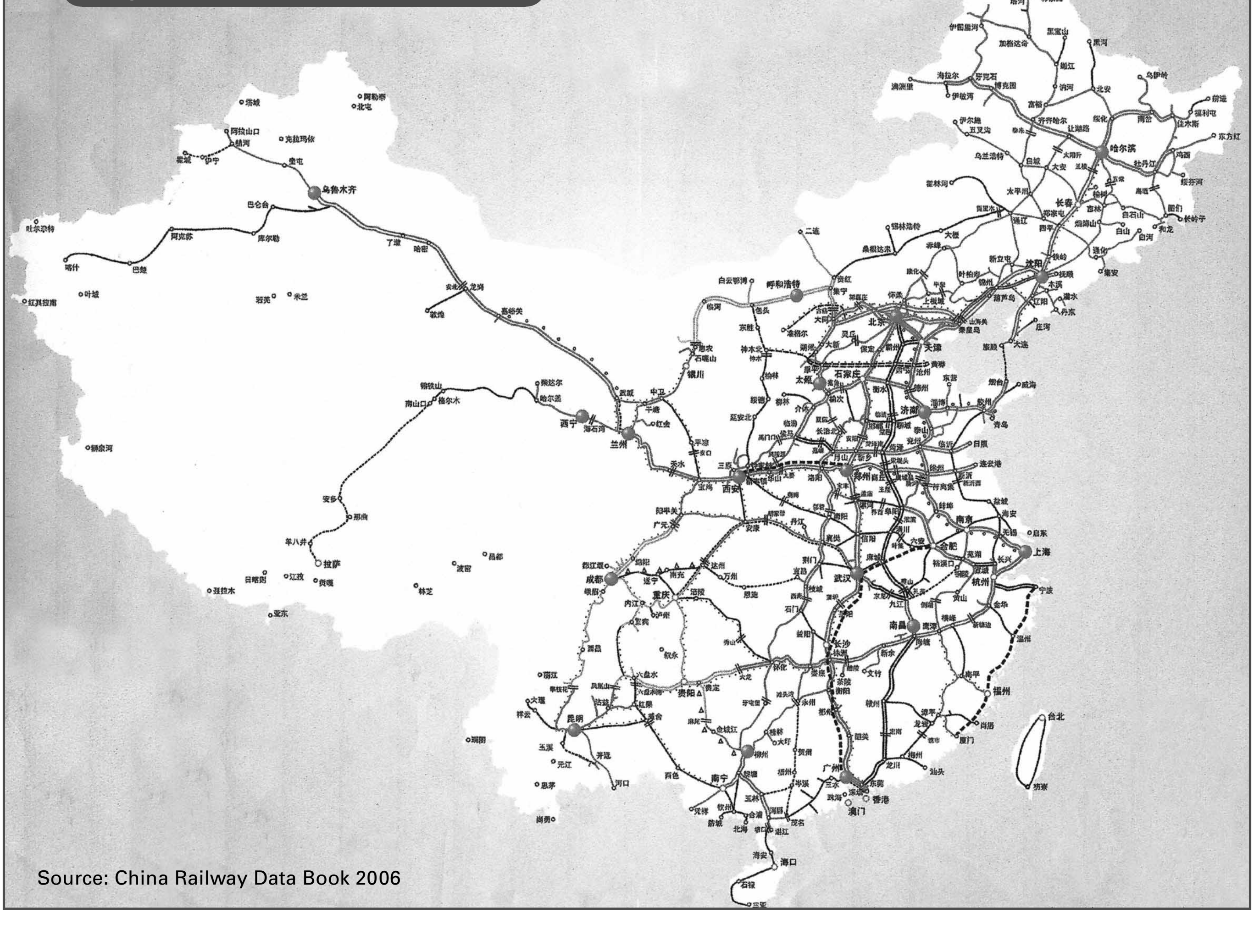
High-Speed Railways in China

Hiroshi Okada

Overview of China Railway Network

China's railway network is expanding rapidly as more than 1000 km of new lines are constructed each year; some are built to separate passenger and freight operations on main lines while others are for increasing the speed of passenger services. One of the many notable recent new-line construction projects is that of the Qingzang Railway, which passes through areas at altitudes of more than 5000 m, the highest railway in the world. At the end of FY2005, the route length of China Railway reached 75,438 km. However, the overall density of lines is low with considerable regional differences due to the varied terrain of this vast country (Fig. 1). As discussed later, the system suffers from a severe lack of capacity due to heavy reliance on railways for both passenger and freight transport. As a result, double-tracking and electrification are being carried out

Figure 1 China Railway Route Map



Source: China Railway Data Book 2006

at a fast pace. Thanks to such efforts, 34% of the network is now double-tracked and 27% electrified—both relatively high figures.

The length of railway lines in China per land area (7.8 km/1000 km^2) and per capita (0.6 km/10,000 people) are far less than those in countries, such as Japan, Germany, France, the USA, and India (Table 1), and both are low even taking the vast mountainous regions and deserts in western China into consideration. Because China has a massive population and a vast area, the length of railway lines per capita is only about a quarter of that of Japan and less than a tenth of that of the USA. The length per km^2 is less than 10% of the corresponding figure for Japan and only about 7% of the figure for Germany.

Table 1 International Comparison of Railway Lengths

	Length of railways per capita (km/10,000 people)	Length of railways per unit area (km/1,000 km^2)
China	0.6	7.8
Japan	2.2	72.8
Germany	4.4	100.8
France	4.9	54.0
USA	7.7	23.1
India	5.8	19.9

Overview of Railway Transport

Traffic density

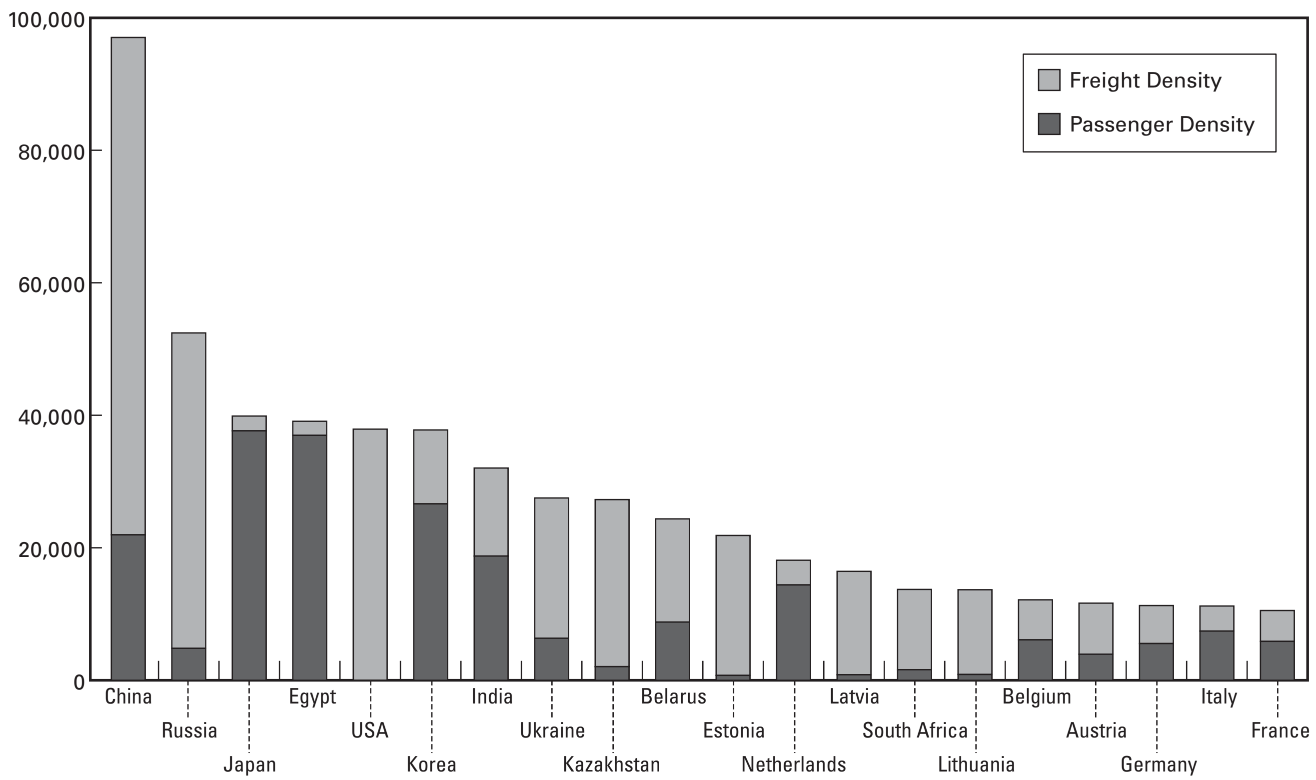
Figure 2 shows the average passenger and freight density for various countries or regions arranged in descending order, calculated by dividing the freight and passenger volume per day (sum of passenger-km and tonne-km) in the country or region by the route length of railway lines. Since passenger-km and tonne-km are indicators of the total output, traffic density is a measure of the productivity of countries or regions' railway system.

Traffic density in China is by far the highest of all the countries or regions and about double that of second-placed Russia. With a freight tonne-km figure of almost twice the passenger-km, the Chinese railway system can be described as freight oriented. In any case, it is clear that Chinese railways are heavily and efficiently used.

Although Japan has the highest passenger density, the geographical conditions of the country are such that railways are not as widely used for freight transport as in other countries, so Japan is third in the total traffic density.

The traffic density in the major countries of Europe such as Germany, France and the UK is only about 25% of the figure for China or half of the figure for Japan.

Figure 2 International Railway Traffic Densities



Share of railway transport

Tables 2 and 3 show the modal split for passenger (passenger-km) and freight (tonne-km) transport respectively for different countries. The tables indicate that railways in China command a much larger share for both passenger and freight transport than in Japan, Germany or France. Although Japanese railway's share of passenger transport exceeds 25%, which is much greater than in France or Germany, it is not as high the 34.7% figure for China. It is worth noting that air travel in China commands a share exceeding 10%, reflecting the vast nature of this country. The share of railways in China for freight transport exceeding 25% by tonne-km is far greater than the figure for Japan of only 4%, and even for France and Germany, which are in the low teens. When looking at the figures for road transport in China, it should be noted that construction of roads is proceeding at a rapid pace with an expressway network spanning 41,000 km compared to 8920 km in Japan.

Table 2 Modal Split of Passenger Transport

Mode	Share by passenger-km (%)			
	China	Japan	Germany	France
Rail	34.7	26.1	7.8	9.5
Road	53.2	67.9	8.3	89.0
Water	0.4	0.3	79.3	0.0
Air	11.7	5.7	4.5	1.5

Table 3 Modal Split of Freight Transport

Mode	Share by tonne-km (%)			
	China	Japan	Germany	France
Rail	25.8	3.9	14.2	13.1
Road	10.8	54.7	69.9	78.6
Water	61.9	41.3	12.7	1.9
Pipeline	1.4	0.0	3.0	5.8
Air	0.1	0.2	0.2	0.5

Increase in railway transport

Despite the development of roads, harbours and airports mentioned above and the rapid increase in the use of motor vehicles, railway transport has shown an average annual increase in the last 5 years of 6% in passenger-km and 8.5% in freight tonne-km—not much less than the increases in transport by all methods and the GDP of China.

Characteristics of freight transport

Coal haulage take top position by a wide margin in Chinese rail freight, accounting for 46.4% of the total in terms of tonnes and 32.9% in terms of tonne-km. Coal is a fundamental source of energy for economic activity in China, providing 70.7% of energy requirements. Since railways play the major role hauling coals in China, it would not be going too far to say that railway transport is playing a key role in Chinese economic development. As a result, concerted efforts have been made recently to increase freight capacity, including development of freight cars with an axle load of 25 tonnes, which are among the largest in the world, and operation of long freight trains hauling 20,000 tonnes. Increased container freight volumes are expected due to construction of integrated marine and railway freight terminals.

Characteristics of passenger transport

Rail passenger transport in China has several unique features compared to systems in other countries.

Column A in Table 4 shows the average number of railway trips made per capita, calculated by dividing the total number of railway passengers per year by the total population for various countries. The number of trips per capita in Japan is very high due to the well developed urban rail network and contrasts with the very low figure for China, which is still less than 5% of the figures for France or Germany. This low figure is believed due to the lack of development of urban railways in China, and the resident permit system, which has more or less prevented free travel. If the average number of journeys made per capita rises to the same levels seen in France or Germany, the total number of railway passengers will rise by a factor of 10 or more.

Column B in Table 4 shows the average length of passenger trips, calculated by dividing the total passenger-km by the total number of passengers. The average trip

Table 4 Riding Habits and Average Trip Length of Railway Passengers

	Average annual number of trips per capita (A)	Average trip length (km) (B)
China	0.9	524.5
Japan	171.3	17.6
Germany	20.4	41.3
France	15.0	81.7
USA	0.1	369.7
India	46.9	96.9

length in China of 525 km, which is unbelievably long—greater than in the USA, over ten times the figure for Germany and about five times the figure for France. The long average trip length for China might be attributed to the large size of the country and also to the underdevelopment of the urban railway system for commuters and other short-distance travel.

Eleventh 5-year Plan

Construction of railways

As discussed above, railways are used extensively in China for both passenger and freight transport, and the scarcity of transport capacity is a very severe social problem. Operating services on major routes can be a difficult balancing act, so restrictions are imposed on freight services due to huge passenger demand during periods such as Chinese New Year. Conversely, passenger services are restricted during periods of significant freight volume in autumn and winter. The lack of capacity on the railway system, the principal means of transport in China, could create a bottleneck hindering the nation's economic growth.

The Eleventh 5-year Plan, covering 2006 to 2010, was adopted in March 2006. This plan states, 'Railways are an important social infrastructure and a method of transport for all people of the nation. There are many merits of railway transport, including high capacity, low costs, efficient use of land, low energy consumption, environmental friendliness and safety. Every effort will therefore be taken to speed up construction of railway lines and enhance methods of transport.' The plan sets an annual GDP growth target during the term of 7.5% and predicts an average annual increase for both passenger and freight transport exceeding 5% based on this GDP rate of increase. (The highest increase forecast is 5.7% for the passenger-km.) In light of these predictions, it is likely that the railway capacity shortage will become even more severe.

In an attempt to solve the problem of insufficient capacity, China has built approximately 1000 km of lines every year (Fig. 3)—an extraordinary pace not seen anywhere else in the world. The 5-year plan calls for railways to be constructed at an even faster pace, with 17,000 km of new lines scheduled to be constructed during the term and 8,000 km of existing lines to be double-tracked and 15,000 km to be electrified.

Plans for dedicated passenger lines

The best measure for alleviating the problem of capacity shortage on lines where both passenger and freight trains are operated is separating the two types of trains onto different tracks. Such a project equalizes the operating speed of each type of train on each line, remarkably enhancing both passenger and freight capacity.

One option to achieve this objective is to construct new dedicated freight lines avoiding urban areas. However, there are far more operational advantages from constructing dedicated passenger lines with high specification and operating trains on these lines at the highest possible speeds. As well as increasing capacity, this also enhances the competitiveness of railways compared to other transport modes and increases the productivity of rolling stock and staff. The Tokaido Shinkansen in Japan was built to improve overall both quantitatively and qualitatively the existing Tokaido main line, traffic volume of which had exceeded its capacity.

Figure 3 Increase in Railway Lengths

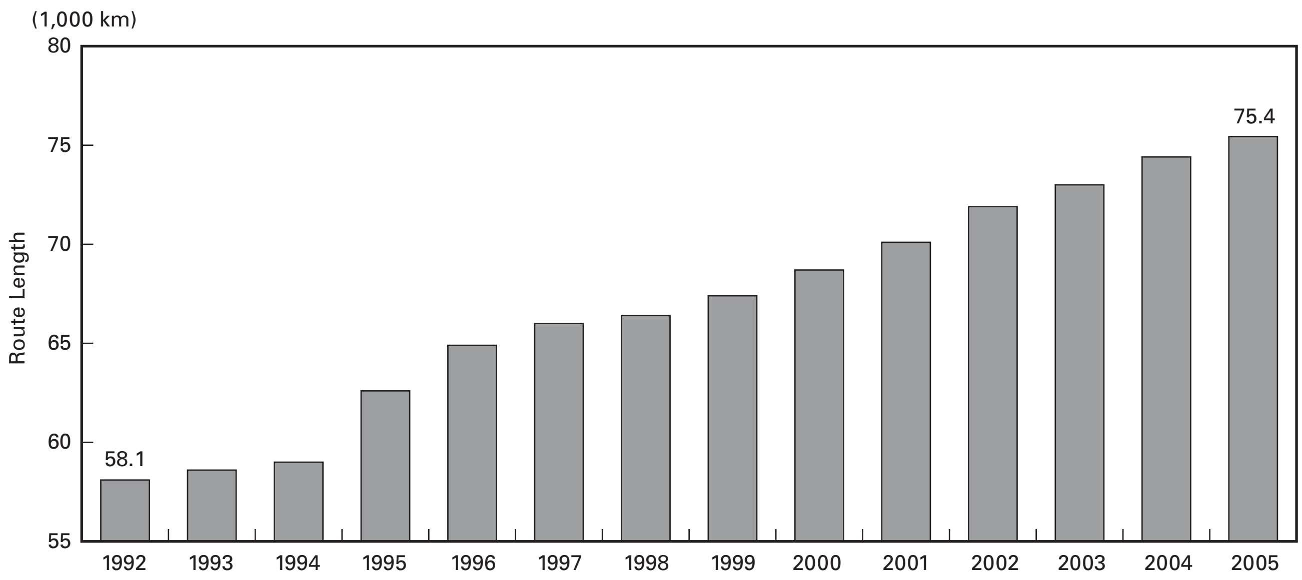
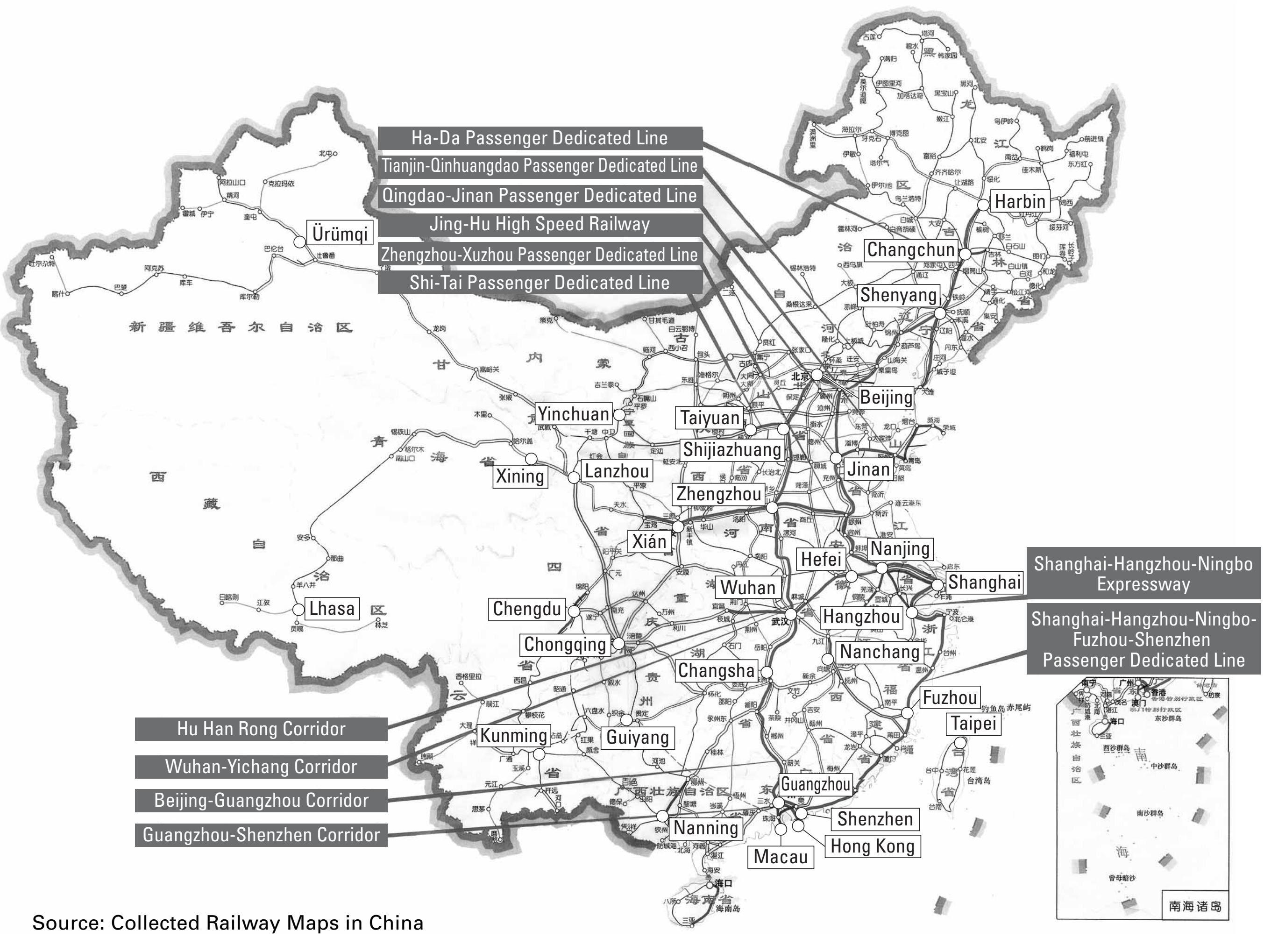


Figure 4 shows dedicated high-speed passenger lines included in the long-term plan until 2020. The plan is magnificent, consisting of 11,940 km of lines on 8 routes: Beijing–Tianjin–Qinhuangdao–Shenyang–Harbin (including Dalian–Shenyang); Qingdao–Jinan–Shijiazhuang–Taiyuan; Beijing–Shanghai; Beijing–Zhengzhou–Wuhan–Changsha–Guangzhou–Shenzhen; Xuzhou–Zhengzhou–Xián–Lanzhou; Nanjing–Wuhan–Chongqing–Chengdu; Hangzhou–Ningbo–Fuzhou–Xiamen–Shenzhen; and Hangzhou–Nanchang–Changsha. Among these 8 routes, a total of approximately 7000 km of such lines are scheduled to be constructed and come into service by the end of 2010, the last year of the Eleventh 5-year Plan, including Beijing–Tianjin, Beijing–Zhengzhou–Wuhan–Guangzhou–Shenzhen, Shanghai–Hangzhou–Ningbo, Jinan–Qingdao, and Xuzhou–Zhengzhou–Xián–Baoji. All these lines will be advanced, electrified, high-speed railways with double track and full grade separation. Construction of some sections is already underway and the aim is to run trains at maximum speeds of 300 to 350 km/h.

Speeding-up existing lines

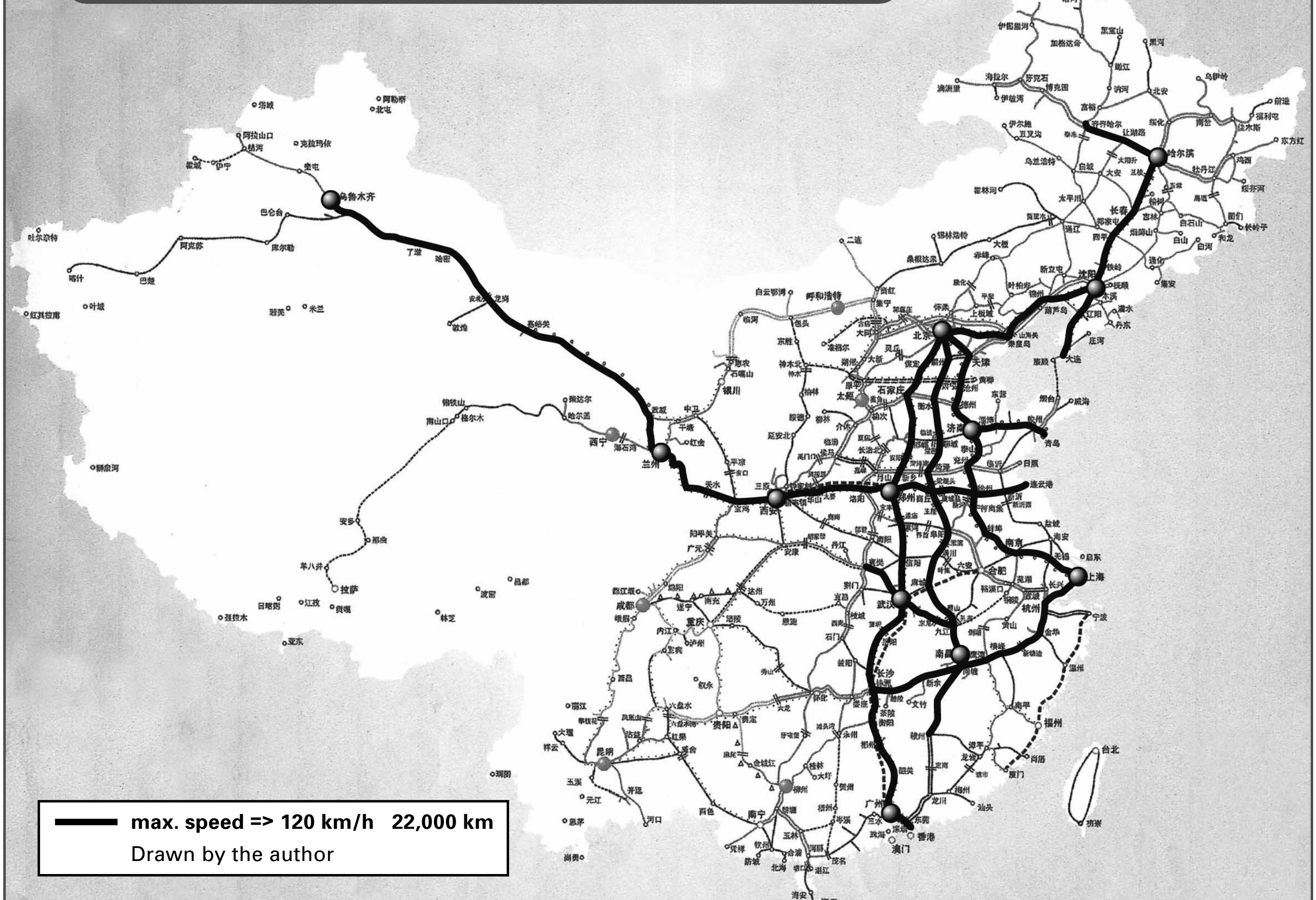
Attempts are being made to increase the speed of services on existing main lines as a pilot project for the large-scale construction of dedicated passenger lines outlined above. Major railway lines in China use standard gauge, are relatively straight and there are a few level crossings. Therefore, speeds of 200 km/h or more could be achieved by introducing new rolling stock (called medium-speed rolling stock in China), and upgrading tracks, signals and power equipment. Figure 5 shows lines on which train speeds were increased on 18 April 2007 for the 6th Speed-up Project. Passenger trains currently run at maximum speeds of 120 km/h or faster over approximately 22,000 km of lines, and 160 km/h or faster over about 14,000 km of lines. However, the focus is the 6003 km of lines where maximum speeds of 200 km/h or greater have been achieved and sometimes even 250 km/h on certain sections. The electrified Beijing–Shanghai route is included in this group. Electrical multiple units (EMUs) manufactured with

Figure 4 Construction Plan for High-Speed Dedicated Passenger Lines



Source: Collected Railway Maps in China

Figure 5 Scope of 6th Speed-up Implemented on 18 April 2007



Map Source: China Railway Data Book 2006

technical cooperation from Japan, Canada, and France are being used for these high-speed services.

Total investment

It is estimated that a total investment of up to Japanese ¥30 trillion will be required to implement the Eleventh 5-year Plan outlined above—approximately four times the amount for the Tenth 5-year Plan. Various sources of funds are being investigated to raise this huge sum of money, including social insurance and private equity.

Japanese Cooperation with High-Speed Railways in China

Comparison of Chinese and Japanese 'shinkansen'

It goes without saying that railways vary significantly by country and must meet the individual natural and social conditions in each.

Figure 6 shows the population and distribution of cities along several high-speed railway corridors in China (projected), Japan, Germany, and France. The horizontal distance is proportional to the actual distances along railway lines while the area of circles is proportional to the population of cities. Only cities with a population of 400,000 or more are shown.

Clearly, the high-speed lines due to be constructed in China connect many densely populated large cities. In particular, the total population and size of cities along the Beijing–Shanghai route are comparable with the Tokaido and San'yo shinkansen in Japan. In Comparison, the population along high-speed lines in Germany and France is much thinner with larger cities significantly further apart than in Japan or China. This fact is reflected in transport volumes. There are large differences in traffic density between the Tokaido Shinkansen in Japan and high-speed railway systems in Germany and France. The distance between stations is also greater in Germany and France. A Japan Railway Technical Service's (JARTS's) survey conducted jointly with a Chinese think-tank concerning projected demand for the high-speed Beijing–Shanghai route estimates that traffic density will be roughly the same as that of the Tokaido Shinkansen.

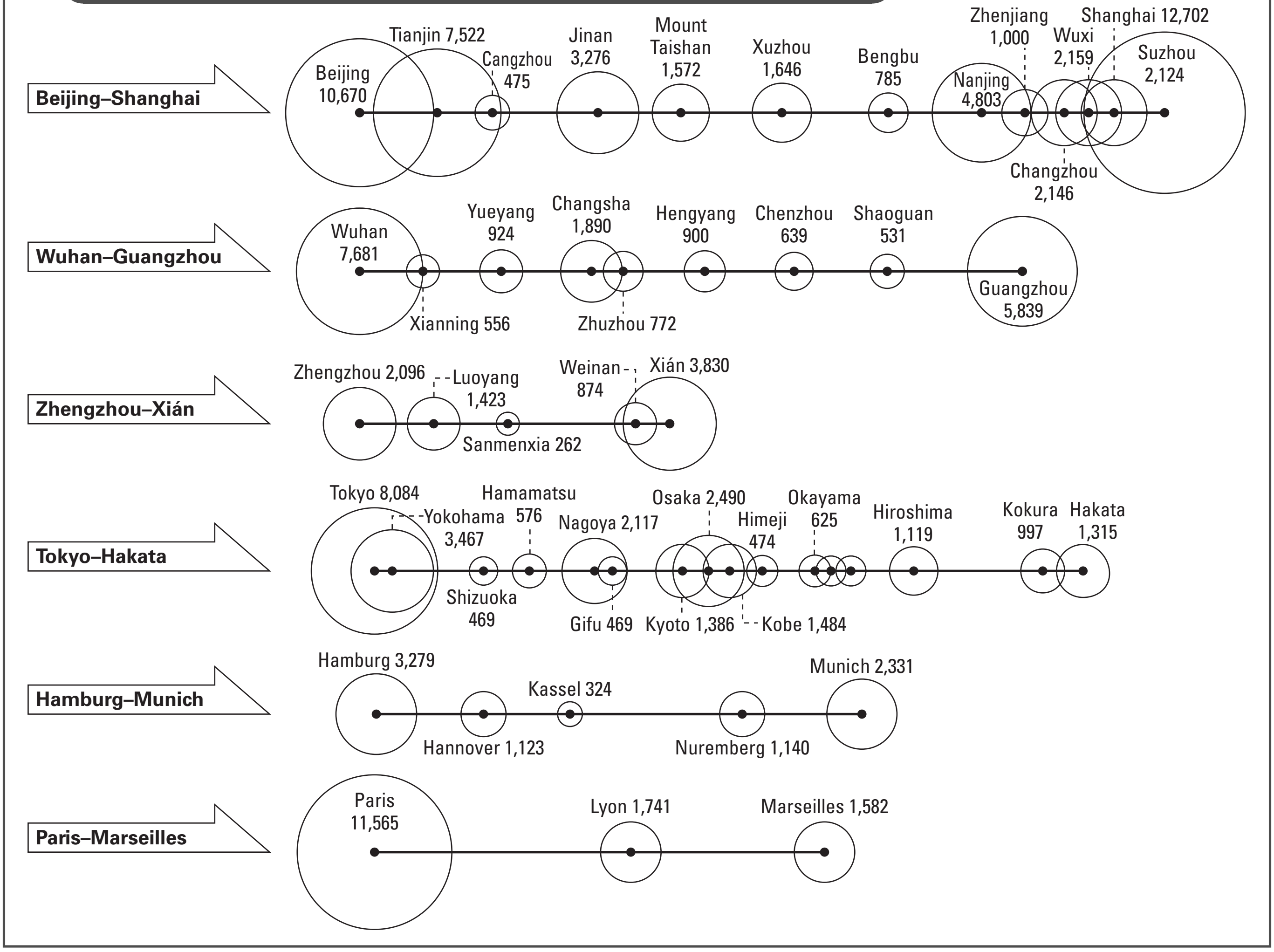


Figure 6 Large Cities on International High-Speed Rail Corridors

Characteristics of Japanese shinkansen

The Japanese shinkansen took their origins from the *Shonan* EMUs introduced immediately after WWII on sections longer than 100 km, such as Tokyo–Numazu, to alleviate problems of insufficient capacity without large investment. These new trains, which took the place of loco-hauled trains, had enhanced acceleration and deceleration, and faster turnaround, so they could be operated at shorter headway, making them very popular with passengers. The technology developed and services were expanded gradually to cover larger distances. The introduction of the *Kodama* EMU in 1958 on the narrow-gauge Tokaido main line made it possible to travel from Tokyo to Osaka and back in one day. It is widely known that this train was the forerunner for the shinkansen.

Furthermore, most major cities in Japan are located on the coastal plain or near a big river, so lines linking these cities usually run on soft ground. When the project to construct the Tokaido Shinkansen became reality, EMUs were adopted as a matter of course because of their low axle weight and suitability for carrying large numbers of passengers with short headways between relatively close stations. However, there were a few problems remaining with EMUs, including high maintenance cost due to the large number of motors, as well as in-carriage noise. These difficulties were solved by adopting simple and light VVVF motors instead of conventional DC motors. Moreover, using these motors as a regenerative brake system at deceleration saved the large amount of brake maintenance and energy costs, thereby further highlighting the advantages of EMUs.

Japanese shinkansen model for Chinese high-speed railways

There is little doubt that the Japanese shinkansen is the best model for Chinese high-speed railways considering social and natural conditions in China, such as land use along high-speed railway lines, the likelihood of an explosive growth in traffic volume, and the considerable amount of soft ground. Cooperation with Japan about high-speed rail began in 1994 with the establishment of a Cooperating Council for the Beijing–Shanghai High-Speed Railway. Further progress followed in 1997 when the Japan–China Railway Conference for Promoting

Mutual Friendship was formed, comprising JARTS, the Japan Railway Construction, Transport and Technology Agency (JRTT), railway operators such as the JR group, Tokyo Metro, etc., and various related manufacturers and trading companies, with government officials as observers. A cooperative agreement was reached with the Chinese Ministry of Railways and a steady succession of results has been achieved in information exchange, personnel development, joint research, and other fields.
Until recently, most passenger trains in China were hauled by locomotives and there were no intercity EMUs operating at any speed. Every conceivable opportunity was taken by the Japanese parties to persuade China that EMUs would be an excellent choice for high-speed railways in China, including holding seminars and inviting decision makers to ride on trains in Japan. Thanks to these efforts, the Ministry of Railways understood the merits of EMUs.

Problems with cooperation

As borne out by many articles in the international press, there is fierce competition between Japan, France, and Germany over cooperating with China in building a high-speed railway system. Although I firmly believe that the Japanese shinkansen is the best model, nobody knows who will be the eventual winner. In addition, there are still remaining technical issues. For example, safe and reliable high-speed services require integration of the entire system, especially rolling stock, signalling, and traffic control. Of course, loss and damage arising from accidents increase greatly with operating speed. Powerful electric current for propulsion accompanied by higher harmonics generated by VVVF inverters can significantly interfere with data transmissions for signalling systems. High-speed trains in Japan are the result of many years of deliberate trials repeated several times with the corresponding signalling systems. There is a high possibility that complex problems will occur when trains designed for one system are run on a different system and troubleshooting problems will be difficult and require a long time to solve.
On the other hand, the Chinese side has strong and reasonable hopes to operate the same trains on both high-speed and conventional tracks because of the gauge uniformity. In that event, the assertion of some Chinese engineers, that the prevailing signalling system of conventional lines should be used as a basis of the new high-speed lines, cannot be ignored. Future events will depend on the extent to which Japan's assertions about the necessity for integrating systems are understood.

Urban Railways in China

Last, I would like to talk briefly about urban railway systems in China. It must be said their development has been slow, despite their importance. Statistics for 2000 show that China had 30 cities with a non-farming population exceeding 1 million (excluding Hong Kong). Shanghai had the largest population (9.86 million), followed by Beijing (7.61 million), with Shenzhen taking thirtieth spot (1 million).
Private ownership of motor vehicles is increasing rapidly, especially in major cities, reflecting the marked economic growth of recent years. Although construction of urban railways in major cities is proceeding at a rapid pace, it cannot be denied that China still lags behind other countries. Only 10 cities, including Beijing and Shanghai, currently have an urban railway (including monorails). The total length of urban lines operating in these 10 cities is just 585.6 km, with 115 km in Beijing and 145 km in Shanghai. This compares with about 2250 km of lines (including monorails and similar transport modes) within the Tokyo Megalopolis (50-km radius of Tokyo Station). Clearly, construction of urban railways integrated with an appropriate urban plan is a pressing necessity in China, especially considering energy conservation and global warming problems. Since Japan has long experience in developing a range of urban railway systems meeting regional needs, it is well positioned to provide China with technical support for building urban railways.

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Hiroshi Okada

Dr Okada is Principal Senior Adviser of Japan Railway Technical Service (JARTS). After obtaining a degree in civil engineering from the University of Tokyo, he joined JNR in 1953. He transferred to Japan Railway Construction Public Corporation in 1989 where he served as President for 4 years before becoming President of JARTS.