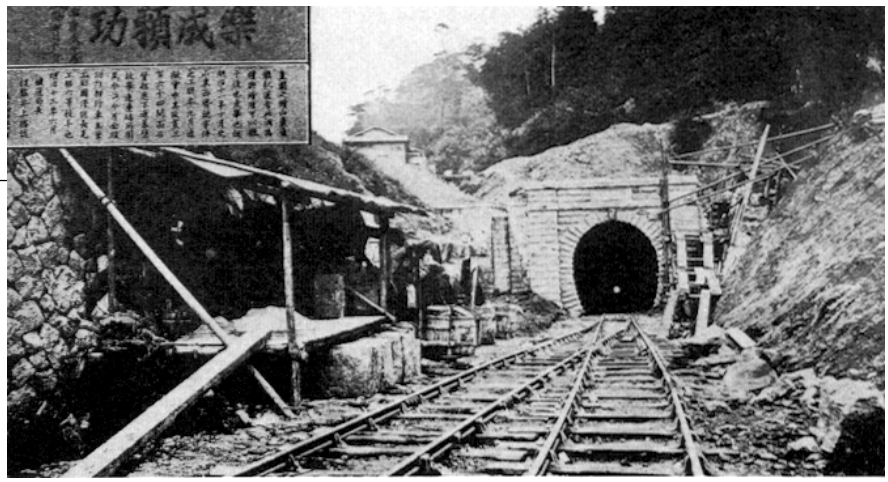
Growth of Independent Technology

Eiichi Aoki



■ Portal of Osakayama Tunnel, completed in 1880. Both portals are nowpreserved as a national railway monument. (Transportation Museum, Tokyo)

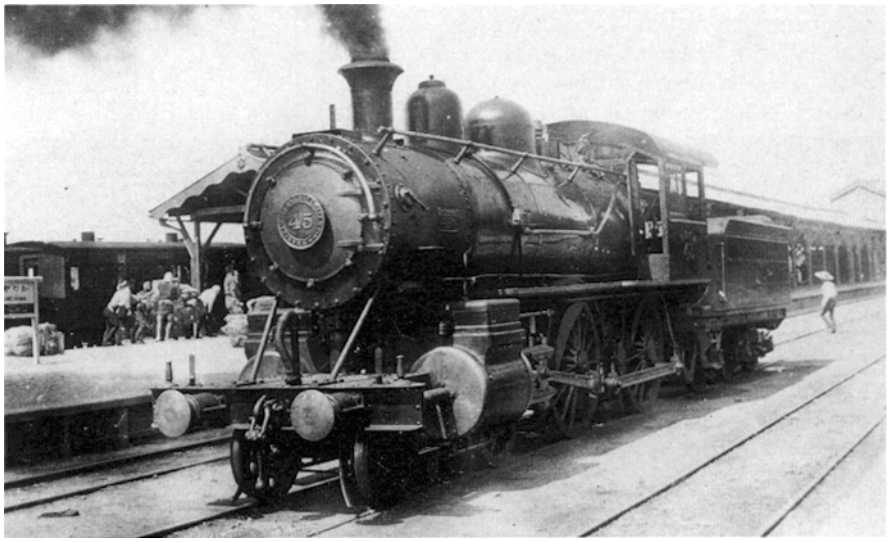
Absorbing Foreign Railway Technology

Since Japan lacked railway technology, foreign engineers were hired by the Japanese government to work on all aspects of the railway between Tokyo and Yokohama, including direction and supervision of surveying and construction, inspection of imported machinery and materials, train operation and preparing of timetables.

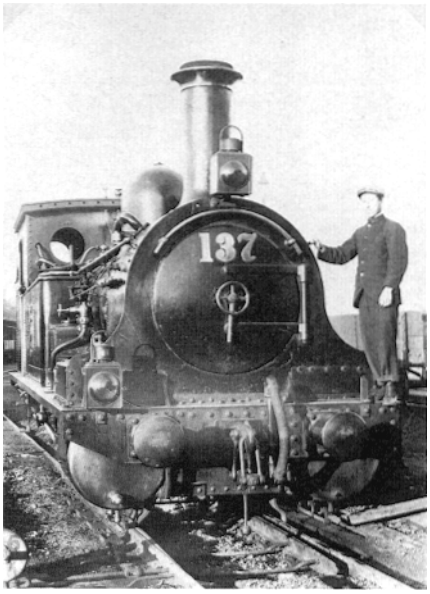
However, Japan already had some engineering knowledge in the Edo period that could be applied to railway construction. For example, cutting, embanking, drifting and artesian well construction were widely used. However, these techniques had been developed through long experience and were not based on scientific and mathematical theories. Advanced mathematical theories such as differential and integral calculus were in use in Japan, but people did not think of applying them to engineering.

Railway construction requires a basic knowledge of mathematics, physics, geology and modern civil engineering. The Engineer Training College established at Osaka Station in May 1877 was Japan's first school teaching railway construction, as mentioned in the first article in this series. Graduates participated in construction of the railway between Kyoto and Otsu, including the 646-meter Osakayama Tunnel completed in 1880, which was the first mountain tunnel designed and built by Japanese engineers. The Engineer Training College graduates were later engaged in surveying and construction of the Tokaido railway and other new railways elsewhere. In the 1880s, many graduates from the National College of Technology (which later became the Imperial College of Technology) began playing an active role as railway engineers.

In the Edo period, few permanent bridges were built across large rivers, because the river flows tended to change drastically with the season, and wooden bridges were easily washed away by frequent floods. When the Tokaido railway was built, solid brick piers were sunk more than 20 meters below riverbeds to ensure that bridges



■ American 2B tender engines were popular for passenger trains. Kansei Railway had locomotives with large-diameter driving wheels(5'2"). Built at Pittsburgh Works. (Transportation Museum, Tokyo)



■ Type 1B1 compound tank engine. First domestically-built locomotive.
(Transportation Museum, Tokyo)

would not be destroyed by floods. The bridge construction set a new standard of engineering in Japan. The bricks for the piers were made of clay from along the railway line. However, the bridge trusses were made of either wrought iron or steel, designed by C.A.W. Pownall, a British engineer, and manufactured in the UK, based on three standard types (100 feet, 150 feet and 200 feet). The graduates from the Engineer Training College were also engaged in designing and directing bridge construction.

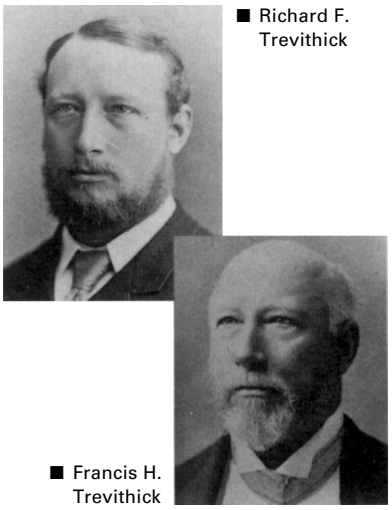
Civil railway engineering was the first field in which the shift from foreign to Japanese engineers occurred.

Foreign and Domestic Production of Steam Locomotives

The locomotives, passenger carriages and wagons used in Japan's first railway between Tokyo and Yokohama, which went into service in 1872, were all made in the UK. The design of ten imported tank locomotives was entrusted to British locomotive builders, who were provided only with simple specifications and performance requirements. The names of the builders and the number of locomotives they manufactured are shown below. The 1B (2-4-0) wheel arrangement was used for all the locomotives. However, since the types varied among the five builders, and five types were delivered to Japan, operation and maintenance must have been challenging.

Tender locomotives and more powerful locomotives capable of running on gradients were imported along with tank locomotives for use in the railway built between Kobe, Osaka and Kyoto after 1874. They were all British as well. In 1876, two C (0-6-0) tender locomotives with a driving wheel diameter of 3'7" (1,092 mm) for freight transport were converted into 2B (4-4-0) tender locomotives with a driving wheel diameter of 4'6 4/5" (1,397 mm) for passenger transport. This large-scale remodelling was conducted under the supervision of W.M. Smith, a locomotive superintendent.

The first railway in Hokkaido was constructed for shipment of coal between Temiya (Otaru) and Horonai coal mine. The line went into service between Temiya and Sapporo, in 1880, and was extended to the mine in 1882. Since this railway was designed and built like an American frontier railway



■ Richard F. Trevithick

■ Francis H. Trevithick

(Transportation Museum, Tokyo)

Richard F. Trevithick (1845-1913)
Francis H. Trevithick (1850-1931)

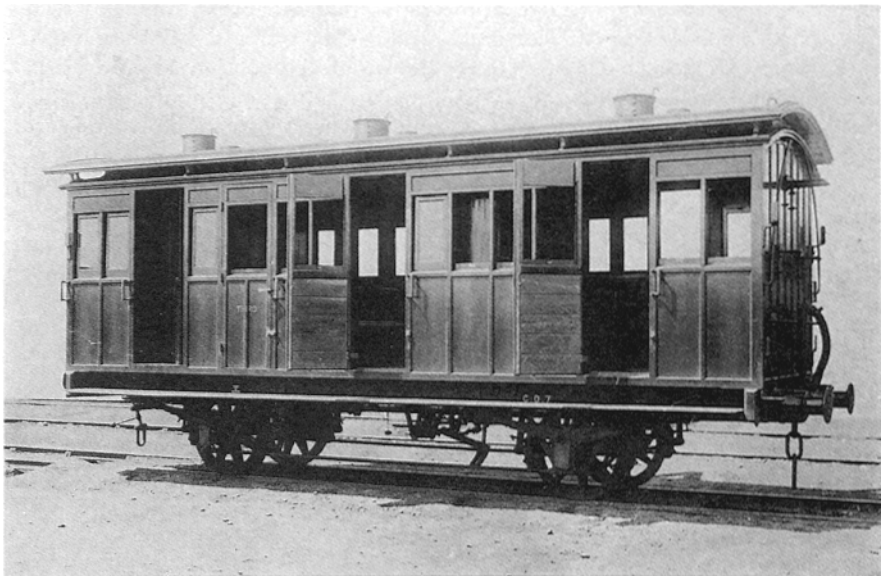
Richard and Francis Trevithick were grandsons of Richard Trevithick (1771-1833) who is well-known as one inventor of the steam locomotive. Since their father, Francis Trevithick (1812-1877), was a locomotive superintendent for the London & North Western Railway, they were both born in Crewe, UK, where the railway had a works.

Hired by the Japanese government railways, Francis, the third son, came to Japan in September 1876; Richard, the first son, came in March 1888. The railways had works in Shinbashi and Kobe where locomotive superintendents were responsible for designing, manufacturing and maintaining rolling stock. Francis took up the position of locomotive superintendent at the Shinbashi works in June 1878; Richard was appointed locomotive superintendent at the Kobe works in March 1888. Both held office for many years until March 1897 serving as leaders in the field of rolling-stock technology.

Francis started production of carriages at the Shinbashi works in 1897. In 1893, he was in charge of importing and making a trial run of an Apt rack-and-pinion locomotive to be used in the section of the Shin-etsu line between Yokokawa and Karuizawa which had a 1/15 gradient. He helped ensure a successful trial run.

In 1893, Richard succeeded in building prototypes of locomotives at the Kobe works for the first time in Japan. He trained many Japanese locomotive engineers who became leaders in locomotive design in the early 20th century.

Francis and Richard both married Japanese women. Francis' two sons became naturalised Japanese citizens and their descendants, named Okuno, still live in Japan.



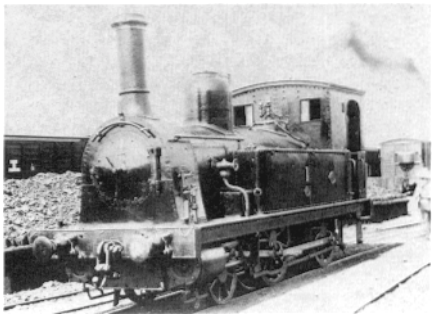
■ Twin-axle third-class passenger carriage with five compartments.
(Reprinted from RAILWAYS AN ROLLING STOCK IN JAPAN)

under the direction of J.U. Crawford, an American engineer, 1C (2-6-0) tender locomotives, manufactured by Porter Inc. (H.K. Vertec) of Pittsburgh, USA, were used. They weighed only 16.5 tons and were suitable for light railways which could be built quickly. These locomotives were famous, because they were named after Yoshitsune and Benkei, popular heroes in the Japanese medieval period.

The Iyo railway, which went into service in 1888 between the outer port and inner city of Matsuyama, Shikoku, was a narrow-gauge railway using 2'6" (762 mm)-gauge tracks for the first time in Japan. 7.8-ton, B (0-4-0) tank locomotives, manufactured by Lokomotivfabrik Krauss of Munich, Germany, were used.

British locomotives accounted for most of the locomotives imported in the 1870s and 1880s, but many American and German locomotives were also imported in the 1890s and 1900s. A small number of locomotives was also imported from France, Switzerland and Belgium. Japan, which was rapidly expanding its railway network, was a big market for American and European locomotive manufacturers.

Most of the imported locomotives used a single expansion system with external cylinders based on an orthodox design concept. In the early 20th century, tender locomotives with a 2B (4-4-0) wheel arrangement were used mainly for long-distance passenger trains, 1B1 (2-4-2) or 1C1 (2-6-2) tank locomotives were used for short-distance, general-purpose trains, and 1C (2-6-0) or 1D (2-8-0) tender locomotives and C1 (0-6-2) tank locomotives were used for freight trains and trains running on steep gradients. Although the use of compound locomotives and *Mallard* articulated locomotives still remained at an experimental stage, Sanyo Railway introduced a large number of Vauclain compound locomotives—24 in total— of which 12 were manufactured at the railway's Hyogo works.



■ Locomotive No.1, imported from Vulcan Foundry, UK, for the Tokyo-Yokohama Railway (Transportation Museum, Tokyo)

The first locomotive manufactured in Japan was a Worsdell compound tank locomotive with a 1B1 wheel arrangement. It was test manufactured at the government Kobe works in 1893. It was designed and built under the supervision of R.F.Trevithick, a locomotive superintendent at the works. However, very few domestically-produced parts were used in its construction, because main parts such as the main frame, boilers, wheels, axles and cylinders were imported from the UK, and spare parts were used for the cab and water tanks. In 1895, a 1C (2-6-0) tender locomotive similar to the Yoshitsune model was manufactured at the Temiya works of the Hokkaido Tanko Railway. It seems that spare parts were used for main parts. The locomotive was named *Taisho-go* (*Great Victory*) to commemorate Japan's victory in the Sino-Japanese War. However, it was the only locomotive manufactured at that works.

Subsequently, copies of imported locomotives were manufactured at some domestic works. Thirty-three such locomotives were built at the government Kobe works from 1895 to 1908, 23 at Sanyo Railways' Hyogo works from 1896 to 1906, and seven at Nippon Railways' Omiya works from 1901 to 1906.

Table 1 First Ten Locomotives Introduced to Tokyo-Yokohama Railway in 1872

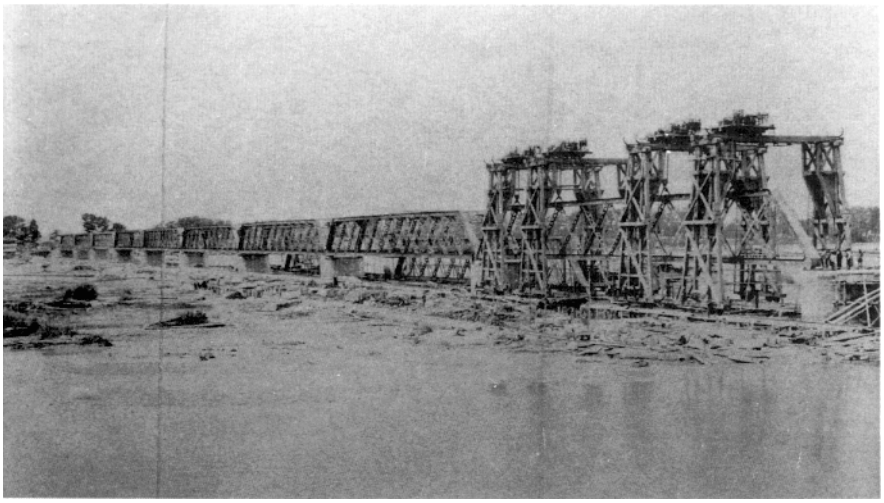
No.	Manufacturer	Location	Weight in working order (tons)	Type No. after 1909
1*1	Vulcan Foundry	Newton-Le-Willow	19	150
2-5*2	Sharp Stewart	Manchester	21.4	160
6, 7*3	Avonside Engine	Bristol	24.2	-
8, 9	Dübs	Glasgow	21	190
10*4	Yorkshire Engine	Sheffield	22	110

*1 Now preserved at Transport Museum, Tokyo.
*2 Two locomotived of same type additionally imported in 1874. One now in operation at Meiji-mura Open Museum near Nagoya.
*3 Transferred to Taiwan in 1900, and No.7 now preserved in Taipei.
*4 Preserved at Ome Railway Park near Tokyo.

In addition, Kisha Seizo (Locomotive Manufacturing) company set up in Osaka in 1899, as an independent private enterprise, manufactured 58 locomotives from 1901 to 1908. Fifty-one were exact copies manufactured from the plans of the government 1B1 tank locomotive.

Full-scale steel production started in Japan when the Yawata ironworks was set up in 1901. However, the quality and quantity of domestic steel did not fully meet the requirements of locomotive production. As a result, imported or spare parts were used for the main locomotive parts, and parts that did not require difficult processing technology were made in Japan. The locomotives made of imported parts and some domestic parts were said to be domestically-produced at that time. Processing and casting of main frames and cylinders could be done in Japan by 1900, but the number of domestically-produced wheels, smoke pipes and laminated or coiled springs passed that of imported counterparts only after World War I, because high uniformity and durability were required for these parts and advanced processing technology was needed to make them.

Full-scale domestic production of locomotives started after 17 major private railways were nationalised from 1906 to 1907. German Schmidt system superheated locomotives, which were developed originally in Japan, were promoted as the standard model.



■ Bridge across the Tenryu River under construction. The longest bridge on the Tokaido Railway(ca. 1886). (Transportation Museum, Tokyo)

Manufacturing of Passenger Carriages

British passenger carriages and freight wagons were used on the Tokyo-Yokohama and the Osaka-Kobe railways. Large, twin-axle carriages with a 12' (3,658 mm) wheel base and a central corridor were used on the Tokyo-Yokohama line, while compartment-type, small twin-axle carriages with an 8' (2,438 mm) wheel base and no corridor were used on the Osaka-Kobe line. However, domestic production of carriages started at the government Kobe works as early as 1875 and in 1880 at the Shinbashi works.

The main models produced at both plants were compartment-type, large twin-axle carriages with a 11' 6" (3,505 mm) or 12' wheel base. However, only the wooden body of the carriages was really Japanese-made. Imported steel materials were processed and assembled into frames, and finished wheels and axles were imported. From 1876 to 1877, prototype bogie carriages were produced at the Kobe works, but continuous production of carriages did not start immediately.

Demand for carriages increased in the late 1880s as the railways expanded, and the production capacities at the Kobe and Shinbashi works could not meet demand. Import of carriages from the UK and Germany was resumed, and private railways and independent manufacturers started producing carriages. The government railways and five major private railways decided on each standard specification for bogie carriages and expanded production based on these specifications.

Both covered and open goods wagons were produced at that time with a loaded capacity of about 5 tons. When Japan's first railway went into service, horse trucks and horse carriage wagons were used as goods wagons. Special-purpose wagons such as oil tank cars and cattle wagons appeared in the 1890s.

Sanyo Railways introduced Japan's first diners in 1898 and sleeping carriages in 1900. The railway, which ran along the Inland Sea, faced fierce competition with regular coastal liners and always tried to keep a step ahead of other private railways in improving passenger services. Sleeping carriages and diners were introduced on government railways (Tokaido) in 1900 and 1901, respectively; Nippon Railways started a diner service in 1905.

Train Operation

In October 1872, it took 53 minutes by train from Shinbashi to Yokohama (29 km) stopping at four stations: Shinagawa, Kawasaki, Tsurumi and Kanagawa. The scheduled speed was 32.8 km/h. The engine drivers were all British, with Japanese trainees carried as firemen. The first Japanese engine drivers were appointed in 1877, and at the same time, a training centre was set up to train Japanese firemen as engine drivers. All foreign engine drivers were let go by 1885, and from then, only Japanese engine drivers were employed.

Foreign train managers continued drawing up timetables until the mid-1880s. Training in this area lagged behind with Japanese personnel assuming responsibility for timetables by the late-1880s.

In July 1889, when train services started along the entire Tokaido line, it took a little over 20 hours from Shinbashi to Kobe by through train. The scheduled speed was 30 km/h. In October 1894, Sanyo Railways introduced Japan's first express service stopping only at major stations. In September 1896, the daytime express between Shinbashi and Kobe on the Tokaido line took 17 hours and 22 minutes to Kobe and 17 hours and 9 minutes from Kobe. In January 1903, the time was reduced to 15 hours, and the scheduled speed reached 40.4 km/h. The time fell further to 13 hours and 40 minutes in April 1906 when a lightweight express train consisting of four first- and second-class carriages was introduced. The scheduled speed was also boosted to 44.3 km/h. Express passengers were required to pay express charges in addition to the normal fare. The train was called a "super express" to distinguish it from other express trains. After Sanyo Railways was nationalised in December 1906, the section of the Tokaido line covered by the express train was extended, and Shinbashi and Shimonoseki, a port located at the westernmost end of Honshu were directly connected in March 1907. ■

Eiichi Aoki

After graduating from the Faculty of Science at Chiba University in 1957, Mr. Aoki received a doctorate in science from the Tokyo University of Education (now called Tsukuba University). After serving at Tsuru City University and Tokyo Gakugei University as an assistant professor, he became a professor at Tokyo Gakugei University in 1978. He specialises in transportation geography and is also a leading Japanese scholar of the history of railways and marine transportation.
Mr. Aoki is now president of the Japan Railway History Society. His publications include *World History of Sea Power and Japanese Railway – Its Rise and Development.*