The Shinkansen—World Leading High-Speed Railway System

Roderick A Smith

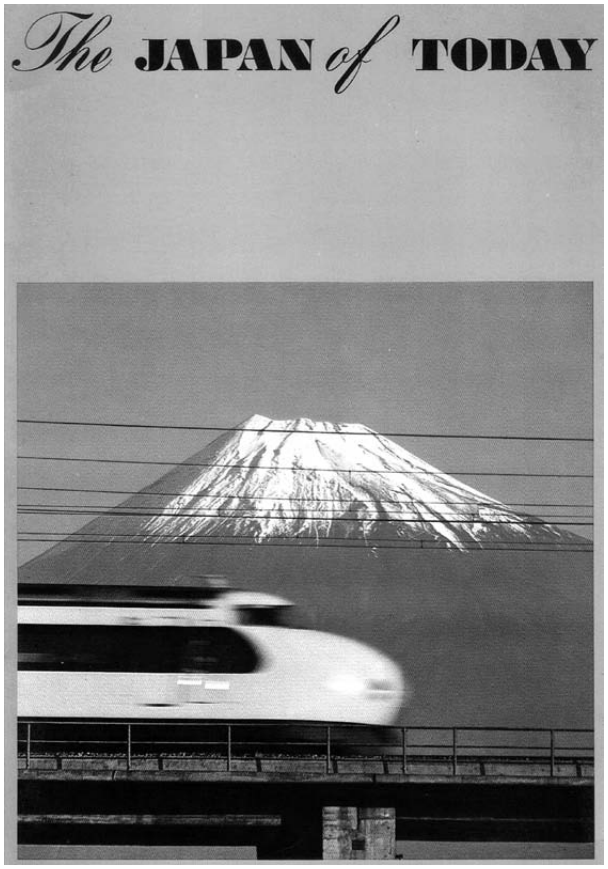
Every time I enter the shinkansen at Tokyo Station, I pause to read the dignified plaque written in both Japanese and English, which proclaims:

New Tokaido Line
Product of the wisdom and effort of the Japanese people
Tokyo-Shin Osaka 515 km
Work started 1959 20 April
Opened to traffic 1964 1 October.

What a marvellous evocation of the unity of purpose and of the pride that the Japanese people felt for this achievement. The inscription on this plaque can hardly be bettered. The opening of the line coincided with the 1964 Summer Olympics, a visible symbol to the world that Japan had emerged from the dark days of the war and post-war depression. Indeed, from about that date, the Western world began to look to Japan as a model for successful manufacturing, based on consensus and harmony with the people; Western businesses asked for advice and began to wonder how the 'economic miracle' had been achieved. However, the railway world was initially somewhat muted in its praise for the shinkansen, and although the round-nosed streamlined trains rapidly earned the affectionate 'Bullet Train' title with the public around the world, it was to be some time before other railway administrations recognized the scale and success of the Japanese achievement.

In order to put the shinkansen into historical context as we approach its 50th birthday, this article discusses the opening of the new railway, its development and its impact on Japanese society and on the environment. Its life as a system is emphasized together with human factors and safety. The article mentions overseas reactions to the shinkansen at the time of its birth, and how the shinkansen subsequently impacted railways outside Japan. It concludes with a personal view of the future of high-speed railways*[1].

Perhaps, first I may indulge myself with a personal anecdote of my own involvement with Japan. In 1969, I was an undergraduate at Oxford. A close friend told me he could invite a companion to the birthday party of Prince Tomohito of Mikasa (a first cousin of the current Emperor) who was then studying at Magdalen College. Out of curiosity I tagged along, only to be instantly fascinated by the Japaneseness of the event: sumo, flower arrangement, origami, drumming, with drinks and Japanese snacks served by the most charming, smiling and beautifully kimono attired Japanese girls. I resolved to increase my knowledge, then almost zero, of a far-off country which could produce such elegance; this resolve was strengthened when on leaving the party, we were presented with a well illustrated book, *The Japan of Today*, which described many aspects of the development of shipbuilding, manufacture of cars, precision machinery, cameras and electrical equipment, some examples of which were just beginning to arrive in the West. But most striking



The author's introduction to Japan, 1969 (Author)

*1 In the spirit of an informal opinion piece, I have not included detailed references and footnotes. This footnote is an exception, given for explanation. A short further reading list is appended.

First ride Tokaido Shinkansen Bullet Train 1974 (Author)

The author initiated from JR Central of this retired Series 0 to the National Railway Museum, York, UK (NRM)

of all was the picture on the front cover of the Bullet Train streaking past Mount Fuji—a powerful, and now famous image, combining the essence of speed, streamlined beauty and excitement with the potent symbol of Japan's highest mountain. Irresistible! 'I want the shinkansen to complement the beauty of Mount Fuji', said Shinji Sogo, so-called father of the Bullet Train. As a young engineer, I resolved to further my knowledge of Japan and its railways. Reducing a long story to its essentials, I first visited Japan in 1974 to meet the family of my wife to be. I have lost track of the number of subsequent visits, some extended, and the huge number of trips I have made on the shinkansen system as its geographical reach has widened. I have promoted the gift of an original bullet-nosed leading car from the Series 0 shinkansen to the National Railway Museum in York in the hope that it may help make the UK realize what it has been

The evolution of the Bullet Train to the Series 500 (Author)

missing. There are strong signs now that this may have been achieved.

Building Tokaido Line

Despite the words on the plaque, the concept of the Tokaido Shinkansen was not without its critics. Some likened the project to the Great Wall of China or the battleship *Yamato*, some had more personal or local concerns, some were concerned about their proximity to the route (others, of course, felt they were too far away) whilst yet others thought the country could not afford the project. However, the many and various objections were overcome and the line opened on 1 October 1964. The reaction overseas was initially muted. This was the era of the automobile in which railways worldwide were seen as yesterday's technology, and were generally in decline and haemorrhaging money. But in Japan private car ownership was in its infancy, the national road network was poor and major intercity highway building had yet to happen. *The Times* of London did manage to raise some enthusiasm, but with financial misgivings:

All the seats on Japan's latest wonder were sold out the first day of advanced booking. From early next Thursday morning so named Hikari (Light) and Kodama (Echo) electric expresses will leave every half-hour from Tokyo and Osaka to give, for a modest price, probablv the safest approach to 125 m.p.h. hedge-hopping yet devised. Put more simply, a brand new railway, 320 miles long, will open. This bald fact of the high-speed New Tokaido Line is doubtless more of a tonic to railwaymen everywhere than the detail making the ride so comfortable a thrill. It seems typical of Japan to have taken up so unfashionable a challenge to transport of the 1960s, and an expensive one at that. The line cost 380,000m. yen (£380m.) at the final estimate, almost double the estimate when work began in April, 1959. Even that amount was secured only through a gratefully received £580m. loan from the World Bank... it is pleasant to report the superb fittings and finishing in this train. In first class, seating, with adjustable foot-rests, is roomier than its airline equivalent; mustard coloured carpet matches the upholstery, where removable-and regularly removed-white seat and headrest covers are fitted. In second class, seats are five abreast, and while they do not recline there is ample leg room, even for foreigners. The train is air-conditioned throughout, and the wide windows, enhancing the impression of speed, are attractively beaded in stainless steel.

When the Occupation Forces arrived in Japan in 1945, they were stunned to see the extent of urban destruction caused by bombing. Over 60 cities were damaged and the railways had suffered to an extent that made continued operation difficult. Resources had been absorbed by the war effort, with the result that both equipment and infrastructure were in a grievous state. Nevertheless, the railways continued to run; indeed, they were the only

Calm and order in the shinkansen cab. Notice the driver's pocket watch (above his gloved right hand), given to him when he joins the company (Author)

Professionalism in attire (Author)

reasonably practical form of transport available to the vast majority of the impoverished people. Overcrowding was the norm, but perhaps the fact that the railways struggled through gave them a special place in the hearts of the Japanese people.

A significant contribution to the shinkansen was made by the transfer of military scientists to civilian roles early in the occupation period. The Railway Technical Research Centre (RTRI) in Tokyo benefitted in this way with previous aeronautical engineers injecting new ideas into the rather conservative field of railway engineering. Just less than 20 years since the end of the war, Tokyo was now about to host the 1964 Summer Olympics and open its sparkling new Tokaido railway between Tokyo and Osaka. The people had good cause to feel intense pride in this remarkable achievement.

Technical Innovations

Some of the technical advances of the new railway are worth enumerating—made even more impressive by the fact that some 3300 steam engines were still in use on Japanese railways in 1964, although this number would shrink to nearly zero in the next 10 years. The advanced features decided upon included: the use of standard track gauge at 1435 mm, as opposed to the narrow 1067 mm gauge used on the existing national railways; the use of 25 kV AC power to overcome the low power limitation of the 1500 V DC supply used on the existing electrified narrow-gauge system; the

abolition of lineside signals, with all necessary indications for the driver inside the cab; the adoption of a comprehensive system of Automatic Train Protection (a major step towards full Automatic Train Control: the steam trains mentioned above would not have a speedometer on the footplate!); the use of distributed power along the axles of the train to reduce the heavy axle loads under single power cars and to improve traction; new types of track, which in many places ran along considerable lengths of low viaduct, including welded rail in 1500-m lengths; and retention toilets avoiding depositing of human waste on the tracks. The coaches were airtight to eliminate the effect of sudden pressure changes on passengers' ears when in tunnels and fully air-conditioned for comfort. The minimum radius of curves was 2500 m, which in retrospect may have been better limited to the 4000 m used on later shinkansen lines. And, importantly the new line was completely separated from its surroundings with no level crossings and continuous lineside fences.

The immediate effect of the new line was to reduce the journey time between Tokyo and Osaka from 6 hours 30 minutes to 4 hours and from 1965, after a sensible bedding-in time for the new track and trains, to 3 hours 10 minutes at a maximum speed of 210 km/h. I clearly recall my excitement at first riding the shinkansen, tempered a little with incredulity. Can we really be travelling at 210 km/h as indicated by the meter at the end of the coach? The smoothness of the track removed the bumps and bangs I associated with speed—it was only when one saw the view from the window rapidly flashing by that the speed sensation was restored.

The reputation of the new line spread very quickly as any lingering scepticism was dispelled. The speed, comfort, punctuality and safety rapidly set a new standard for rail travel and the Tokaido Shinkansen might truly be said to be the catalyst that lead to the renaissance of rail elsewhere in the world.

Development of Shinkansen System Route Expansion

The success demonstrated by the Tokaido Shinkansen encouraged plans for a nationwide system to be gradually implemented. This work is largely completed but still ongoing, as the system has now achieved wide coverage of the most populated areas of the nation. The progress is summarized in Table 1. The separation of the system

Table 1 Development of Shinkansen System

Line	From/To	Length (km)	Opening Year(s)	Max. Speed (km/h)
Tokaido	Tokyo–Shin Osaka	515	1964	270
San'yo	Shin Osaka–Hakata	554	1972–1975	300
Tohoku	Tokyo–Morioka		1982–1985 1991–2002	320
Hokkaido	Morioka–Shin Aomori Shin Aomori–Shin Hakodate Shin Hakodate–Sapporo	675 149 211	2011 2016 (due) 2035 (due)	
Joetsu	Tokyo–Niigata	270	1982	275
Nagano	Takasaki–Nagano	117	1997	260
Hokuriku	Nagano–Kanazawa Kanazawa–Tsuruga	228 349	2015 (due) 2026 (due)	260
Yamagata (a)	Fukushima–Shinjo	149	1992–1999	130
Akita (a)	Morioka–Akita	127	1997	130
Kyushu	Kagoshima–Shin Yatsushiro Shin Yatsushiro–Hakata	127 130	2004 2011	260
Hokkaido (b)	Shin Aomori–Shin Hakodate Shin Hakodate–Sapporo	360	2016 (due)	

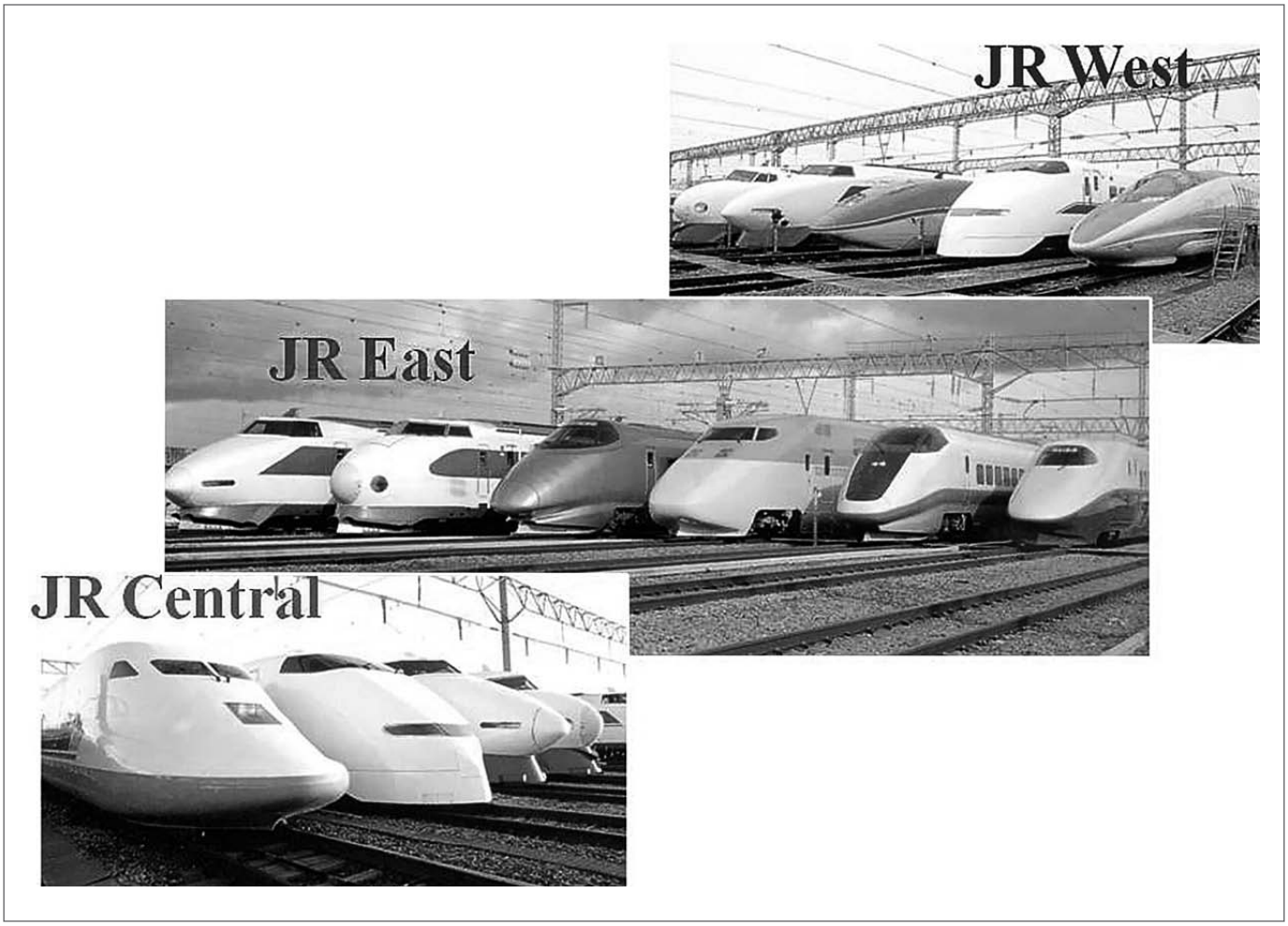
Notes: (a) Mini-shinkansen running on conventional track with added third rail to convert to standard gauge (b) Connecting with Hokkaido through the Seikan Tunnel, with additional third rail, speed limited by interactions with conventional freight trains in tunnel.

from external influence has been maintained with two interesting exceptions in the JR East operations area, the Yamagata Shinkansen and Akita Shinkansen. In both cases, trains separate from their parent services from Tokyo and run forward on conventional line fitted with a third rail with the usual level crossings, sinuous route geometry and signalling systems. Speed is therefore correspondingly slower. Furthermore, these operations depend on excellent punctuality of trains on both systems, a quality well supported by the Japanese rail system. On all the other new lines, the minimum curvature radius is 4000 m and the formation of the infrastructure is mostly based on slab rather than ballasted track.

Improvements in Performance of Rolling Stock

The current N700 is the fifth generation of the train to operate on the system. It is a product of continuous efforts for improvement and detailed research. It is noteworthy that although the RTRI acts as a national railway research organization, both JR East and JR Central have developed their own considerable in-house research facilities and expertise. The principal objectives of the railway research programmes are to simultaneously increase speed, reduce energy consumption, reduce track wear and tear, automate maintenance, and improve safety and passenger comfort. In many ways these are competing objectives. When the Series 300 trains were introduced in 1992, they demonstrated a 30% improvement in energy consumption over the original Series 0. The current N700 has a further 25% improvement. This is the outcome of many detailed efforts in, for example, lightening the weight of the train, using new materials, and in developing electric motors with significantly reduced mass and improved available power density. The interface between mechanical and electrical engineering has become increasingly blurred. The mechatronic train has existed for some time and considerable improvements have been made in control systems, condition monitoring of equipment, reporting of running irregularities, etc. All these combine to make much more 'intelligent' trains than their predecessors.

Huge improvements have been made to the aerodynamics of trains; the longer and more elegant nose shapes of successive generations are witness to this



The evolving nose shapes of the various shinkansen (Author)

point. These improvements in aerodynamic styling not only decrease drag and therefore energy consumption of the trains but significantly reduce generated noise; pantograph noise has been reduced through extensive studies.

There have also been improvements to the passenger interface with the railway, particularly in developments of pre-paid contactless cards that can also serve on many other forms of transport and indeed as normal credit cards. Mobile phones have been incorporated into the booking and ticketing system and the information technology revolution has greatly assisted the companies that move passengers' baggage, the so-called *takuhaibin* companies, which collect luggage from one's home and deliver it to, for example, the destination hotel. As a result, most shinkansen passengers are unencumbered by heavy and bulky baggage so their journey is easier and more pleasant.

Impact of Shinkansen on Japanese Society

The shinkansen has had many external effects on economic life. These range from the short-term spill-over effect of construction expenditure, through reduction in travel times and the introduction of private investment for the creation of employment due to the influx of new industries and enterprises in areas along lines, and increased sightseeing and recreation demands.

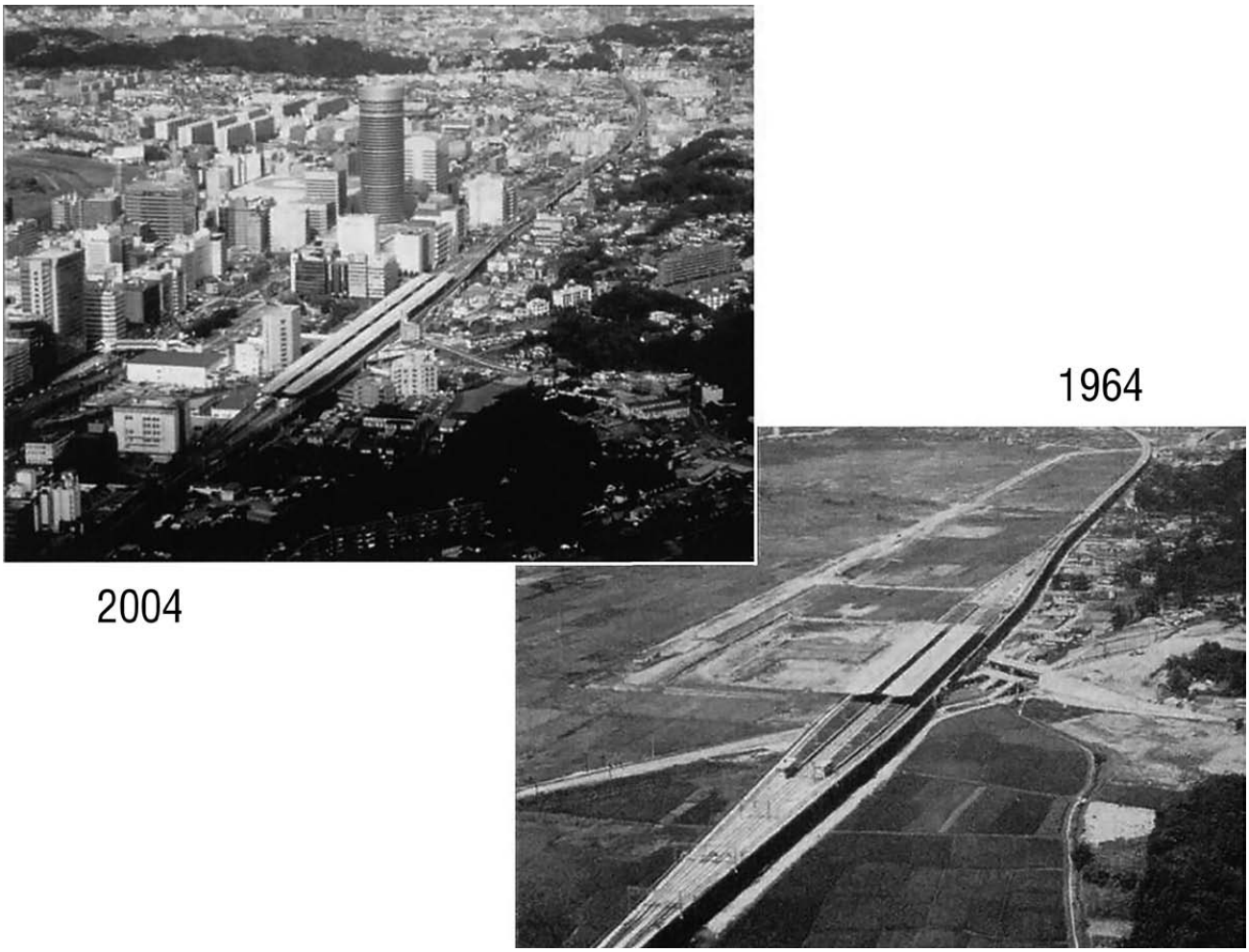
Between 1969 and 1999, ridership on the Tokaido Shinkansen increased from 66 million to 130 million passengers per year, that is, more than doubled. During this period, Japan's GDP trebled. Many graphs have been produced showing the close linkage of ridership with GDP, and the government has always held the view that transport infrastructure is an enabler of economic growth. It may be useful to add that transport infrastructure is a necessary but not in itself sufficient condition for economic success. The last decade or so has seen Japan rather stumbling economically with little or no real growth. Transport demand has not seen its previous spectacular annual rises and shinkansen ridership increases have slowed. In 2012, the Tokaido Shinkansen carried 143 million passengers, a total hardly changed for several years, but representing 42% of all shinkansen passengers in Japan carried on 27% of the 2620 km extended network, emphasizing its importance as the backbone of Japan. Signs of the decoupling of the propensity to travel and GDP are emerging in many other economies in the world.

Many of these external effects have significant impacts on local economies; for example, the benefit due to reduced travel time might be estimated by converting the time saving over conventional transport into monetary values. If 85% of total passengers on the present shinkansen lines are assumed to have shifted from conventional lines, the annual time saving calculated from the difference in timetables is approximately 400 million hours.

By calculating the value of this time from GDP *per capita* data, its value may be approximately equated to ¥500 billion per year (based on 2003 figures).

To illustrate the shinkansen's effect on local economies, the case of Kakegawa, a medium-size city with a population of 72,000 some 230 km west of Tokyo and 50 km west of the prefectural city Shizuoka, should be considered. When the Tokaido Shinkansen was built in 1964, the trains ran straight through Kakegawa and the city enjoyed none of their benefits. Because the distance between the nearest shinkansen stations (Shizuoka and Hamamatsu) was more than 70 km, the longest in Japan, and because Kakegawa was well-served by local lines branching from the existing conventional Tokaido main line at Kakegawa Station, it was believed that stopping shinkansen services at Kakegawa would revitalize not only the city but also the areas along the conventional and local lines. After funds had been raised from mainly local sources, a new shinkansen station was built in 1988, with an almost immediate positive effect on the local economy; employment rose by 8% in the subsequent 4 years, commercial production by 38%, and industrial sales by 39%. Five new hotels opened in the new station area to accommodate the ever-increasing number of tourists visiting nearby golf courses and other recreational facilities. The position of Kakegawa approximately mid-way between Tokyo and Osaka has made it a convenient site for national symposia and conferences, and, in the other directions, the citizens of Kakegawa can now experience the cultural life of Tokyo or Osaka because of the easier access afforded by the shinkansen.

Many further examples can be given of the catalytic effect of the shinkansen on local economies. Many stations on the route are not in the original city centres. For example Shin Osaka and Shin Yokohama have become thriving new centres in their own right and proved the worth of moving away from often overcrowded historic centres, which are themselves improved by the removal of considerable traffic. The changes around Shin Yokohama are particularly striking; what was essentially fields in 1964 has become a city of tall buildings and a major transport hub as well as attracting all kinds of commercial, shopping, and leisure opportunities. More recently, the developments around Shinagawa have not only improved connectivity with the shinkansen but have also transformed the fortunes of a somewhat down-at-heel urban area near central Tokyo. Since the opening of the original line, the number of stations serving smaller cities has increased, and service is possible because of the hugely increased frequency of train operations and the technique of allowing different patterns of stops along the route and 'leapfrogging' of through trains past stationary trains



Intense and rapid development around Shin Yokohama Station (Authors' collection)

at intermediate stations. The importance and potential of stations to become the focal point of many types of activity render their description as 'jewels in the necklace of the line' particularly appropriate.

Shinkansen and Environment

In 1964, the desirability of economic growth was so powerful everywhere that environmental effects were of little concern. However, world opinion has changed and the dangerous consequences of measurable increases in carbon-dioxide (CO_2) concentrations in the atmosphere and their effect on global warming are being recognized. The depletion of resources, particularly fossil fuels, is causing concern and the local effects of pollution, noise and vibration on people's lives are causes of much anxiety.

The environmental impact of the shinkansen can be subdivided broadly into the (generally) beneficial energy effects and the effects on local areas, which are sometimes detrimental. By 1990, the transport share of Japan's oil consumption had reached about 25% of Japan's total energy consumption. Compared with 1973, the industrial field had greatly reduced energy consumption owing to changes in industrial structure and energy-saving efforts, despite greater volume of output. Conversely, the energy used in transport had increased by a huge 170%. Because transport energy is mainly derived from oil (98%) and Japan now imports all its hydrocarbon energy, energy saving in transport continues to be an urgent priority.

A broad comparison of energy use on a journey from Tokyo to Osaka, in terms of energy consumption *per capita*, shows the shinkansen to be by far the most efficient mode, largely because of the extremely high seat occupation rates. If the Tokaido Shinkansen had not been constructed, an additional 360 million litres of oil would have been consumed by transport in 1985—a figure that approximately

corresponds to the oil consumption of 1.1 million families. The consequence of energy use is, of course, the production of pollutant gases. Broad trends of use may be traced to emissions, with again considerable *per capita* advantage to the shinkansen. We note that because electricity is used to power the shinkansen, the CO_2 emissions depend on the generating mix. The amount of CO_2 per unit transport volume produced directly by the shinkansen is only about 16% that of a passenger car. The benefits of the 80% share held by the shinkansen of the transport volume between Tokyo and Osaka can thus be measured by, for example, an estimated 15,000 tons of CO_2 emissions in 1985. This corresponds to the annual amount of CO_2 emitted by industry in and around Tokyo. The terrible 2011 Great East Japan Earthquake off the northeast coast and devastating tsunami that followed caused severe damage to the Fukushima nuclear power station. In the aftermath all of Japan's nuclear capacity was shut down in an understandable, but probably irrational response. It will be increasingly difficult for Japan to meet its CO_2 reduction targets if this ban on nuclear power generation continues, and ever more expensive to meet its power needs as the price of imported fossil fuel continues to rise.

It has been estimated that replacing the carrying capacity of the shinkansen between Tokyo and Osaka would require three Jumbo jets every 5 minutes, increasing domestic air travel by 50%. In general, the shinkansen has captured the internal market for journeys up to about 3 or 4 hours. For example, from Tokyo northwards to Yamagata on JR East nearly 100% of traffic is carried by the shinkansen, but to Akita the ratio has dropped to 60%. Similarly, from Tokyo westwards to Osaka, the shinkansen carries 85% of traffic, to Okayama about 70%, but to Fukuoka only 11% for a train ride of just under 5 hours. To achieve the same capacity as the Tokaido shinkansen by road, 40-seat buses would need to run every 10 seconds, or if passengers switched to private cars, 1800 deaths and 10,000 serious injuries would result every year. When the shinkansen was first built, it was relatively easy to route the line without opposition from nearby residents or difficulties with planning enquiries. The process of post-war rebuilding was more important than local sensibilities. However, the shinkansen soon made its presence felt by noise and vibration, with the result that strict regulations have been established to limit these nuisances and countermeasures have had to be adopted by operators to suppress the effects of the passing high-speed trains. The acceptable maximum noise levels set by legislation are 70 dB(A) for residential areas and 75 dB(A) in commercial zones. Because 56% of the land alongside the Tokaido Shinkansen is classed as residential and 30% as commercial, the noise level is limited to less than 75 dB(A) for 86% of the entire track length of 513 km.

Noise increases rapidly as train speed increases, so that shinkansen speed increases have required continued technical developments in order to keep below the noise limits. Track structure and current-collecting equipment have been improved, extensive lineside sound barriers have been developed and installed, car weight has been reduced, and rail technology and wheel-tread cutting methods have been improved. All these measures increase costs.

Moreover, at speeds over 300 km/h, the noise energy increases proportionally to the sixth to eighth power of the speed, making noise-suppression developments much harder. (For example, this power-law dependence means that a 6% increase in speed leads to a 140% increase in noise.) A further problem has emerged with speed increases; a micro-sonic boom is heard over a wide area as trains exit tunnels. Specially designed flared tunnel hoods have been fitted at tunnel portals to contain the problem. It seems likely that problems associated with noise generation are those that will limit further speed increases in the future.

Shinkansen as System: Human Factors and Safety

It is well recognized in Japanese railway circles that the shinkansen is more than a collection of vehicles running on an infrastructure. The whole ensemble acts in unison as a system and the glue that binds this system together is the people who plan, run, operate and maintain it, together with the passengers. No visitor to Japan fails to be impressed by the quality of the staff, from their smart appearance, to their dedicated standard of performance of their duties. This does not happen by accident but occurs through a rigorous system of continuous education, training and development coupled with an intense pride in the company. It acts at all levels from directors to cleaners—all are recognized as playing a part in a successful outcome. For example, when a train reaches a terminus, a group of cleaners descend onto the train and ready it in about 5 or 6 minutes before a new set of passengers enter; these passengers will have queued at marks on the platform, corresponding to their carriage and seat numbers. Thus, a 12-minute turnaround is achieved, which allows JR East to operate 400 trains per day at 4-minute headways from just two platforms and four tracks at Tokyo Station.

This people-centric approach plays a major part in safety, which requires eternal vigilance and strict attention to detail. Coupled with the separation of lines from external disturbance, it has given the shinkansen system an incredible safety record—no fatalities due to train accidents since its inception. (However a passenger was trapped in closing doors and dragged to his death in 1995.) Derailments without casualties have occurred in

major earthquakes, and high winds and heavy rain during typhoons have caused damage. Heavy snowfall is common north of Tokyo, but punctuality is incredible with average delays on the order of 30 seconds, even including these natural disasters.

Shinkansen as Catalyst: Spread of High-Speed Rail Throughout World

There was a considerable delay from 1964 until the opening of the next high-speed rail system in France in 1981 when the 260 km/h Paris Lyon TGV line was inaugurated. The train was compatible with existing lines and despite the development of many new dedicated lines in France, considerable time is spent running high-speed trains on existing lower-grade infrastructure. However, SNCF has been very active in promoting and developing high-speed rail technology; in 2007, it achieved the current world speed record for steel wheels on rails of 574 km/h during a test run. It is unlikely this speed will ever be achieved in regular service because of the considerable damage it causes to both vehicle and infrastructure, resulting in extremely high maintenance costs. In 1991, 10 years after the Paris–Lyon line opening, Germany opened its ICE service on the Hanover–Wurzburg line at a speed of 280 km/h. Like the TGV, the ICE had power cars at each end of the train and correspondingly higher axle loads. The next major development in Europe was in Spain with the opening of the Madrid–Seville line in 1992. Other lines have opened since and the Spanish government plans that 90% of the population will live within 50 km of their AVE lines by 2020. It remains to be seen whether this can be achieved under the present economic circumstances.

In Asia, Korea opened its Seoul–Busan line 40 years after the opening of the shinkansen. Taiwan followed in 2007, but the most remarkable developments in Asia have occurred more recently in China. The pace of China's development has been absolutely astonishing. It now has by far the world's longest network of dedicated high-speed lines much of which has been built in the last 7 years and more are promised in the next 2 years, bringing the total length to about 18,000 km. Currently, over 1.33 million passengers travel on the Chinese network every day. On a recent trip from Hangzhou to Beijing, I was astonished by the excellent ride quality of Chinese trains operating at speeds over 300 km/h, and by the passenger service and comfort matching anything offered in other regions of the world. One can only stand back in astonishment and applaud China's remarkable achievement.

In Britain, we have lagged behind these developments, although the fastest diesel trains in the world, the so-called HST trains, have been in service for more than 28 years and operate at speeds up to 200 km/h on conventional track. Some 9 years passed after the 1994 opening of the Channel Tunnel linking the UK and France for the first time before the high-speed link from the tunnel to London was completed in 2003—Britain's first true segregated high-speed railway. There are now plans to build further high-speed lines from London to Birmingham and onwards to Manchester and Leeds. However, the pace of planning is glacial and opening is not expected until 2026. Even America is planning high-speed rail. There have been persistent rumours for many years about developments in California and on the East Coast corridor. It is not yet clear whether these rumours will become reality.

Current Status and Future Prospects for High-Speed Railways in Japan and World

The shinkansen system is undoubtedly the world leader in terms of volume, safety and punctuality. It has enabled trains to retain a much higher modal share of passenger traffic measured in passenger-km than in any other country. The ratio in Japan is 28%, despite the rise in automobile use in the last 50 years, moving up from a 9% to a 53% share. However, although the total transport market in Japan has increased strongly over the last 50 years, the future size of the travel market is likely to shrink because the Japanese population has now reached a peak, and the age distribution is skewed considerably to the older end, causing many to foresee a rapid real decline over the next 30 years.

It must be remembered that the Tokaido Shinkansen serves an area that has created the largest and most stable demand in the world. The greater Tokaido area is 17% of Japan's land area but houses 40% of the population and produces 49% of GDP. The other shinkansen lines do not have this benefit of concentration. The extensions of the system to Hokkaido in the north and Kyushu in the south are extensions into much less populated areas. It is difficult to see significant expansion beyond these schemes in the future. In essence, the obvious and profitable routes have now been built and low traffic densities at the extremities are likely to prove unfavourable. Environmental opposition mainly concerned with noise and vibration is also gathering strength, and is likely to prevent significant speed-up of existing lines. As distances from Tokyo grow, so time competition from airlines becomes more difficult for trains to match, and price competition on existing routes is becoming more severe as internal airlines are liberalized as low-cost ventures. Travel conditions in the major cities are becoming yet more difficult despite increases to the extensive networks of public transport. The time taken to travel to and from a shinkansen station is becoming an ever-increasing and significant proportion of door-to-door journey times. Therefore, national priority is likely to shift to these

The author samples high-speed rail in China (2010) (Author)

urban transport problems.

However, on the first and earliest shinkansen routes, capacity limits are being reached—not only in line capacity for trains, but also in station capacity for handling large numbers of people. The new station at Shinagawa in Tokyo has allowed an increase on the Tokaido Shinkansen to 15 trains per hour. Further increases beyond that will require drastic measures. Just as the shinkansen was born out of the inability of the old conventional Tokaido main line to absorb further expansion, so history is repeating itself as a new type of train is being tested on a trial section of a proposed new line connecting Tokyo and Osaka, the Chuo Shinkansen. The projected route lies inland, generally well to the north of the Tokaido, roughly following another ancient route of Japan, the *Nakasendo*. Because of the very mountainous terrain and need for very shallow radius curves, most of the route will be in tunnels, with consequent heavy civil engineering costs. A 42.8-km test section has been built in Yamanashi, where superconducting magnetically levitated (maglev) trains are being tested. Technical progress has been another spectacular example of Japanese prowess. Passing tests have achieved a relative train speed of 1026 km/h and a world speed record for a manned train of 581 km/h was reached during running tests. JR Central has made the bold announcement that it will finance the project from its own resources, and expects to open a 505 km/h service taking just 40 minutes to Nagoya in 2027, then onto Osaka by 2045. This is likely to be the first major maglev project in the world, although a much shorter public service is operating from Shanghai Pudong International Airport in China.

New high-speed train systems are being planned in a wide range of countries in Europe, in Asia, in the Middle East, and in America. The major challenge for all will not be technical but financial. Trains in general, and high-speed trains in particular, need high frequency of operation and high passenger load factors in order to be profitable. Given these conditions, it is possible to finance operations and maintenance out of revenue, but the cost of initial infrastructure build is burdensome. In most cases, the costs will be justified by drawing a wide system boundary containing a cost benefit analysis with public funds being justified through wider societal benefits.

Concluding Remarks

On the occasion of the 30th anniversary of the Tokaido Shinkansen, Hideo Shima, then aged 93, the 'father' of the shinkansen and doyen of the Japanese railway industry, was interviewed for a special issue of the *JR Tokai* in-house magazine. He commented, *'There seems to be a kind of competition around the world today to achieve ever higher railway speed. Personally, I think they are making a mistake targeting their sights always on faster and faster speed alone. Instead of speed, other countries should try instead to emulate the shinkansen's remarkable frequency of train headway. Frequency, I believe, is far more vital than higher speed. For unless you boost operation frequency, you can't reduce passenger fares and attract more customers. From now on, the first priorities of train transport must be low energy, safety and comfort'*.

It is difficult to argue against that assessment on the 50th birthday of the shinkansen. I would however add that the major lesson to be learned from the Japanese experience is that the shinkansen runs as a separate dedicated *system*, removed as far as possible from external perturbations, but also as an integrated system in which people are a major component, and the infrastructure and vehicles form a vertically integrated whole. ■

Further Reading

Japanese national railways: its break-up and privatization, Yoshiyuki Kasai, Global Oriental, 2003, ISBN 1-9011903-45-1

The Privatisation of Japanese National Railways, Tatsujiro Ishikawa, Mitsuhide Imashiro, Athlone Press, 1998 , ISBN 0485114526

Shinkansen: From Bullet Train to Symbol of Modern Japan, Christopher Hood, Routledge, 2006, ISBN 978-0-415-32052-8

Success Story: The Privatisation of Japanese National Railways, Shoji Sumita, Profile Books Limited, 2000, ISBN 1861972474

High Speed in Japan Shinkansen - The World's Busiest High-Speed Railway, Peter Semmens, Sheffield: Platform 5 Publishing Ltd, 2ndEd., 2000, ISBN1 902336 14-3

A History of Japanese Railways 1872-1999, Eiichi Aoki et al., East Japan Railway Culture Foundation, 2000, ISBN 4875130899

Old Man Thunder: Father of the Bullet Train (Shinji Sogo), Bill Hosokawa, Sogo Way (Dec 1997), ISBN 0-9659580-0-0

Many articles in previous volumes of *Japan Railway & Transport Review (JRTR)* available from the JRTR Web site: www.jrtr.net

Annual Reports and Data Books of the various JR Group companies

Roderick A. Smith

Professor Smith is currently a research professor at Imperial College London. Prior to his current positiion, Professor Smith was a Chief Scientific Adviser to the Department for Transport 2012 to 2014. He is an author of several books and over 300 papers