Feasibility of High-Speed Railway in Asia and Oceania

Masao Saito

The opening of the 515.4-km Tokaido Shinkansen connecting Tokyo with Osaka on 1 October 1964 marked the completion of a grand national project for Japan. It was the first high-speed railway in the world and if it had not been developed, railways would have fallen far behind the times, losing out to other modes of transportation, such as cars and airplanes.

The opening of the shinkansen proved its superiority. The 200 km/h or faster speed halved the time required to travel between Tokyo and Osaka from 6.5 hours to 3 hours and 10 minutes. (Further subsequent speed increases have cut the time even more to 2 hours and 30 minutes.)

The belt between Tokyo and Osaka is a megalopolis containing many large and medium-size cities. Forty-five percent of the population live in it, generating 70% of the GNP.

The Tokaido Shinkansen was planned on the basis of this huge demand, and was constructed using Japan's long experience in railway engineering. Passengers have increased year-by-year since the opening and now (30 years later) as many as 360,000 people use it every day, 60% on business trips.

Safety is important for any means of transportation, and since its opening, the Tokaido Shinkansen has transported more than 3 billion passengers without loss of life or serious injury. Without such excellent safety, no high-speed railway can succeed.

After the success of the Tokaido Shinkansen, the Sanyo Shinkansen, Tohoku Shinkansen and Joetsu Shinkansen were opened in quick succession. They use advanced technologies based on the experience of the Tokaido Shinkansen. In addition, the Hokuriku Shinkansen is now under construction to reinforce Japan's high-speed network. At present, there are 1850 kilometers of shinkansen lines in full service.

Without the success of the Tokaido Shinkansen, there would have been no high-speed railway network in Japan, and the TGV and IEC might not be running in Europe. High-speed railways are being built in Italy, Spain and Sweden, with construction starting in Russia. In addition, the Channel Tunnel connecting England with France has been completed with passenger services between Paris and London starting later this year.

Railways were born in the 18th century but are developing toward the 21st century as a safe high-speed mode of transportation using new high-level technologies.

New high-speed railways are based on completely different ideas from conventional railways. The track bed, structures, track, electrical equipment, control techniques and rolling stock are not extensions of conventional railway technology. Each is a complete technology in itself, while needing to be integrated with the other technologies.

1. Problems to Solve in Achieving High-Speed Railways

It is wrong to create high-speed railways by modifying conventional railways. Most tracks for old railways were constructed for steam locomotives. From the speed point of view, such tracks have many sharp curves and narrow tunnels, so high-speed trains cannot run on them. Increasing the radius of curves and widening tunnels cost much the same as constructing a completely new line.

On conventional railways, safety is secured by the driver checking signals. This means that the train must run slow enough for the driver to have enough time to stop the train when a red signal is seen.

Namely, the maximum speed of a train is determined by the brake distance required for the driver to check signals and stop the train. At high speeds like 200 km/h, the brake distance is so long (2400 m at 200 km/h), that a collision could not be avoided by the driver applying the brake. Therefore, high-speed railways require a radical change in the way of thinking. Grade separation, and development of new control systems best suited to high-speed running, etc., all become necessary.

From the environmental viewpoint, the higher the train speed, the higher the noise due to rolling (wheels on rail) and current collection (pantographs on trolley line). At higher speeds, aerodynamic noise (made by the train pushing through the air) increases. Therefore, noise-reduction techniques become necessary.

High-speed railways are mostly required in regions with many densely-populated cities, but if they are constructed in sparsely-populated areas, they do not pay due to the low ridership. To build high-speed railways, it is important to solve these contradictions.

Construction and Running Costs

These costs are related directly to raising funds and the loan conditions. Before starting construction, the priority sections and whether or not they will pay must be given very serious thought. It is important to develop the necessary simulation techniques and to educate skilled staff to design, construct and coordinate such a large project. First, it is necessary to train staff so that they can integrate the new technologies into a high-speed railway system and run the business properly. People with experience of conventional railways are not necessarily useful for high-speed railways, because past experience often prevents them adapting to new technology.

2. Effect of High-Speed on Business

It is certainly the mission of high-speed railways to shorten travel time by increasing the maximum speed.

Obviously, shortening the travel time leads to expanded market share. However, if increased speed leads to increased energy consumption or repair costs, or degraded environmental conditions, the business does not pay. The problem is how to solve these difficult contradictions technically.

Everybody wants to increase the maximum speed, which is the driving force in further development of high-speed railways. However, the high-speed railway thus developed cannot be said to be successful unless the new technology improves the environment and secures business.

3. Areas Requiring High-Speed Railways

Improved infrastructure is indispensable to the progress of culture, civilisation and society. Political stability and balanced economic growth are indispensable to creating a society where all can enjoy the benefits of civilisation and which is stable and rich materially as well as spiritually.

These aims require the spread of education, access to clean water and medicine, development of agriculture, industry and commerce in good balance, and increased productivity in all these fields. In addition, the distribution system cannot be neglected and reinforcement of finance and capital are also important.

The basis of these prerequisites for social progress is the improved infrastructure, including better water supply and drainage, electric power networks, clean air, and efficient communication networks. Better transportation cannot be omitted. In former times, transportation just meant transporting passengers or freight from one place to another. This no longer holds true. Nowadays, in passenger transportation, it also means transmitting information, while in freight transportation, it is integration in the distribution system.

The necessity for high-speed railways originates in this concept. Together with airlines and motorways, high-speed railway networks contribute greatly to national and regional prosperity.

This is easily understood from the role that the shinkansen has played in Japan. In the 30 years since its opening, the number of passengers per day on the Tokaido Shinkansen has expanded six fold. There is no precedent for such success in known history. The more easily people can travel, the higher development the area along the railway experiences, which increases passengers further in turn However, this may not always be true in all districts.

The traffic system of a nation is complete when high-speed railways, airlines and motorways lead their own fields with each showing its unique worth.

4. Characteristics of Each Mode of Transport

4.1 Speed and Travel Time

The fastest mode of transport is the airplane followed by high-speed railways, and motorways. However, in travelling from one city to another, faster speed does not necessarily mean earlier arrival. In large cities, the vast area required by airports, results in long distances from the city centre to the airport, so it takes a long time to access the airport. For airlines, the travel time is calculated by adding this access time to the flight time.

On the other hand, railway stations are already in the centers of cities because of the railway's long history and because tracks are constructed between cities. Therefore, unlike airlines, high-speed railways require no access time, so the travel time is the actual travel time.

The Tokaido Shinkansen has an 85% share of the traffic between Tokyo and Osaka. Although the actual flight time between Tokyo and Osaka is approximately 1 hour, the required time becomes 2.5 hours when access time is added, very similar to the time for the shinkansen.

Air passengers on the Tokyo-Sendai, Tokyo-Niigata and Tokyo-Nagoya routes have decreased largely due to the opening of the shinkansen. The airlines cut operations on these routes because the distance between these cities is only about 350 km and the shinkansen travel time fell to 2 hours or less.

Motorways have a technical speed limit of about 120 km/h for safe driving. Weather conditions may lower this limit further thereby affecting punctuality.

4.2 Safety

Thirty years of operation by the Tokaido Shinkansen transporting 3 billion passengers without loss of life or severe injury demonstrates the safety of high-speed railways. Similarly, the Sanyo Shinkansen, Tohoku Shinkansen and Joetsu Shinkansen prove the safety of high-speed railways. This is another reason why shinkansen passenger numbers are increasing.

Faster speeds dictate establishment of safer safety systems. To prevent accidents, Japan has strict safety regulations prohibiting entry to the track, railway sabotage and vandalism of safety devices.

Railway companies use elevated tracks and prohibit working on the track during operation hours. Data processing is completely computerised, and test cars run at service speeds to collect track-related data, and control-system and current-collector data to check for wear and fatigue. Staff are also trained using simulators.

4.3 Punctuality

For travellers, transport is not reliable unless it is punctual. If one mode of transport is unreliable, they will soon select another means. High-speed railways are an integration of various technologies. When these various technologies are well integrated and controlled, the trains are punctual as planned. Recent advances in electronics and quality control make it possible to further increase train punctuality without relying on the experience of staff.

Each shinkansen train cab receives data about when and at which speed to pass each point on the route from a central computer. The operation system is backed up by the ATC as explained above, an important element of the safety system.

Japan suffers various natural disaster including typhoons, floods, earthquakes, and heavy snow. Countermeasures are achieved based on 30 years of experience. For example, the Joetsu Shinkansen runs in areas with heavy snowfall, but thanks to snowfall countermeasures, the shinkansen trains run punctually even when other means of transportation are interrupted. Although various countermeasures are used by airlines and motorway authorities, punctuality is low compared with high-speed railways.

5. Finance

5.1 Fares

Fares are determined by various factors. The most important factor is the balance with cost. Namely, the investment necessary to construct the railway and the expenses to run it. When the costs are high, fares must be raised.

On the other hand, there are limits on the passengers' ability to pay the fare. A proper fare system is established by comparing both factors.

Railways are a big national project, and they contribute to national prosperity to a large extent. High-speed railways are an important part of a nation's infrastructure, so fares cannot be determined just by the policy of the railway company from a purely commercial point of view. They must be determined considering the effect on the nation, companies, prices and national income.

When Japan was planning the 515.4-km Tokaido Shinkansen in 1956, it was forecast to be in the red for 10 years going into the black from year 11.

However, although the fare was set 30% higher than that of the conventional lines, the number of passengers increased by 40% every year after the opening. As a result, although the investment due to reinforcement of rolling stock and power facilities, as well as running costs related to personnel and energy consumption increased in proportion to the increase in the number of trains, the increased income exceeded costs and the business entered the black as early as 1966; it has been continuously in profit ever since.

5.2 Raising Funds

As explained above, the total construction cost is determined by design, transport volume (passengers per day) and fare. At the early planning stage, the construction cost has to be estimated according to the OD (origin and destination) table. However, because construction takes a long time, the actual cost often deviates from the initial estimation due to inflation or change in transport demand during the period. Thus construction costs may increase.

As a matter of course, it is better to divide the route into several sections, to determine the order of priority for each section based on business efficiency, funding, construction capacity and transport demand, and to complete and open from the higher to lower priority sections in order, instead of completing the whole route at one time.

6. Training Experts

No company can expand its business without skilled staff. This is an important point to consider in raising funds, and constructing and operating a high-speed railway.

In planning, priority should be given to fostering skilled staff. People who have mastered the technologies start building higher business efficiency. As they accumulate experience, other experts are fostered, and all the sections come together one-by-one.

7. Airlines, High-Speed Railways and Motorways in Japan

Each of the three modes of transportation has unique features for the 21st century. In Japan, construction of high-speed railway networks is planned in relation to the other modes of transport. High-speed railways are planned for densely-populated areas with travel times of about 3 hours. Railways have the advantage that large numbers of passengers can be transported safely at one time while requiring small site area compared with airport and roads. However, Japan is an archipelago with many mountain ranges requiring many long tunnels. Consequently, the shinkansen travel time from Tokyo to Hakata is 5 hours, so airlines dominate this route. Similarly, airlines dominate the Tokyo-Sapporo route.

Based on the above Japanese experience, let's look at the feasibility of high-speed railways in other countries in Asia and Oceania.

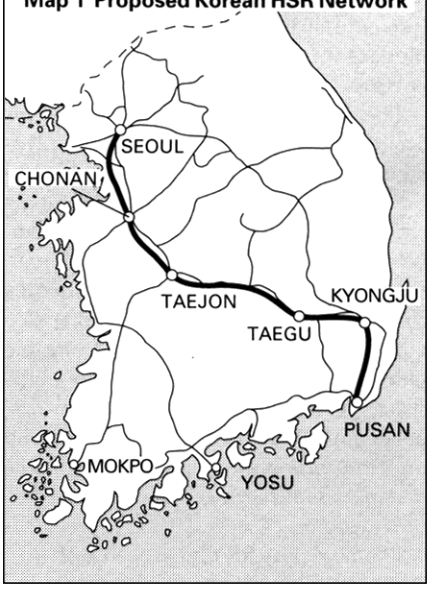
8. Feasibility of Rapid Transit Railway in Asia and Oceania

8.1 Korea

Korea is stable politically and has shown remarkable economic growth, mainly in heavy industries. It is also placing emphasis on foreign relations.

The trunk transport route in Korea is the Seoul-Pusan axis, of which the railway has a high share. Many large and medium-size cities are scattered along the axis, and the number of railway passengers is increasing remarkably every year. The representative train on this line is the Saemaul connecting Seoul to Pusan (444.5 km) in 4 hours and 12 minutes. The 300 tonnes of passenger cars are hauled by a diesel locomotive at 105.8 km/h schedule speed. The maximum speed is 140 km/h. The Saemaul stops at two stations en route (Taegu and Taejon) and offers 18 return services each day. In addition, the Mugung-hwa offers 24 return services (stopping at seven intermediate stations), and the Tong-il offers six return services (stopping at seven intermediate stations). Thus, the line boasts a

Map 1 Proposed Korean HSR Network



large transport capacity typical of a great trunk line.

Railways in Korea are mostly standard gauge (1,435 mm). With this line as the main axis, various express trains connect cities like Seoul-Taejon-Mokpo, Seoul-Taejon-Yosu and Seoul-Taegu-Kyongju-Pusan.

Because the Seoul-Pusan Line is operating at almost full capacity, construction of a high-speed railway connecting Seoul with Pusan at a maximum speed of 300 km/h will be started. Doubtlessly, its completion will lead the country to further economic growth.

We admire Korea for planning a high-speed railway while overcoming difficult political and diplomatic problems, and hope the railway will be completed as early as possible.

The new high-speed railway will have the same gauge as the conventional lines in Korea, making interoperation possible. Therefore, when completed, the high-speed railway will be included in the existing railway network to create a new high-speed network with the new line at the centre.

8.2 China

Railway has a large share (75% or more) of the Chinese transport market. Comparing 1992 with 1949, passenger number-km expanded by 14.4 times, while tonne-km for goods expanded by 16.0 times. In spite of such remarkable growth, only 60% the transportation demand is satisfied. This shortage in railway capacity is impeding the nation's industrial growth. To settle this problem, the following reforms are needed.

1. Modernisation of railway operation and management
2. Improvement and development of railway technology
3. Increase in the transport capacity of major trunk lines

For **2**, introduction of electric or diesel locomotives is already progressing (75%). The tractive force of freight trains has increased from 3500 ton/train to 5000 ton/train.

It is also planned to increase the maximum speed of passenger trains from 110 to 140 km/h.

For **3**, the share of double-track sections in the total of 60,000 km in service has increased to 25%.

8.2-1 Planning Beijing-Shanghai High-Speed Railway

The area along this route has 26.6% of the Chinese population generating 37.9% of the GNP. The per capita income is twice the national average. Although its share of the service kilometers is small (14.4%), the existing line earns five times more operating income than the national average. As a result, the railways in this area are operating at almost full capacity.

To solve these problems, it is necessary to expand the railway from a double-track to four-track system so high- and low-speed trains can run on different tracks.

It would be best to construct a new line dedicated to super-express and express passenger trains.

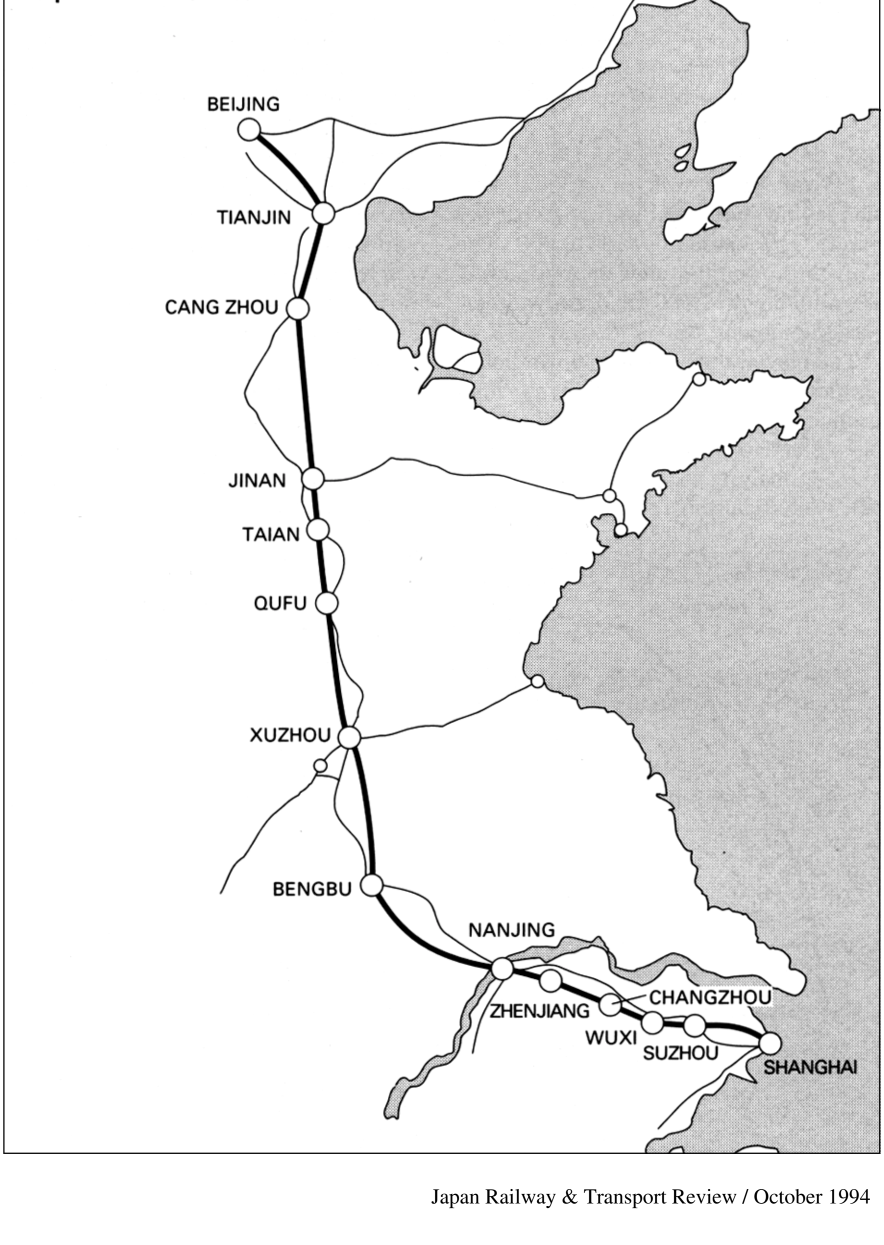
The design conditions should allow operation at 250 km/h at the opening (350 km/h in future).

In addition to super-express trains connecting Beijing directly with Shanghai, other express trains connecting other cities outside the line will run on it.

However, these express trains will operate at maximum speeds of 160 km/h on the new line and at the current speed limits on the conventional lines.

The Chinese railway network runs across a vast land, so it is inevitable

Map 2 Possible Chinese HSR Line



that medium-speed (160 km/h) trains will run on high-speed sections (250 km/h or more). Consequently, sidings and ATC systems are needed to control trains efficiently.

8.2-2 Guangtong-Shingseng-Hong Kong

The Guangtong and Shingseng districts in south China are a Special Economic Zone where industry, banks and trading companies have concentrated. These two districts border Hong Kong. Express trains run frequently in these regions, but the tracks are old, resulting in low speeds.

To solve this problem, a new double-track high-speed line is under construction and will soon be completed. This line will be the first medium-high-speed railway in China, operating at 160 km/h. It will be managed by the Guangtong Railway Group, an independent third-sector company.

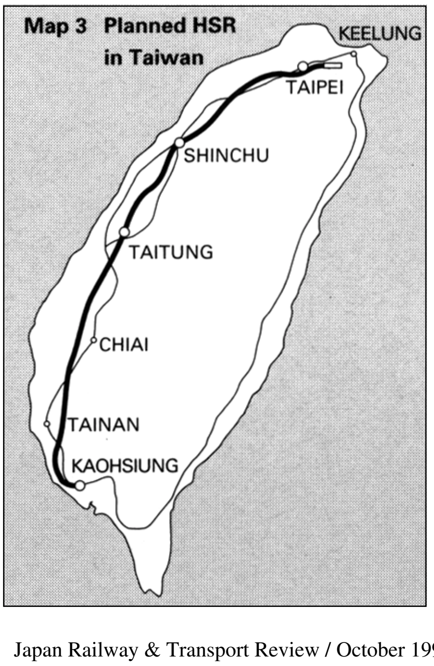
8.3 Taiwan

Taiwan has shown remarkable economic and industrial growth, with per capita GNP exceeding US$10,000. The Taiwanese population is approximately 20 million with 1,000 km of railway service kilometers.

The eleven major plans shown below cannot be neglected in achieving high economic and industrial growth.

(1) Electrification of Keelung-Taipei-Kaohsiung section
(2) Construction of new Taipei Station (underground)
(3) Completion of Round-Taiwan Line connecting Taipei-Hualien-Taitong-Kaohsiung
(4) Completion of Taipei International Airport
(5) Completion of Taipei-Kaohsiung Highway
(6) Reinforcement of power and communication networks
(7) New construction or expansion of Taitung Port and Kaohsiung Port
(8) Reinforcement of water supply and drainage in major cities
(9) New measures for environmental conservation
(10) Reinforcement and expansion of banking
(11) Spread and raising level of education

Map 3 Planned HSR in Taiwan



In addition, a subway is now under construction in Taipei, and Kaohsiung is planning subway construction. Passengers on the 400-km Corridor Line connecting Taipei-Taitung-Kaohsiung are increasing every year, and the railway is operating at almost full capacity.

In these circumstances, construction of a high-speed railway is in planning, and construction of the Keelung-Taipei-Shinchu highway section in under way.

The high-speed railway will be 345-km long starting from Sungshan and reaching Kaohsiung by way of Taipei Station, Taouen (international airport), Shingchu, Taitung, Chiai and Tainan. The planned maximum speed is 250 to 300 km/h (350 km/h in future). However, the location of stations, how to raise funds, who will run the business, etc., have not been determined yet, and the plan has not been ratified by the legislature.

We hope these matters will soon be settled so the plan can be realised as early as possible.

8.4 Australia

In October, 1993, the Australian Ministry of Transport announced that they would start a feasibility study on a high-speed railway between Sydney and Canberra. The route is 326-km long and includes part of the rapid transit railway (VFT) planned and surveyed previously to connect Sydney with Melbourne. The planned line starts from Sydney Station, runs on an existing New South Wales line and then on a new line to reach Canberra.

If constructed, the travel time will fall from 4 hours and 40 minutes to 1 hour and 15 minutes. ■

Masao Saito

Mr Saito was born in 1919 and studied mechanical engineering at Waseda University. He joined the national railways in 1946. He was responsible for train operations on the Tokaido Shinkansen for a long period after its inauguration. He also served as Director General of JNR's Labour Science Research Institute. He left JNR in 1972, and joined the NEC Group, the Japanese electronics giant. As President and then Chairman of NEC Railway Communication Engineering Co., he travelled extensively and visited almost every railway in the world. Since 1988, he has been Executive Consultant for Railway Systems Engineering of the United Nations Development Program.