The Rolling Stock Manufacturing Industry in Japan

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Introduction

Railway systems consist of integrated subsystems of infrastructure and rolling stock. The infrastructure includes tracks, electric power supply substations and feeder lines, signalling and train control systems, station facilities, maintenance depots, etc. Each of these component parts must function as it is designed to do, and must also work together as a whole.

While rolling stock is an important subsystem within the whole railway system, it also acts as the railway's face to the customer and could be described as the main 'actor' on the rail transport 'stage.' Rolling stock manufacturers must evolve with the times by supplying operators with rolling stock using new technologies that meet both the local and specific needs of railways as well as customers' requirements. A review of the industry's history shows that rolling stock production has always been influenced by the social requirements of the times.

This article is divided in three sections; first, it examines the latest demand for rolling stock in Japan and the present status of the rolling stock industry. Next, it looks back in history to see how the rolling stock industry changed over time, and finally, it looks ahead to future possibilities for the industry.

Series E231 running on Tokaido main line (JR East)

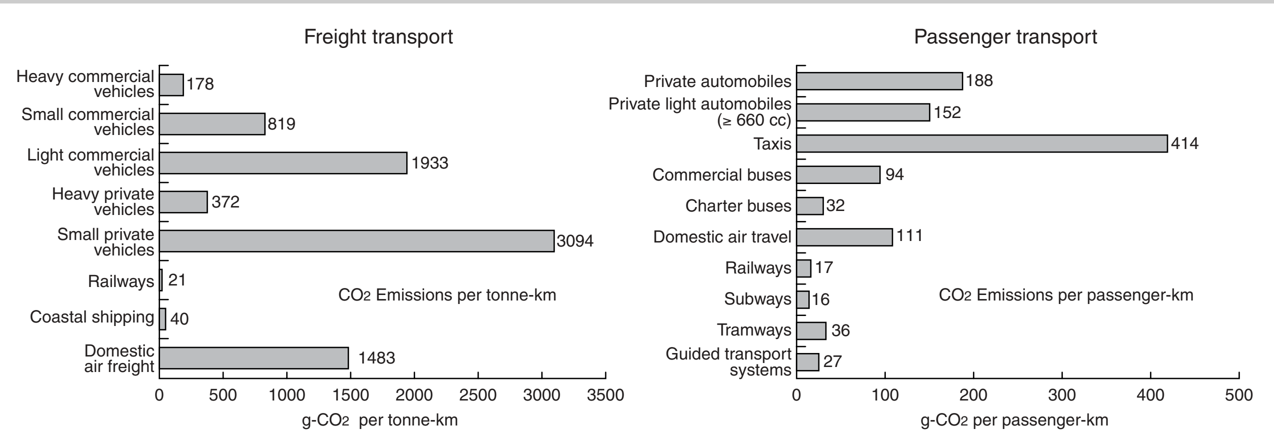
Rail Transport and Rolling Stock in Japan Today

Overall trends

In Japan, rail ridership has been declining generally over the last few years. This is primarily due to years of economic stagnation and changes in demographics—birth rates are dropping faster, and the population is aging faster than in most other countries.

However, compared to motor vehicles, full trains are far more efficient users of energy, and their per passenger- and per tonne-km CO_2 emissions are much lower

Figure 1 Freight and Passenger CO_2 Emissions (FY2000)



Source: Ministry of Land, Infrastructure and Transport

Note: Commercial and heavy private vehicles have a minimum capacity of 3000 kg than other modes (Fig. 1). Government policies have been trying to promote a modal shift from road to rail for both passenger and freight transport. These policies have had more bite since February 2005 with the coming into force of the Kyoto Protocol, binding Japan to cut its CO_2 emissions. Clearly, it is important to promote measures to reduce emissions from vehicles and a modal shift to railways even more than previously. The Japanese government is supporting railway operators in projects to improve services, which will favour a modal shift to rail from cars, trucks and planes.

Passenger transport

Table 1 shows the annual increases in the movement of people in Japan. Domestic travel kept expanding during the 1980s and 1990s, but has almost levelled off since then. Rail ridership and rail passenger-km figures have stagnated since the mid-1990s and any increase in the movement of people is basically due to more road and air travel. Average distance travelled for each transport mode has changed little since the 1980s. And, as Figure 2 shows, the share carried by rail (the JR passenger companies and other private railways) is now slumping year-on-year. In major cities, rail transport still enjoys a majority share (see Table 2 for Greater Tokyo data), although travel trends (all modes) has remained basically stable since the early 1990s, with train and motor vehicle ridership remaining relatively unchanged. New railway lines are being constructed in the Greater Tokyo and Greater Osaka areas, although not as energetically as before, and this, combined with other improvements for the convenience of commuting workers and students, is bound to ensure that rail remains the main transportation mode in Japanese metropolises. Congestion remains a problem, and there is a consensus that commuter rail services need further improvements to reduce overcrowding. Other improvements being called for include offering transport information on board, easier connections to other trains and other modes, and a wider range of services at stations and terminals. These improvements will require new rolling stock and infrastructure.

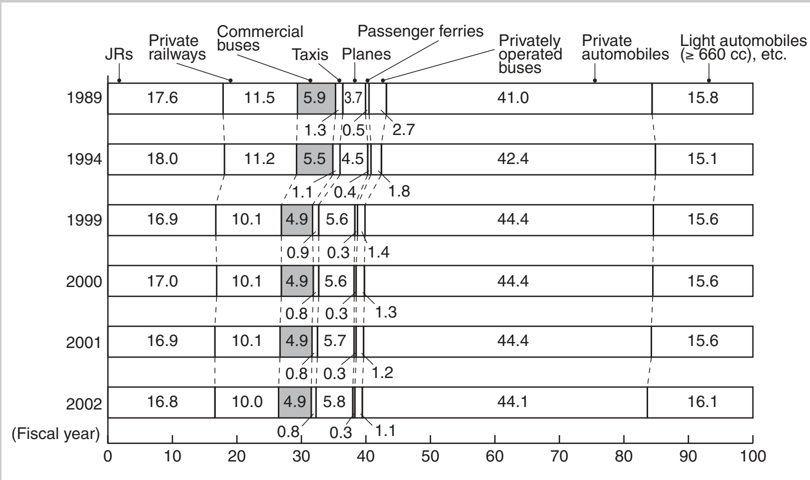
Airlines and railway operators are competitors, but they can also complement each other's services. Nine airports in Japan have air–rail links (ARLs). These have become popular access routes for passengers who choose rail because it is dependable and fast. On the flip side, ARLs encourage more people to fly; more

Table 1 Passenger Transport in Japan by Mode

	Number of passengers (millions)					
Fiscal year	Total	Motor vehicles	Railways	(share)	Passenger ferries	Planes
1965	30,787	14,863	15,798	51.3%	126	5
1980	51,680	33,515	18,005	34.8%	160	40
1990	77,869	55,767	21,939	28.2%	163	65
1995	84,051	61,272	22,630	26.9%	149	78
2000	84,598	62,841	21,647	25.6%	110	93
2001	86,421	64,590	21,720	25.1%	111	95

Source: *Summary of Land Transportation Statistics*, Ministry of Land, Infrastructure and Transport

Figure 2 Share of Passenger Modes in Japan (1989–2002) (passenger-km)



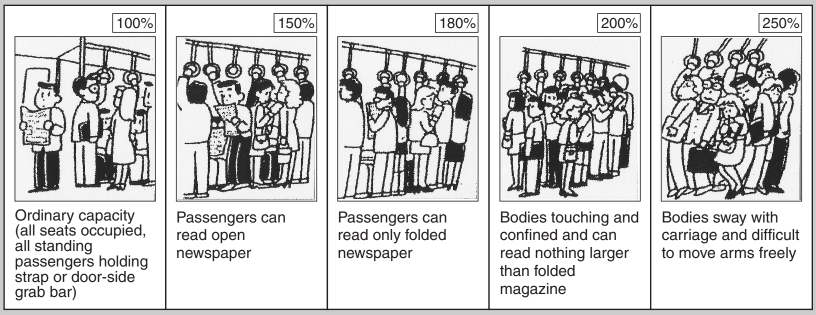
Source: Ministry of Land, Infrastructure and Transport
Note: Figures indicate percentage share

Table 2 Passengers in Greater Tokyo by Mode

	Number of passengers (millions)				
Fiscal year	Total	Railways	(share)	Buses	Motor vehicles
1990	22,752	12,799	56.3%	2,197	7,756
1995	24,021	13,320	55.5%	2,025	8,676
2000	23,410	12,979	55.4%	1,769	8,662
2001	23,410	12,979	55.4%	1,769	8,662

Source: *Urban Transport Yearbook*, Institute for Transport Policy Studies

Figure 3 Commuter Train Congestion Ratios



are on the drawing board, and we can expect more airports to have rail connections soon.

In today's Japan, high-speed railways are the main transportation mode for journeys up to around 900 km. Railways can continue playing a leading role in this sector, especially if they introduce new IT services, such as on-board information tools, facilities for laptop users, and monitors showing useful data such as location, weather, etc.

Urban commuter trains

In major cities, rail is the primary mode of travel for commuting workers and students. Rush-hour congestion is expressed as a percentage of capacity, which is calculated as number of seats plus floor area divided by the area required by one standing person. Typical congestion ratios are explained and illustrated in Figure 3. Efforts to reduce congestion aim for an average ratio of 150% during the most crowded times, but many lines in Greater Tokyo and other major cities have still not reached this level. The most congested sections in the JR East network—one on the circular Yamanote Line, the other on the Keihin Tohoku Line (both between Ueno and Okachimachi in Tokyo)—had congestion ratios of 230% on weekdays between 08:00 and 09:00 in 2001. Both sections are double-tracked, offering four parallel tracks for commuter trains. Between these two stations, trains on the two lines carried a total of 162,410 passengers per hour in one direction. These passengers travelled on a total of 48 trains—24 train sets with 11 cars, and another 24 with 10 cars. As another example, during rush hour, Tokyo Metro's double-tracked Marunouchi Line offers 32 trains per hour in each direction. In Greater Tokyo, Nagoya and Osaka, 28 lines have at least 25 rush-hour trains per hour in each direction. Lines with at least 30 trains per hour per direction are listed in Table 3.

These figures indicate the unusually high density of commuter train operations in Japan's major cities. High-density operations require reduced headway between trains, and to accomplish this safely, rolling stock must be able to accelerate and decelerate quickly, and signalling and other safety equipment must be reliable and up to date. Faster acceleration requires lighter carriages and high motive power. Equipping AC motors with a variable voltage variable frequency

Table 3 Lines with 30 or More Rush-hour Trains in Each Direction (per hour)

FY2001

Line	Section	Time period	Number of trains (one direction)	Number of tracks	Number of passengers during time period	Congestion ratio (%)
JR East Chuo main line (rapid service)	Nakano–Shinjuku	8:00–9:00	30	2	91,460	218
JR East Yamanote and Keihin Tohoku lines	Ueno–Okachimachi	8:00–9:00	48	2+2	162,410	230
Higashiyama Line (Nagoya city subway)	Nagoya–Fushimi	8:00–9:00	30	2	31,272	185
Midosuji Line (Osaka city subway)	Namba–Shinsaibashi	8:00–9:00	30	2	59,521	154
Ginza Line (Tokyo Metro)	Akasaka-mitsuke –Tameike-sanno	8:00–9:00	30	2	30,863	169
Marunouchi (Tokyo Metro)	Shin Otsuka–Myogadani	8:00–9:00	32	2	37,575	158
Isezaki (Tobu Railway)	Kosuge–Kita Senju	7:30–8:30	45	4	75,850	150
Keio Line (Keio Electric Railway)	Shimo Takaido–Meidaimae	7:40–8:40	30	2	70,467	168
Inokashira Line (Keio Electric Railway)	Shinsen–Shibuya	7:50–8:50	30	2	29,757	149
Sagami main line (Sagami Railway)	Nishi Yokohama –Hiranumabashi	7:29–8:29	30	2	57,349	140
Nagoya main line (Nagoya Railroad)	Jingumae–Kanayama	7:40–8:40	36	4	32,046	131
Keihan main line (Keihan Electric Railway)	Noe–Kyobashi	7:50–8:50	46	4	60,448	144

Source: Railway Bureau, Ministry of Land, Infrastructure and Transport

(VVVF) control system offer lighter weight and smaller size, saving energy. Furthermore, in addition to plans to lighten the carriages themselves, there was an increase in the number of EMUs with aluminium-alloy double-skin panels formed by extrusion molding, which also cuts process costs. In-carriage IT systems are now being introduced to monitor conditions and conduct virtual inspections while trains are running, which saves labour costs as well. The high-tech inspection system supplements other immediate-response inspections.

Series 253 EMU *Narita Express*, ARL between the cities of Tokyo, Yokohama, Omiya, etc. and Narita Airport (JR East)

Air–rail links—two examples

Tokyo International Airport (Haneda) offers a choice of ARLs for accessing the airport—the Tokyo Monorail and Keihin Electric Express Railway's Airport Line (annual ridership, 50.341 million and 44.4 million, respectively). In 2001, a total of 59.504 million airline passengers used the airport. These figures show that not all ARL users are air passengers—many are airport employees and other commuters. The Central Japan International Airport (Centrair) near Nagoya opened in February 2005. Nagoya Railroad's *μ-Sky* (pronounced mu-sky) limited express offers convenient, rapid (28 minutes) services linking the airport with Meitetsu Nagoya Station.

Series E653 is used for the Joban Line's *Fresh Hitachi* (name of a region and a city) business and tourist express services (JR East)

Medium- to long-distance passenger routes

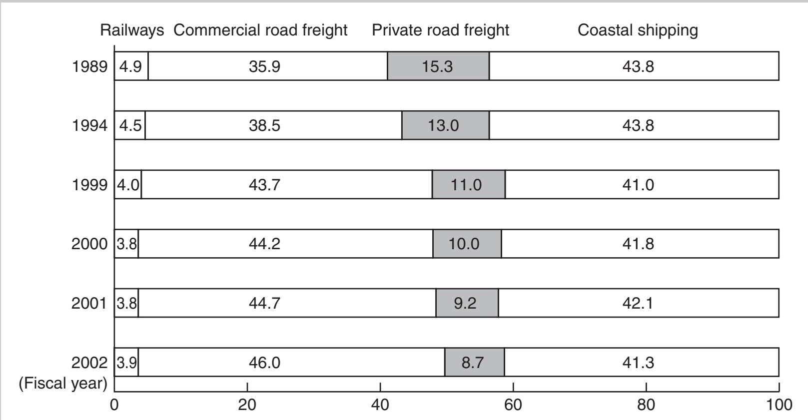
Modal share for passenger travel between the Tokyo and Osaka metropolitan regions is 15.7% for air, 3.0% for motor vehicles 3.0%, and 81.3% for rail. However, rail's share drops over longer journeys. For example, modal shares between Tokyo and Hiroshima Prefecture are 49.3% for air, 2.4% for motor vehicles, and 48.3% for rail, giving air and rail almost equal weight. The fastest shinkansen from Tokyo Station to Hiroshima Station takes 3 hours 50 minutes, while the fastest from Tokyo Station to Hakata Station in Fukuoka City takes 4 hours 58 minutes. Modal share for travel between Tokyo and Fukuoka is air 85.4%; motor vehicles 1.1%; rail 13.5%, showing how rail loses out to air on long-distance routes. Travellers tend to fly when journey time exceeds 4 hours, although they consider other factors as well, such as fare, comfort, existence of other travel modes, and convenience (changing modes, airport access, flight frequency, etc.). Rail will surely remain the most popular and attractive mode for trips of less than 4 hours (about 900 km by shinkansen). The JRs continue to pursue higher speeds for medium and longer distances, hoping to lure passengers from airlines. While such a modal shift would reduce Japan's energy consumption and CO_2 emissions, high population densities along lines linking major cities, and the closeness of houses to the tracks in urban areas cause problems with more noise and vibration resulting from higher operating speeds, requiring environmental countermeasures. Rolling-stock designers

Table 4 Freight Transport Modes

	Freight (million tonnes)				
Fiscal year	Total tonnage	Road freight	Rail freight	Coastal shipping	Air freight
1965	2,616	2,193	243	180	0.03
1980	5,981	5,318	163	500	0.03
1990	6,776	6,114	87	575	0.08
1995	6,643	6,017	77	549	0.09
2001	6,370.1	5,773	59	537	1.10
2002	6,158	5,578	59	520	1.02
2003	5,894	5,339	57	497	1.00

Source: *Summary of Land Transportation Statistics*, Ministry of Land, Infrastructure and Transport

Figure 4 Domestic Freight Transport by Mode (1989–2002) (tonne-km)



Source: Ministry of Land, Infrastructure and Transport
Note: Road freight includes freight on trucks using ferries

Series 250 EMU with two powered cars at each end and 12 intermediate trailing flat wagons (JR Freight)

are working on a much lighter type of high-speed shinkansen. At present, these problems have been partially solved by using aluminium alloys to reduce carriage weight, and an EMU-type distributed traction design for less vibration. Engineers are working on new technologies to cut the noise of high-speed operations, such as pantograph covers to cut pantograph whistle, and streamlined noses to reduce aerodynamic noise. A low-vibration bogie under development will maintain the same high safety and comfort standards at higher speeds. In-carriage information services using more advanced telecommunication devices are also in planning.

Current situation and future for rail freight

Freight volumes in general peaked in Japan in 1990 (Table 4) and then dropped consistently, reflecting the downturn in the Japanese economy. Table 4 also shows how rail freight declined after peaking in 1965. Rail transport accounts for only about 4% of total domestic freight in tonne-km terms (Fig. 4). However, the average distance traveled by road freight is only 50 km, compared to about 400 km for rail freight, demonstrating that rail freight is considered more suitable for long distances. Trains emit far less CO_2 per tonne-km than trucks (Fig. 1) and are much more fuel efficient. They are also less labour-intensive, an added benefit against the background of declining numbers of truck drivers. Due to these advantages of rail freight, some long-distance trucking companies are experimenting with a combined truck-rail container system, and are considering abandoning some long-distance truck operations. To speed up its services, JR Freight brought an EMU-type freight train into operation in 2004, and the ratified Kyoto Protocol is expected to lead trucking firms to launch more intermodal container operations.

Freight wagon manufacturing in Japan peaked at about 15,000 units in 1967, and now only about 100 wagons are built annually, reflecting the overall decline in rail freight operations. However, with trucking companies interested in the above-described new methods, manufacturing of freight rolling stock—including locomotives—is slowly recovering.

Japan's Rolling Stock Industry —From Beginning to Present

Japan's first railway started operations in 1872, linking Shimbashi in Tokyo to Yokohama. In the early days, the main components of the rail system, including locomotives, passenger carriages, freight wagons and even some construction materials, were imported from Britain. Japan's first domestically built rolling stock was produced in 1875 at the government-owned Kobe Works. From then until the 1930s, rolling stock manufacturing was considered a vital element in the nation's industrial sector, and was promoted by the government. During the chaos immediately after WWII, one of the government's most urgent policies was to get the transportation system back on its feet. The government and private sector cooperated in this effort, with both manufacturing new rolling stock. Japan's economy recovered and began expanding rapidly before long. Although rolling-stock production increased as a result, the economic boom also helped road transport come into its own. Consequently, demand for rail transport peaked and then began declining. This created unsupportable financial difficulties for Japanese National Railways (JNR), and caused a slump in rolling-stock production. JNR was a public corporation and ended up with annual losses of around ¥2 trillion, making it ripe for breakup and privatization into the JR group of companies in 1987. The resultant JRs began operations with a clean slate and have remained healthy ever since.

However, today's low birthrate and aging population have crippled domestic demand for new rolling stock. The market is saturated and most orders come from operators just replacing aging stock. There is little possibility that the domestic market will return to its old golden growth years. As a result, rolling stock manufacturers and their suppliers may find it impossible to develop their businesses if they depend only on the domestic market—the obvious solutions is to expand into new, overseas markets.

Table 5 shows data on rolling-stock production in Japan from 1945 to 2000 and Table 6 lists freight wagon production indices (1975 = 100).

We can divide the history of Japan's rolling stock manufacturing industry into the following six periods

- Formative years (1875–1926)
- First growth years (1927–41)
- War years (1942–45)
- Second growth years (1946–68)
- Doldrums (1969–87)
- Era of JRs (1988–present)

Formative years

Under government leadership, Japan began building passenger carriages and freight wagons in the mid-1870s. The first Japanese-built steam locomotive was manufactured in 1893 at the government-railways Kobe Works and the privately owned Locomotive Manufacturing Company (*Kisha Seizo Kaisha*) established in 1896 was building steam locomotives

Table 5 Japanese Rolling-stock Production (1945–2000)

Fiscal year	Locomotives 1)	Passenger carriages	EMUs & DMUs 2)	Freight wagons	Total
1945	115	45	46	897	(1,103)
1950	104	244	605	2,354	(3,307)
1955	166	266	599	3,894	(4,925)
1960	242	275	1,489	8,742	(10,748)
1965	438	158	2,581	9,293	(12,470)
1970	382	435	1,380	4,727	(6,924)
1975	141	186	1,232	2,788	(4,347)
1980	83	390	1,765	1,517	(3,755)
1985	9	54	1,309	107	(1,479)
1990	21	73	2,253	791	(3,138)
1995	20	–	1,809*	416	(2,245)
2000	11	18	1,763*	195	(1,987)

Source: Japan Association of Rolling Stock Industries
1) Total electric, steam and diesel locomotives
2) Included electric and diesel railcars
Note: Figures include production by Niitsu Rolling Stock Manufacturing Factory

Table 6 Production Indices (1975 = 100)

Fiscal year	Indices
1945	23.5
1950	64.1
1955	75.7
1960	141.1
1965	230.5
1970	159.1
1975	100.0
1980	120.0
1985	64.4
1990	128.8
1995	90.7
2000	97.9
2001	105.9
2002	96.2
2003	90.1

Source: Japan Association of Rolling Stock Industries by 1901. Success in locomotive manufacturing proved that Japan had the technical skills required for the nation's rail industry to stand on its own. By the mid-1920s, electric locomotives were also being made in Japan. New companies sprang up to design and manufacture rolling stock and parts. Some major companies still in the industry today began operations during these formative years (Table 7). Other businesses making electric equipment and rolling-stock parts soon came on the scene (Table 8).

This was the time when the government railways was extending its network. After it was clear that rail transport would play a growing role in the nation's economy, the government launched a restructuring initiative. Government responsibility for railway affairs was wielded first by the Railway Board (*Tetsudocho*) and then Railway Bureau (*Tetsudokyoku*) under ministerial control. But in 1908, the Railway Agency (*Tetsudoin*) was established under direct control of the prime minister. Then in 1920, the Railway Agency became the independent Ministry of Railways under a cabinet minister.

Shimpei Goto, the first Director-General of the Railway Agency decided that works belonging to the Railway Agency would continue to repair locomotives owned by the government railways, but that new locomotives would be purchased from the private sector. This arrangement remained basically unchanged until JNR was established in 1949 and Goto's decision still influences the development of Japan's rolling-stock industry.

First growth years

Japan's financial crisis of 1927 and the 1929 Great Depression dampened demand for rolling stock. But Japan's increasing military expansion in Manchuria in NE China, increased the need for rail transport and pushed production levels ever higher until 1941 when Japan entered WWII. At the time, almost all rolling stock and parts were being manufactured domestically and standards were as high as in other advanced countries.

During the growth period beginning in 1927, Japanese railways achieved high technical standards for reliability and safety—standards that are still admired today. As early as 1940, the government unveiled a plan to run a 'bullet train' on standard-gauge double-track from Tokyo to Shimonoseki, at the western tip of Honshu.

Development was abandoned due to WWII, but the concept came to fruition in 1964 as the shinkansen.

The high-speed steam-powered express *Asia* running on the South Manchuria Railway symbolized the high level of Japanese railway technology.

The strong demand for rolling stock forced the companies established during the formative years to install more advanced manufacturing equipment, expand their factories, and invest in new facilities. Some of the factories operating today can trace their roots to this period.

War years

With war raging, the government urgently needed more rolling stock to boost capacity, but a scarcity of materials pushed production into decline as early as 1942. The situation worsened after bombing in 1944 and 1945 destroyed one factory after another. The destruction was so extensive that production could not resume immediately after the war.

Wartime austerity designs called for development of a standard electric train constructed with minimum materials, labour and financial resources, but the project was abandoned after facilities and equipment were destroyed. About 13,000 pieces of rolling stock, including freight wagons, were destroyed in the war, and more than 20% of all steam locomotives were out of service by 1945 with no way to repair them. For a while, rail transport was in great difficulties.

Table 7 Rolling Stock Manufacturers established during Early Years

Year	Company	Notes
1986	Nippon Sharyo, Ltd.	
1986	Locomotive Manufacturing Company (Kisha Seizo Kaisha)	later merged into Kawasaki Heavy Industries, Ltd.
1907	Hyogo Works, Kawasaki Shipbuilding Corporation	predecessor of Rolling Stock Division of Kawasaki Heavy Industries
1910	Niigata Engineering Co., Ltd.	
1920	Tanaka Rolling Stock Industries	predecessor of Kinki Sharyo Co., Ltd.
1921	Kasado Works, Hitachi, Ltd.	
1923	Mitsubishi Shipbuilding Co., Ltd. Kobe Shipyard	predecessor of Mitsubishi Heavy Industries, Ltd.

Source: Japan Association of Rolling Stock Industries

Table 8 Parts Manufacturers established during Early Years

Year	Company	Notes
1893	Shibaura Engineering Works Co., Ltd.	predecessor of Toshiba Corp.
1917	Hitachi, Ltd.	
1920	Sumitomo Seikosho	predecessor of Sumitomo Metal Industries, Ltd.
1921	Mitsubishi Electric Corp.	
1925	Nihon Air Brake K.K.	predecessor of Nabtesco Corporation

Source: Japan Association of Rolling Stock Industries

Table 9 Private Rolling Stock Manufacturers established soon after WWII

Year	Company	Notes
1945	Kinki Sharyo Co., Ltd.	Kinki Nippon Railway Co., Ltd.
1945	Tokyu Car Corp.	Tokyu Corp.
1948	Naniwa Koki	name changed to Alna Koki Co., Ltd. Hankyu Corp.

Source: Japan Association of Rolling Stock Industries

Second growth years

When WWII ended, Japan's rolling-stock industry was in ruins and reconstruction efforts created an urgent need for both passenger carriages and freight wagons. Production continued to rise during this period with some fluctuations. The first step, beginning in earnest in 1946, was to repair all recoverable rolling stock. Demand for new stock was intense, but manufacturing facilities had been destroyed during the war and there were not enough engineers in the existing factories to meet the demand for private railways other than JNR. Private railways established new manufacturing companies with their own capital (Table 9).

These newcomers also contributed to the post-war reconstruction effort. Later, they would go on to supply the rolling-stock market during Japan's high-growth period, but when demand slumped later, their presence—combined with that of the older manufacturers—would cause concern that too many makers occupied a limited market.

Around 1955, rolling-stock production had returned to its prewar level. The later years of high-economic growth boosted demand and encouraged more production. Some companies built new factories, although many just made more effective use of the facilities they had operated during the first growth years. They installed new, advanced manufacturing equipment to raise production capacity and the booming rolling-stock industry saw rising profits. Some profits went to marketing overseas and to expanding into other sectors. This was the last 'golden age' for rolling stock manufacturers and suppliers.

It was also a time of transition from steam to electric and diesel power. JNR's last steam locomotive was built in 1948. Electrification of the Tokaido main line began in 1956 and other trunk lines followed suit before long. Electric trains became increasingly more common and companies in the electric equipment industry had higher sales revenues than rolling stock manufacturers. High-performance EMUs were developed for both JNR and the private railways. JNR's *Kodama* (Echo), the precursor to the shinkansen, began operations on the narrow-gauge Tokaido main line in 1958, and the Tokaido Shinkansen opened on standard-gauge track in 1964. This was a time of exciting technological advances—including small but powerful AC motors, new control systems, and lighter carriages—making it possible to raise speeds. The Tokaido Shinkansen was born both from the accumulated technology and experience of people working in the industry from Japan's early railway days and from the hard work, know-how and technical developments of modern engineers.

The shinkansen's success created increased demand for shinkansen train sets, and the 1968 JNR timetable revision demonstrated the improved trunk-line capacity, resulting in more demand for new trains and continuing growth in rolling stock production. But surprisingly, the opening of the Tokaido Shinkansen and JNR's major timetable revisions were soon followed by the end of the second growth years for rolling stock manufacturers.

Doldrums

Road transport came into its own around the time of JNR's 1968 timetable revisions. Improvements in the road network lured people from trains and buses (except in large cities), and the nation's adoption of

Trains running on quadruple section on JR East's Sobu Line (JR East)

Table 10 Number of Motor Vehicles registered in Japan (1960–2000)

Fiscal year	Number (1000)
1960	3,404
1970	18,919
1975	29,143
1980	38,992
1985	48,240
1990	60,499
1995	70,107
2000	75,525

Source: *Summary of Land Transportation Statistics*, Ministry of Land, Infrastructure and Transport

the motor vehicle was remarkably swift—the number of vehicles increased by around 10 million every 5 years or so until the mid 1990s (Table 10).

As a public corporation, JNR could support its huge deficits by tapping into the public purse, but if it had been a private business, it could not possibly have obtained sufficient capital to stay afloat. Management was unable to bring labour conditions in line with declining revenues, unable to rationalize operations and unable to improve passenger services. It continued to lose passengers and freight business and debts rose year-on-year. Worsening finances led to drops in rolling stock orders. The situation continued to deteriorate until JNR was broken up and privatized in 1987 when rolling-stock production was 70% lower than in 1968. Naturally, these difficulties impacted all manufacturers and suppliers. Some merged, combined manufacturing operations in fewer factories, or withdrew altogether from the industry (Table 11).

Due to advances in power electronics, some technological advances were made during this period, including development of a chopper control system for electric motors. Otherwise, development of rail technology stagnated; there was little progress in high-speed technologies. The downturn led to staff reductions, and some companies could not hire new staff who would have driven next-generation developments. The entire industry found itself without sufficient engineers, and this shortage created hurdles that still exist today.

Long nose and white body of JR Kyushu's Series 800 *Tsubame* (Swallow) (JR Kyushu)

Era of JRs

The seven JRs born from JNR's break up and privatization in 1987 all took steps to improve operations. They set out to improve services and during the first 2 or 3 years ordered large quantities of rolling stock, mainly types that JNR had been using.

Subway construction continued in urban areas along with upgrades to permit more subways and private railways to provide through services on each other's lines. These advances also boosted orders for new rolling stock and production rose for a while.

Before its demise, the impoverished JNR could neither order new stock nor replace existing aging stock, placing the entire rolling-stock industry in a slump. But now orders were up, and soon the JRs were ordering new types designed to their own specifications. However, once this demand had been met, the industry as a whole experienced another slump.

Another trend was the greater variety in designs for both shinkansen and conventional lines. This trend toward greater variety raised design and manufacturing expenses, boosting overall production costs. Meanwhile, competition was so severe that companies struggled to cut costs in order to meet demand for lower prices and even accepted orders with no profits. Manufacturers found themselves on hard times yet again. The situation was worsened by collapse of the 'bubble economy' around 1992, which brought on a period of economic stagnation and recession now known as the 'lost decade.' This recession reduced transport volumes, forcing railway operators to make fewer investments in rolling stock.

In 1995, the JR East Niitsu Rolling Stock Manufacturing Factory began building commuter EMUs for JR East, which reduced the number of outside orders. Rolling stock manufacturers found themselves in a difficult business environment, and some were forced to downsize or withdraw from the industry (Table 12).

Today, there is little hope for increased domestic demand, so manufacturers are attempting to expand overseas. There are some opportunities to export entire carriages, but in many cases, overseas railway operators, especially in developing countries, are looking to buy entire railway turnkey systems, and many ask for special financing too. Rolling stock manufacturers cannot easily deal with this type of market unless they first form a partnership with a railway operator with the required expertise. To participate in the global market, Japanese rolling stock manufacturers generally find they must partner with other companies, often through the auspices of a trading company. However, in order to compete well in the international market, they are reorganizing to develop staff with international business experience and are gradually solving the problems one-by-one. Working in their favour is the fact that Japanese technology is strong in electric traction motors, control systems, train information systems, etc. As a result, the industry is exporting these parts, and producing higher volumes of electric devices and rail systems.

During this period, Japan has made considerable technology advances, including the changeover from DC to AC motors, and from gate turn-off (GTO) VVVF inverters for traction control to insulated gate bipolar transistor (IGBT) systems. Other examples include IT for train-control systems, advanced diagnostic systems, and leading-edge technologies for faster shinkansen services.

Table 11 Restructuring During Doldrums (1969–87)

Year	Notes
1968	Tokyu Car acquired Teikoku Sharyo Industries
1969	Kawasaki Heavy Industries merged with Kawasaki Kokuki and Kawasaki Sharyo
1972	Nippon Sharyo closed Warabi Works and concentrated operations at Toyokawa Works
1972	Kawasaki Heavy Industries absorbed Locomotive Manufacturing Company
1981	Mitsubishi Heavy Industries stopped manufacturing rolling stock

Source: Japan Association of Rolling Stock Industries

Table 12 Abandoned Production and Downsizing after JNR Breakup and Privatization

- Niigata Engineering sold rolling-stock business after receiving approval under Company Reorganization and Rehabilitation Act
- Fuji Heavy Industries stopped manufacturing rolling stock
- Alna Koki liquidated, reorganized, and stopped manufacturing new rolling stock
- Nabco, a brake manufacturer, was absorbed in the newly-founded Nabtesco

Source: Japan Association of Rolling Stock Industries

Future of Rolling Stock Manufacturing Industry

The Japanese economy has finally started showing some signs of recovery from the long-term recession, but growth rates are still low, and some regions are still in recession. For example, the Osaka region is not doing as well as Greater Tokyo. In the Osaka region, private railway ridership has continued declining for 10 years, forcing down investment levels even for replacing rolling stock, and depressing overall demand to very low levels.

However, the government has joined the international campaign against global warming and is committed to reducing Japan's CO_2 emissions. It is promoting projects aimed at getting people out of their cars and onto rail-based transport. In the passenger market, these efforts include promoting tramways, a mode once thought out of date. In the freight market, policies are promoting higher speeds and longer trains. Thus, the domestic rolling-stock market is experiencing some interesting structural changes.

On the negative side, the birthrate continues to drop and the population continues to age, so Japan's population will decline. The domestic rolling-stock market is already saturated and demand for new stock will have to come from replacement requirements. We can expect only a very slight increase over the present number of units being manufactured and a small rise in today's production value (now approximately ¥300 billion). This explains why Japan's rolling-stock industry is eyeing the export market even more keenly.

However, any effort to expand globally will face fierce international competition and require considerable enthusiasm. On the positive side, a number of developing countries have modernization plans that include construction of railways and many of these plans include urban rail systems for commuters and intercity high-speed passenger services—fields in which Japan has a lot of experience. Meeting large capacity demand, expecially during rush hours, requires high-density operations while maintaining safety and staying on timetable. Locomotive-hauled trains are unsuitable for these types of operations and Japan's experience in EMUs offers excellent marketing opportunities in this business area.

Japanese rail technology is also ideal for high-speed passenger services and offers advantage of high volumes without high noise, vibration, or energy consumption. Countries planning to construct a high-speed passenger railway should surely find the expertise and products of Japan's rolling-stock industry attractive. The industry will have to meet requests for turnkey rail systems and financing, and is therefore poised to take advantage of growing opportunities in the global market. ■

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