9

Traffic and Transport Technology—Road, Railway, and Water-borne Transportation

Modernization and the Railway

The government-operated Yawata Ironworks produced iron and steel for both munitions and for railway- and bridge-construction materials.

The mission from Russia that visited Nagasaki in 1853 to request the opening of the port brought with it a model of a locomotive that used alcohol for fuel to officials of the shogunate and, to everyone's surprise, claimed the full-scale locomotive could pull several carriages and carry 500 persons up to 280 *ri* (1,081 kilometres).

In the following year, the US Navy fleet visited Japan for the second time and brought with it a large model of a locomotive, along with telegraph instruments. The American locomotive was purportedly 2.4 metres long, 1.5 metres wide, and 3 metres high (see Harada 1979, 1980), and it pulled a car on a 109-metre loop railway with a 550-millimetre gauge. The story is told that people could get on the roof of the carriage. In any event, there was great excitement and curiosity among the onlookers. In the same year, the Japanese translation of P. van der Berg's *Eerste Grondbeginselen der Natuurkunde* (1884) was published, in which the mechanism of the locomotive was systematically described.

Thus, considerable knowledge of railways had accumulated by the end of the Tokugawa period, and it is said the shogunate had plans for a railway. It was not until the Meiji period, however, that the plans were realized: A man named L. C. Portman of the US legation in Japan pressed the new government for confirmation of the concession to lay a railway between Edo (Tokyo) and Yokohama that he claimed he had obtained in 1867 from an official of the shogunate's government. The new government, however, had no policy concerning a railway and was startled by the request.

In a hasty decision, the government declined to confirm the concession. Starting with the laying of rails between Tokyo and Kyoto, the government intended to construct and to operate all railways in Japan independently.

This decision brought on a diplomatic dispute with Portman and the US legation. The new government, while over-sensitive to diplomatic problems generally, was able to refuse because it had the strong support of the British minister to Japan, H. S. Parkes. The government's policy to build and operate a railway independently suited Britain's desire to eliminate its competitors, and, through Parkes's mediation, an agreement was made to raise a loan for construction on the London market and to introduce the technology from Britain. Applications were accepted for the concession to lay a railway not only between Tokyo and Yokohama but also between Osaka and Kyoto.

Japan's decision to inaugurate a railway system was taken in direct response to foreign pressure, in particular, to British diplomatic and commercial interests, and this was opposed by such technocrats as Inoue Masaru (1843–1910), who advocated Japanese "government construction and government operation."[38]

Subsequent to the Meiji Restoration, Edo was renamed Tokyo and made the new capital, but Japan actually seemed to be a country with two capitals: one in Tokyo and the other in Kyoto. Consequently, the construction of a railway connecting the two cities was necessary for political stability.

Thus it came about that, although railways in Europe had developed as industrial railways on the basis of economic development after the Industrial Revolution, the railway in Meiji Japan began as a political railway and the industrial aspects arose later.

Ninety years after the first Japanese train puffed its way between Tokyo and Yokohama, the Shinkansen (the so-called bullet train on the New Tokaido line) began operation concurrently with the Tokyo Olympic Games in 1964, and Japanese railway technology thus became among the most advanced in the world.[39] The Shinkansen was an inspiration to people in the world's railway industries, people who had been discouraged by the industry's decline under the influence of automobiles and aeroplanes. As a consequence, Japanese railway technology has come to share a part in the export of technologies.

The role of the railway in Japan's modernization is so great that it may be called the "keystone of modernization" (Harada 1979, 1980). Besides its effect on economic development, the railway—along with schools and the military—is said to have been a principal contributor to the Japanese habit of punctuality. In fact, the railway helped in many ways to spread modern Western civilization throughout Japan.

Iron manufacturing and the railway each constituted a cornerstone of Japan's technological development. Conversely, the railway also constituted a prerequisite for colonization, and in the Japanese colonies, the railway was an important tool in maintaining authority.

The Transportation Network

The railway symbolized the "civilization and enlightenment" policy of the Meiji government. It was the symbol of a new, modern government for Japan and its people. Indeed, the railway revolutionized transportation, but it also accelerated the confusion predominant in those days among the diverse means of transportation. Japan had not experienced a full-scale development of the horse carriage when the railway was introduced (Yamamoto 1979, 1980). Before the Meiji Restoration, vehicle transportation on the highways was prohibited. Travel was allowed only by foot, horseback, or palanquin. Heavy cargo was usually transported by boat on rivers and canals. For moving goods, people depended on the coastal and inland waterways as main transportation routes; water-borne transport was quicker and cheaper and had a greater capacity than road transport. Consequently, roads were secondary.

Nevertheless, the roads were well-developed; all villages were connected by roads, though they could not be used in all kinds of weather. With the roads and the well-organized network of boat transportation, Japan experienced high traffic density in the nineteenth century.

Even by the 1980s, statistics reveal, total road mileage in Japan had increased but 20 per cent since the Meiji Restoration. The old roads, however, had been constructed for travel by foot, horseback, and palanquin; thus, their widths and grades were unsuitable for vehicles; stoned-paved roads were rare. Although the increase in total kilometres has been small, the total area of roads has expanded several dozen times. Motorway construction got underway in earnest in the 1960s, and before long a network of highways blanketed the country.

After World War II, the Occupation forces were surprised by the poor roads in Japan, but this was due to Japan's short history of automobile use. There had been no full-scale development of carriage transportation to serve as a preliminary stage for the age of motor vehicles. Because the diffusion of railways was so quick, Japan was an advanced country for railway travel but one underdeveloped for road travel.

The highways (there were five) that had been directly administered by the Tokugawa government were well maintained, and many Europeans left records of favourable impressions. However, for security reasons, the Tokugawa government limited travel and prohibited the construction of bridges.

The new Meiji government, however, granted freedom of travel and transportation, allowed the construction of bridges, and promoted the development of roads. It even allowed toll collection for a limited period to cover construction costs for the bridges, which were built and financed by the private sector. In one sense, the Meiji period had introduced the first road age in Japan nearly a century before the second one. Road and railway traffic were added to water-borne traffic, and a period of mixed transportation thus commenced (Yamamoto 1979, 1980).

Regarding road traffic, the palanquin disappeared; in its place, the carriage appeared, and a large cart (called *daihachi-guruma*) and the horse. The horse-tramway was newly introduced, and travel by horseback was still popular. The rickshaw, a Japanese invention, also appeared. In a period of approximately 10 years, a great variety of transport means had emerged. The "express" route between Tokyo and Kyoto (495 kilometres) consisted in 1878 of 1 section of railway, 7 of horse-drawn carriage, 1 of rickshaw, and 4 of walking, creating a very patchy traffic route totalling 13 sections that required 60 hours of travel.

In 1889, the railway between Tokyo and Kobe was opened to through traffic, and extensions of trunk railway lines spread the network throughout Japan and thus alleviated much of the patchiness of the system. Nevertheless, because Japan is an island country, patches have remained in marine traffic where ferry routes are operated by the railway companies. The Kammon undersea tunnel was constructed in 1942 to connect the main island of Honshu with Kyushu; its extension on the other end of Honshu, connecting that island with Hokkaido, was completed in 1988.

Digressing momentarily, mention might be made of marine transport, which was an important element of industrialization and which developed in relation to railway development in Japan. Japan's closed-door policy had included a prohibition against the construction of ocean-going ships, and, consequently, Japan had no technology for constructing and operating large vessels. Thus, one of the first steps taken by the Tokugawa shogunate in establishing its defence policy was to purchase from the Netherlands a steam-powered warship (300 tons, 3 masts, 100 hp) and training for its crew.

The opening of Japan's ports allowed foreign vessels to enter into the coastal transport business. Japanese ships could not compete with these vessels in speed and carrying capacity, and consequently in freight rates. To cope with this situation, a semi-governmental shipping company was organized, using government-owned ships (which were foreign made and which the Meiji government had inherited). The business went bankrupt within a few years, however, and in 1875, the government adjusted its policy to one of fostering a powerful private steamship company. In this way, Mitsubishi acquired 13 government-owned vessels and a subsidy of Y2.53 million for 10 years, enabling it to overtake its competitors, the Pacific Mail Steamship Co. (US) and the Peninsular and Oriental Steamship Co. (Britain), in domestic coastal transport, and, in 1876, to enter into service between Yokohama and Shanghai. From that year, Mitsubishi was obliged to establish a merchant marine school and was granted a 14-year subsidy for its shipping operation.

A long time was necessary for shipbuilding technology to become independent, and it is noteworthy that its arrival at self-reliance precisely coincided with the development of self-reliance in railway technology.

Although Japan had the ability to create basic design, it did not have expertise in the details of design and the processes or specifications of shipbuilding. It therefore placed orders for ships with foreign countries and, in an attempt to master the technology, requested that delivery include a complete set of drawings and other pertinent documents.

Returning to the railways, railway technology was of great importance because its spread led eventually to the establishment of machine manufacture throughout Japan. Machine manufacturing technology was transmitted through the individual manufacturing divisions that developed in the railway industry, and many local plants became the site for the accumulation of technology.

For example, the Hamamatsu plant became the birthplace of the No. 1 model of the Type C51 locomotive, used on the special express train Tsubame (swallow), which marked the golden age of the Japanese National Railway. This was in 1919, seven years after the wholly domestic production of locomotives had been achieved. Although electrification had been completed between Tokyo and Numazu, a steam locomotive was used for this "star" train because of its high reliability.

It is significant that a locomotive of this stature was manufactured in a regional plant. In 1920, Hamamatsu had a population of only 65,000, but on the eve of World War II it had become a major centre of the machine industry and of radio-wave technology. After the war, makers of famous musical instruments and motorcycle manufacturers sprang up in this area, the seeds for this industrial development dating back to the establishment of the railway's machine manufacturing division. Further in the background was the technology of woodworking and the manufacture of weaving machines, but our interest lies more with an examination of the machine manufacture division.

The railway represents a compound technology; it embraces complicated, precise mechanisms of several branches of technology, such as construction, communications facilities, signalling, electricity, supplying of coal and water, and the utilization and administration of machines, tools, and power. It symbolizes well the formation of a national network of technology because the scale of its technological linkage is extensive and its level is high. At least this has been so in Japan, and for this reason, the focus on self-reliance in railway technology is perhaps well justified.

Issues in Railway Policy

Railway technology consists roughly of the following five systems: (1) operation (running, communications, and signalling); (2) maintenance (track maintenance, repair); (3) production (design, production); (4) construction (surveying, laying track, including construction of tunnels, bridges, and facilities for transmission and distribution of electricity); (5) station services (for passengers and freight, planning and administration of running and marshalling, safety).

Because of the wide range of these systems, one problem is to interrelate the technological independence attained in one sector with that in others. It is thus apparent that technology can be developed only in a spiral through the convergence of linkages.

Railway technology was imported for its usability—not so that it could be reproduced domestically—and its transfer depended on the pre-existence of a native civil engineering technology. Foreign engineers were in charge of basic design, and according to their records, the Japanese level of surveying was already high and the Japanese were quick to master new technology. This was in thanks to the good use made of the stock of traditional technology, the essence of which lay in castle construction.

The standard gauge (1,435 millimetres) used in European countries was not adopted in Japan. Rather, the narrow gauge, of 1,067 millimetres and called the "colonial type," was adopted. It was in use in India (between Bombay and Turner), Australia (Flinderstreet and Melbourne), and in China (Shanghai and Wusung).

It is not certain why the narrow guage was adopted. One reason may be that the politicians simply did not know railway technology, or it may have been, since the money and materials were procured in England, the Japanese authorities were forced to accept the standards of railway construction adopted in Asia by the English. The cost of the narrow gauge, less than that of the wide gauge, was perhpas an important consideration at the time.

However, as the value of the railway as an industrial artery increased, a call arose for revising the gauge so that the efficiency and high speed possible with the wider gauge could be realized. In general, railway engineers and bureaucrats advocated the wider gauge. As with the Yawata Ironworks, the formal English name of Imperial Government Railway expressed Japan's desire, as a late comer, to catch up with the forerunners and take its place among them.

Because a change of gauge included the improvement of tunnels and bridges, it was advantageous to start the conversion as early as possible. Changing the gauge after completion of the network would be impossible because of the greater difficulties and financial burdens this would generate.[40]

On the other hand, there were those concerned with the role of the railway in local development who rejected this technology-first attitude. They maintained concern ought to be over an extension of absolute mileage rather than technological quality. Railway policy thus became a political issue: change over to the international standard with an eye to technological independence or give priority to development, in other words, vertical or horizontal expansion of technology.

In the 1910s, in parallel with the development of party politics, the matter of the railway became a serious election campaign issue—that is, a rallying point for mobilizing local interests—among the political parties. One result was the construction of the "hooded crane" of the Ofunato Line (Iwate Prefecture), a U-shaped line that was three times longer than the shortest possible route promoted for the interests of their constituents by powerful Diet members. Similar political decisions were repeated after World War II, which constituted one reason for the overall decline of the Japanese National Railway.

Regarding railway technology, the role played by the military at the initial stage of the opening of the railways should not be overlooked. When the decision was made to establish the railway, it was complicated by diplomatic issues, and the new government's financial basis, burdened by the debts inherited from the former government, was weak. The Emperor, although the sovereign, did not have the imperial military forces under his direct control and was guarded by soldiers provided by the powerful anti-Tokugawa clans.

Under such circumstances, a few leading figures of the Meiji Restoration, such as Saigo Takamori (1827–1877), insisted that the railways were the "way to financial ruin" and that it was more essential to organize the nation's armed forces.

The military authorities recognized the importance of the railways, however, after the Southwestern Rebellion (1877), but they opposed a plan to lay a trunk line between Tokyo and Kyoto along the old established Pacific coastal route (called the Tokaido) because of its vulnerability from the viewpoint of defence. They insisted instead on a plan for a line through the central mountains (the Nakasendo route), which would have required a huge outlay of money. In the end the military conceded for technological and financial reasons. And from 1887, it fervently insisted on the adoption of the wide gauge. But in 1898, this insistence suddenly stopped, and the military proposed the adoption of standard specifications in design, operation, signals, and administration and had these specifications effected.

The year 1889 was an important year for the Japanese railway system: it was the year traffic opened between Tokyo and Kobe. Also at this time railway construction and operation by the government reached a deadlock for financial reasons, and when private railway companies sprang up, they won the concessions to lay Japan's longest line (from Ueno to Aomori) and the lines beyond Kobe.

In 1890, the total mileage of private lines was 1,364 kilometres, as opposed to the government's 885 kilometres. This mix of government and private operations brought on the need for adjustments in railway construction policy—from both military and commercial standpoints. It was essential and inevitable that all railways in Japan be standardized under a single set of technological specifications (in sharp contrast to the situation in some other Asian countries). In this the interests of the railway technocrats coincided with those of the military technocrats. Thus, technological compatibility and consistency became the integrating feature of the above-mentioned five-system compound technology. Before this standardization, all railway companies had been obliged to allow the government free use of their trains in times of emergency or disturbance.

In 1890, Japan was struck for the first time by a capitalist economic panic. Some private railway companies went bankrupt as a result, and there arose calls from the private sector for nationalization. The leadership in railway construction thus fell again into the hands of bureaucrats (military and railway), hence advancing the cause of nationalization.

Railway construction and operation by the government thus developed, leading eventually to the formation of a Japanese national railway system. However, the national railway system was confined to the trunk lines, and the private railways survived.

After World War II, private railway companies prospered and the national railway declined. One exception to this was the Shinkansen, whose operation co-efficient is 60 per cent (that is, the cost as a percentage of fare is 60 per cent). Many local lines have suffered deficits, and the Japan National Railway carried a gigantic deficit over many years, eventually forcing a fundamental reform.

Original Design and Production by Imitation—The Road to Self-Reliance

The construction of the line between Kyoto and Ohtsu, which was begun in 1878, was difficult because of the hilly terrain, rivers, and other obstacles. Inoue Masaru, mentioned previously, assigned foreigners as advisers, bridge and tunnel designers, and used only Japanese for the actual laying and construction. As a result, the line was built exclusively by Japanese. For the construction of the tunnels, for example, Japanese mining technology (the skills of the miners at the Ikuno Silver Mine) was made use of.

Here, then, is an example of a rational combination of new design technology from abroad and the stock of traditional technology, which proved to be wise management in the process of transfer.

The army's advocacy for standardization of the railway system was a policy of the unification of technology. Depending on whether this unification can arrive at the technology for production, it will become either the starting point or the end-point of self-reliance in technology. In the Japanese experience, first design technology that was easily transferable was mastered, then conceptual design, leaving the design of details to foreign manufacturers. And while mastering the assembly of delivered machines, Japan began independent production of copied component parts.

The most difficult technology to change from user to manufacturer was the locomotive. In terms of the five stages, the gap between the fourth and the fifth stages was enormous. Japanese engineers dealt with the problem as follows.

In 1910, Japan ordered 12 locomotives from Germany, 26 from the United States, and 12 from Great Britain. The basic specifications to be met were: axis location 2C, weight 52 tons; axis weight 12.5 tons; diameter of driving wheel 1,600 millimetres; cylinder 470 x 610 millimetres; pressure 12.7 kg/sq m; whole conduction area 159.8 sq m; heating area 28.5 sq m; height of central line of the can 2,286 millimetres; valve equipment Fullshart type; superheater Schmidt type; maximum speed 96 km/h.

When the first of these new, powerful locomotives was delivered, Japan National Railway engineers and manufacturers carefully measured and tested each part and were able to produce an exact copy using the same materials.

Reflecting the technological situation of each country, the same locomotive could not be manufactured from the same specifications. For example, those made in Great Britain were not equipped with the superheater because the country lacked the technology for it. Perhaps it was to be able to compare the differing models that accounts for Japan's purchasing locomotives that were at variance from the original specifications. In any event, through the dismantling, reassembling, analysis, and testing of each component part, the Japanese engineers gained a detailed knowledge of the design and manufacture of locomotives from around the world. The different national models provided a good opportunity for Japanese manufacturers and repair houses to make a careful comparison.

Through this careful study and testing, Japanese engineers mastered technological know-how from design to production and were able to adjust designs according to the limitations of manufacturing. Thus, in the following year they were successful in achieving improvements to increase the boiler and water-tank capacities.

By the first quarter of the twentieth century, completely new types of locomotives for both passenger and freight trains were being manufactured, based on designs to fit the natural and technological conditions of Japan. These were the C51 locomotive for express passenger trains (1919) and the D50 for freight trains (1923), both enjoying a reputation for outstanding design.

In this way, the technological background was prepared for Japan's entrance into the golden age of railways in the 1920s. It had even become possible to attain speeds on narrow gauge tracks that traditionally could be obtained only on wide gauge.

Electric locomotives appeared on the scene around this time, and the Japan National Railway developed its own power sources and promoted electrification. Although various types of electric locomotives were imported from abroad, they brought with them many troubles. The operating conditions in Japan were quite different from those in the countries where they were manufactured, the level of technological stability was low, and there was a lack of interchangeability of component parts. A policy of domestic production was promoted as a result, and in 1928 Japan produced the EF52.

The first locomotive to be manufactured in Japan was built in 1893. Using a foreign design and foreign expertise, it took two years to build what can only be called a handcrafted locomotive, and without benefit of a pre-existent base of machine manufacture or heavy industry. This is a good example of how, with a model and many skilled workers, it is possible to produce a product.

Such technological independence was pre-modern independence, in essence, and had strictly a cumulative nature; it had neither national linkage nor international competitiveness. The product—the details and mechanisms of which differed one from the other—could be repaired only at the place of manufacture. Consequently, the products were not industrial products so much as examples of handicraft. In this sense, self-reliance in railway technology was not actually achieved until the years 1910–1920.

In any case, the example of the locomotive, and others as well, demonstrate that the ability to imitate is an important element of technology transfer and development. And yet, needless to say, in imitation, the level and quality of production will differ according to the varying technological conditions. The circuit from imitation to original production is likely to be repeated in many countries.

The Role of Foreign Engineers

As already stated, foreign engineers did not play positive roles in iron manufacturing. But the situation was different regarding railways. It was fortunate that the industry was blessed with such talented men as Edmond Morell (1841–1871), who came to Japan in 1870 as the chief engineer for the Keihin Railway Co., and William F. Potter, construction engineer. Morell opposed the importation of ties made of iron because those purchased earlier had proved unsuitable for the humid Japanese alluvial soil and because good-quality wood for ties was available in Japan.

Morell also proposed that the government establish an independent department to specialize in the administration of construction, including railways, and that the department should be in charge of cultivating technology experts. His recommendation led to the establishment of the Ministry of Works (1870, abolished in 1885) and, with the support of enlightened engineers, to the 1871 establishment of an engineering school, the Kogakuryo (this eventually became the Engineering College and later the Engineering Faculty of Tokyo University). Morell, who is buried in the cemetery for foreigners in Yokohama and hailed as "the benefactor of the Japanese railway," laid a solid foundation for this industry during his few years in Japan.

Morell and Potter were highly perceptive of the special characteristics of the Japanese economy and culture and thus knew how to evaluate and effectively apply traditional Japanese technology and skills. The presence of many excellent foreign engineers contributed to Japanese know-how in bridge construction and tunnel excavation and to a growing sense of confidence and expertise on the part of Japanese engineers. Thus, the successful transfer of a technology involves the cultivation of technological talent among the recipients of the technology.

The 30-kilometre connecting line between Shimbashi in Tokyo and Yokohama opened in 1872; the one-way journey required 50 minutes, and five round-trip shuttles were made each day. The advent of rail travel introduced a new equality into Japanese society: on the trains, regardless of social ranking, everyone rode together. The system of ranking by fares was established at a later stage, when the private rail comparies introduced three ranks of cars—white, blue, and red.

By 1982, the Japanese National Railway had become a gigantic modern enterprise with 21,400 kilometres of total operating distance; 6,944 million passengers annually; 100 million tons of freight; 5,290 stations; 3,757 locomotives; 18,235 trains; 4,683 diesel-powered railcars; 556 passenger trains; 84,923 freight cars; and 387,000 employees.

On the other hand, around this time the enterprise had been accumulating an average annual deficit of ¥1,461,900 million (US$6 billion at the rate of 240 to US$1), and its accumulated deficit up to 1982 amounted to ¥18 trillion (US$108 billion), and thus it was forced to pay an immense amount of interest. Nevertheless, the national railway was carrying 40 per cent of all passengers (9.7 per cent of all freight), and one can thus see that the role of the railways in Japan's modernization has not ended, although the industry is no longer the leading sector of technology.