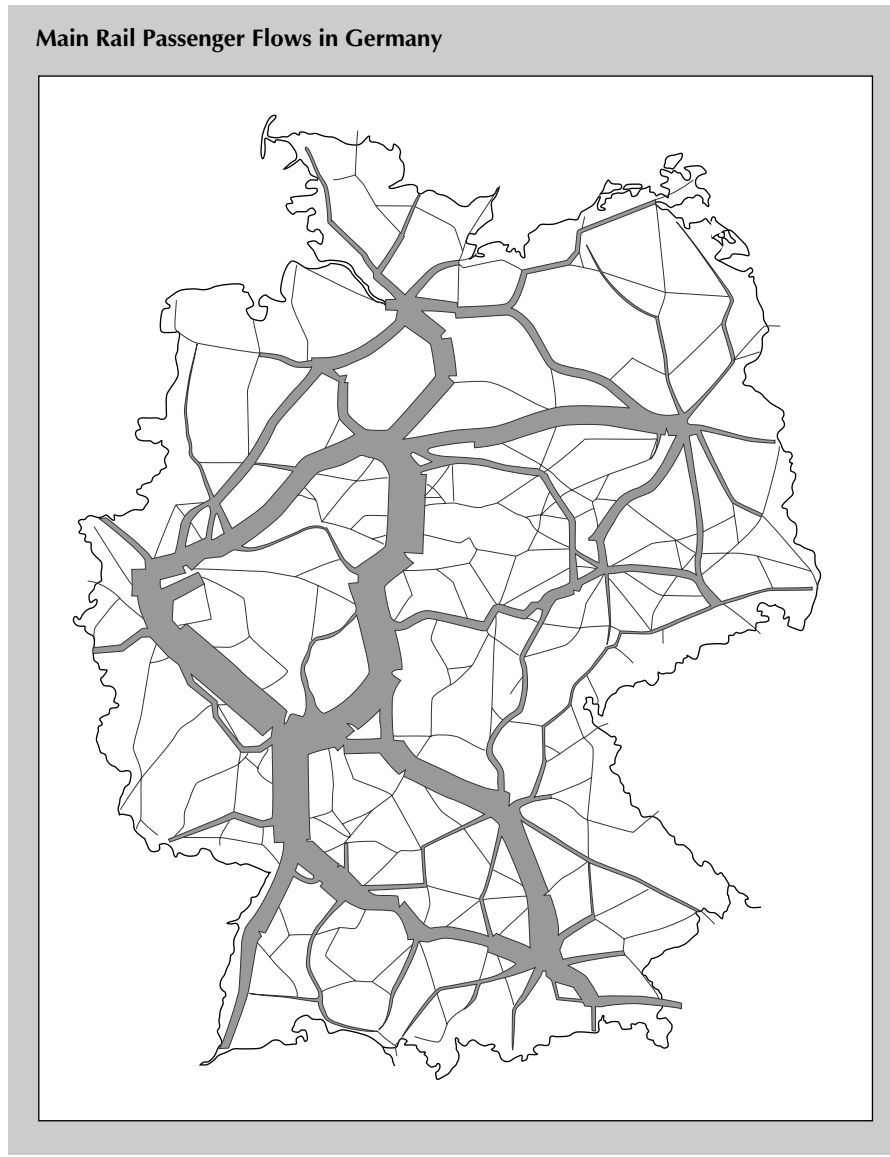
In the course of this new impetus, planning of the Cologne–Frankfurt line was resumed, but now as a pure passenger line. However, it was not the next line to be handed over to passenger traffic. Due to the sudden fall of the Berlin Wall and subsequent German reunification, the ‘provisional’ West German capital of Bonn was moved back to Berlin, resulting in the relocation of the German government and making new transport planning an urgent necessity. In 1992, a new federal timetable was issued which foresaw a new line between Hannover (more precisely Wolfsburg) and Berlin. It too was to be solely a passenger line with the old tracks running parallel to the new alignment to be freight-only. Clearly a new railway strategy was in the offing—systematic separation of passengers and freight—under a plan known as ‘Network 21,’ the name indicating the enormity of the task. The so-called East–West line entered operation in 1998, while the Cologne–Frankfurt line was delayed until 2002.

Due to constraints on the public purse, new plans today centre on projects to complete the intra-German system, including raising speeds on the Hamburg–Berlin line to 230 km/h and connecting the southern conurbation of Munich via Thuringen (Erfurt) and Saxony (Leipzig) to Berlin. However, as the central railway, DB AG must comply with EU plans for European-wide rail transport. The Mannheim–Basle line is important for southbound traffic to Switzerland and Italy, and the Cologne–Aix-la-Chapelle–Lüttich link will complete the Paris–Brussels–Amsterdam–Cologne (PBKA) system. Extensions, starting with the Frankfurt–Basle line towards Saarbrücken and Strasbourg will make a great

contribution to the European Paris–eastern France–south Germany–Vienna axis (POS). Although we are still seeing what has been termed the ‘frontier effect’ (in which a full train becomes nearly empty at the last border station and then fills up again at the first station across the border), the plans for a European high-speed network introduced as early as 1989 by the International Railway Association (UIC) and the Community of European Railways (representing railways at the EU in Brussels) are continuing and are reflected in the concept of the trans-European network pursued by the EU Commission. The Commission made an important contribution by pushing interoperability in the European high-speed system. It issued guidelines on interoperability that came into effect on 17 September 1996. The amended guideline became part of German law in 1999 and stipulates the key aims of interoperability, the scope of application and implementation of provisions, as well as the process for drawing up and adopting the technical specifications for interoperability. The guideline sets its sights on the entire system, both infrastructure (track, power supply, train control/signalling, and rolling stock) and performance (maintenance, operation, environment, and passengers). The aim of the Commission’s policy is free, unimpeded transport of goods and passengers within the European market. Although there was some previous compatibility in conventional traffic, with passenger carriages and freight wagons travelling across borders throughout the entire continent, the different power and signalling systems represented obstacles that hindered the transition of national railway systems to a liberal Europe-wide railway market. The problems of different power supplies were solved by development of multiple-power systems because nobody had the massive funds required to standardize power supply systems. However, standardization of

signalling on which high-speed technology is very dependent is considered rational. Therefore, the EU is supporting development of a standardized European signalling technology called European Railways Transport Management System (ERTMS) or, in accordance with the parlance of railways, the European Train Control System (ETCS) using funds from the research budget. Introduction of ETCS is intended to supplant the multitude of national train-safety systems in high-speed railways, enable more intelligent design of train control and safety through integration, save costs for maintenance and operation of fixed installations, and increase line capacity and speeds. In 1999, the ETCS specified by the UIC was successfully tested on the Vienna–Budapest line but DB AG estimates that Europe-wide introduction of ETCS will take 15 to 20 years with costs of about €500 million in Germany alone and about €8 billion Europe-wide. The present system, which is backwards-compatible with existing signalling systems, is not yet fully mature, so DB AG had to delay its planned introduction on the new Cologne–Frankfurt line and reverted to DB AG's proven continuous train control system (LZB).

Unlike conventional systems, with the LZB system the train driver is not guided by trackside signals, which only safely permit speeds up to 160 km/h due to slow human reaction times. Instead, the driver follows information displayed in the cab. The most distinctive feature of the system is one cable running along the middle of the track and a second cable running along the inside rail. The cables cross every 100 m at track conductors and data is passed from these crossing points to the connected signal box. The dispatchers, stationmaster, etc., can determine the train location to within 100 m. Three LZB computers operating in parallel in the signal boxes feed data to the track and get data from it. At least two of the three



computers must arrive at the same result before a command is passed on. This technology extends the 'view' of the train driver by several kilometers, permitting on-time driver reactions even at substantially higher speeds. A development of LZB is the so-called Computer Integrated Railroad—Increase of Efficiency in Core Network (CIR-ELKE) system, which permits more trains to travel along a track and increases track capacity one step further.

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### Economics

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The high-speed trains of DB AG met with immediate popular success just like their predecessors in Japan and France. The number of train-kilometers increased and demand showed corresponding growth with improving revenues in long-distance passenger traffic. In Germany, with its large population and polycentric conurbations, the economic efficiency





Transrapid maglev running on test track

(Author)

could be sound if the federal government continues helping to fund new infrastructure. However, the low population density in France coupled with smaller and fewer conurbations suggests there is a limit to the profitability of high-speed railways there.

The new efficient high-speed railways have had more impact on air traffic than road traffic; short-haul air traffic has declined noticeably wherever high-speed train services make an appearance. This is especially apparent in France where all air services between Paris and Brussels have been discontinued because the TGV runs from Brussels' South Station to Paris' Charles de Gaulle Airport and from Paris North to Zaventem International Airport in Brussels. Since the TGV Méditerranée started covering the 700 km between Paris and Marseille in 3 hours, many airline customers on this sector have changed to the train. This policy has been pursued in Germany by including the airports at Frankfurt and Cologne in the high-speed network. Budget airlines are a danger due to their unbeatable low prices thanks to fuel and VAT tax exemptions and sometimes preferential treatment by local

authorities. Whether this is a correct policy in view of efforts to use more environment-friendly transportation is hotly debated in Europe. However, high-speed rail passenger traffic in Europe still looks very promising, especially after the next round of line improvements.

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### Alternatives to Steel Wheels on Rails?

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The German magnetic-levitation (maglev) system recently commercialized in Shanghai might suffer the same fate as many other German high-tech developments. The development of magnetic-levitation systems goes back to 1922 when Hermann Kemper was the first person to consider replacing train wheels with electromagnets. Although he patented his idea in 1934, the technology at that time was inadequate to realize his vision of 'flying at zero altitude.' Research on magnetic levitation was only resumed in 1966 by a development team at Bölkow KG. In 1968, Bölkow KG, DB, and Straba Bau AG established a company to evaluate the feasibility of magnetic-levitation technology compared to wheel-

rail technology. It found that a magnetic-levitation 'railway' could be profitable along Germany's north-south axis. In the same year, a maximum speed of 70 km/h was achieved by an experimental vehicle on a 660-m track, providing proof of the technology concept.

Development of a magnetic-levitation train in Japan began 2 years later than in Germany. Its proponents promised lower noise levels with higher speeds than the shinkansen. Japan Airlines (JAL) sensed a good business chance with 'flying at zero altitude' and joined the development effort in 1971 using West-German technology. However, the experimental vehicle produced in 1975 was very different from the German prototype. By 1977, the HSST-01 had reached speeds of 150 km/h soon rising to 500 km/h state-of-the-art magnetic trains but no practical application was adopted. The idea of building a magnetic train between Hamburg and Berlin was rejected by the head of DB AG on the grounds of being uneconomical. A minor success was achieved in January 2001 when China decided in favour of the German *Transrapid* for services between Shanghai's financial centre and Shanghai International Airport. After some teething troubles, the system has been running since early this year at speeds up to 430 km/h. Some proponents hoped it would also be adopted for the Shanghai-Beijing high-speed line, but traditional wheel-rail technology was finally chosen instead. France also tested some alternatives to wheels on steel even before the TGV, using the guided rapid-transit *Aerotrain* running at 418 km/h. To stay on track, the system had a concrete guideway with concrete centre rail. A working model was built in 1963 to promote the idea of a rapid-transit connection between Paris and Lyon at 350 km/h but the project did not reach the production stage due to political reasons. However, Jean Bertin became

famous in railway circles with his development of the air-cushion vehicles. Since these new systems are not easily compatible with conventional wheel-on-steel railways, it seems unlikely that they will be successful. There may be some potential for long routes between Western/Central Europe and Moscow, or for Eurasian routes of 10,000 km or more. However, the outlook is poor and manufacturers and potential operators are making only hesitant development attempts when governments come up with guarantees or subsidies. At present, it seems more reasonable to develop conventional Europe-wide railways with complete interoperability.

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## Outlook

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Although the plans for new and extended high-speed routes for passenger traffic look promising, there must be a change away from the old postwar policies favouring roads over rail. For a region-wide population, continued heavy reliance on the automobile and highways might be sustainable in Europe if all freight switched from road to rail. The railways have shown that there is still development potential but the next important stage is straightening out freight and passenger transport as envisaged by DB AG's Network 21 plan for 6000 km of new lines by 2010 supplemented by line extensions. Perhaps high-speed freight transport might be possible given sufficient resources with direct connections across 1500 to 2000 km, or in a hub-and-spoke system up to about 750 km around an intercontinental airport. How liberalization of the railway market will impact the EU in the long term is anybody's guess. So far, only small parts of short-distance traffic and even less of medium-distance traffic have transferred to newcomers. Inauguration of high speed by a newcomer railway seems out of the



Eurotrain with double-decker carriages

(Author)

question under current conditions. The immensely high requirements concerning technology and financing have given the few major national railways embarking on this new technology an enormous head start that will be very hard to catch up with. What will happen where high-speed passenger trains cross borders? Will there be cooperation like the present examples of *Eurostar* and *Thalys*, or will cross-border competition develop as between *Thalys* and the ICE on the Cologne–Brussels line? In freight, the establishment of Railion by DB AG has formed the nucleus of a successful international freight-traffic railway. Could this also happen in high-speed passenger transport? According to the press, the heads of SNCF and DB AG have discussed whether SNCF should take over high-speed passenger transport in Europe in return for DB AG taking over continent-wide freight traffic. In this matter, the EU Commission has signalled

that it would not accept such an arrangement unless there was competition. ■



### Klaus Ebeling

Mr Ebeling is Secretary General of the European Intermodal Association. He has held various high-level railway posts including Head of the European Policy Office of DB AG in Brussels, Executive Board Director of DB AG, Deputy Secretary General of UIC, Head of International Department of DB, and personal advisor to the President and CEO of DB.