the central problem was to be found in the basic position underpinning the policies of the high-growth period.

As Japan entered the 1970s, both the government and general public became increasingly aware of these problems. With the adoption in 1971 of the "Integrated Transportion Network" by cabinet council, the government recognized that making free competition the basis of its policy on transportation had been destructive and that the government itself should be involved in regulating transportation demand. Nevertheless, the government continued to follow the principle dictating that the user or the beneficiary pays, and, not surprisingly, the Basic Plan of the Economy and Society adopted by cabinet decision in 1973 incorporated the principle that fare hikes were necessary to meet rising costs.

After the oil crisis in 1973, it was recognized that changes would have to be made in transportation policy. In particular, a debate arose as to whether the parties responsible for generating transport should pay part of the cost for public works investment and whether priority should be given to mass transit while applying restraint on motor vehicles. However, the question of whether the motor-car manufacturers should pay a part of transportation costs never really arose, while the costs of construction for mass transit soared and the burden on the user continued to enlarge. Moreover, the rate of construction and improvements dropped off noticeably, and plans were continually revised, indicating that little could be expected in the way of economic benefit from the government's policy.

As long as nothing was done to resolve this conflict, transport problems would only become a serious social problem, affecting the welfare of everyone. After 100 years of dramatic progress and modernization, transportation now confronted very serious problems.

Railroads

Eiichi Aoki

Revolution in Rolling-stock Technology

Establishment of the Distributed Power System

All Japanese trains before the Second World War consisted of a string of non-powered passenger or freight cars pulled by a locomotive. Systems in which individual passenger carriages were fitted with an engine – such as electric or diesel multiple units – were limited to trains with few cars that generally operated in short-haul service. At least, with regard to the National Railways, this was the system to be found, and it was the system characterizing most of the world's railways.

But in the early half of the 1950s, the National Railways started putting long trains together for middle-distance travel using several electric or diesel multiple units, and by the latter half of that decade had significantly expanded this practice. The use of a distributed power system became widespread and eventually superseded the conventional system of "concentrated motive power," in which a locomotive at the head of a train pulls the carriages positioned behind. No other industrialized country has gone as far with the system of distributed power as Japan has.

In a distributed motive system individual carriages are equipped with a motor, which means that the car-manufacturing cost is high and maintenance also is very expensive. But it also increases the operating efficiency of rolling-stock, and in places like Japan where roadbed and bridge structure are weak and it is difficult to run locomotives of high axle weight, there are advantages in distributing weight uniformly throughout the train. Indeed, the National Railways was having difficulty in developing a 2,000-horsepower-class diesel locomotive (prototypes were completed in North America and Europe around 1950), and achieving faster trains was simplified through the use of distributed power. The number of electric and diesel multiple units owned by the National Railways increased until the levels were among the highest in the world (see table 1).

Development of High-Performance Electric Trains and Lightweight Car Bodies

The high-performance electric multiple units developed and test-run during the first half of the 1950s mainly by the large private urban railroads were being used throughout the country and on every type of passenger train during the period under study. These high-performance electric multiple units were designed for faster rates of acceleration and deceleration and to reduce the effects of motor vibration on cars and rails. In order to effect this, high-speed motors that were light and featured a greater r.p.m. were used. Also, the Cardan drive system was used in order to reduce the non-suspended weight of the trucks; the metal springs were harder, lighter, and stronger, and new trucks were developed that used rubber, hydraulics, and pneumatics as their shock-absorbing mechanisms. A concentration in the placement of equipment, control systems, and more efficient brakes were among the innovations called for by the much longer trains. High-tensile steel, stainless steel, and aluminium alloys were notably effective in reducing car-body weight. Thus, 20 m electric multiple units of over 40 tons were able to be reduced in weight by nearly 10 tons to around 30 or 35 tons. Lighter cars contributed to reduced energy use, something that was strongly emphasized in the 1970s. The old resistor control systems were dropped in favour of the more advanced thyristor control systems built with semiconductors.

In 1958, the National Railways began mass-producing its Tokai (model 153) electric multiple units for mid-range and long-distance service and in November of the same year started operating the limited express *Kodama* (model 151 electric multiple unit), which shortened the Tokyo-Osaka run to 6 hours and 50 minutes (in 1960 this was reduced to 6 hours and 30 min-

Table 1. Trends in rolling-stock and locomotives owned (1955–1983)

Fiscal year	Steam locomotives	Electric locomotives	Internal-combustion locomotives	Electric multiple units[c]		Diesel multiple units	Passenger coaches	Freight cars
				National Railways				
1955	4,897	522	6	2,969	—	785	11,340	106,843
1960	3,974	794	256	4,534	—	2,227	11,412	118,729
1965	3,164	1,369	582	9,084	488	4,595	10,632	142,258
1970	1,601	1,818	1,447	12,581	1,150	5,371	8,711	149,485
1975	15[b]	2,051	2,204	16,502	2,240	5,326	6,725	120,597
1980	5[b]	1,856	2,109	17,696	2,415	5,038	6,176	99,562
1985	5[b]	1,288	1,537	18,543	2,866	3,759	4,154	31,519
				Private railroads				
1955	259	267[a]	110	9,956	—	275	789	10,453
1960	167	299[a]	167	12,019	—	307	640	9,710
1965	86	323[a]	207	14,320	—	332	442	9,039
1970	27	316[a]	198	15,214	—	253	197	4,730
1975	4[b]	227[a]	206	16,005	—	202	161	2,825
1980	6[b]	209[a]	201	17,620	—	206	169	2,063
1985	2[b]	167[a]	177	19,274	—	232	158	1,432

Source: For each fiscal year, from both the National Railways Information Systems Department, *Tetsudō yōran* (Guide to the railroads) and *Min(shi)tetsu tōkei nempō* (Annual of statistics on private railroads).
Note: All statistics are for the end of the fiscal year, 31 March of the following year.
[a] Includes storage-battery driven locomotives.
[b] Locomotives maintained in running condition for preservation in museums.
[c] Figures in right column indicate units for Shinkansen use.

utes). The model 581 sleeping-car, an electric multiple unit seen nowhere else in the world, appeared in 1967 as a stunning upgrade in the operating efficiency of sleeping-cars. Model 581 could be used as a standard sitting car during the day and converted into a sleeping-car at night. The private railroads continued to increase the size of their cars, and the use of 20 m long units spread just as throughout the National Railways.

Developments in Diesel Multiple Units and Diesel Locomotives

The National Railways rapidly increased its use of diesel-hydraulic railcars, placing them in service on every non-electrified line and on all passenger-train types.

The mass-produced diesel multiple units were first used for ordinary trains on the non-electrified trunk and sub-trunk lines, but improvements in car-body structure and interior appointments grew rapidly and in a very short period permitted an increase in the number of lines on which these cars were used. A higher horsepower model was produced in 1956 that was used on steeply graded railroads and in local express (later express) service. In December 1960, the first limited express using diesel multiple units began operation, supplanting the steam-operated *Hatsukari* limited express between Ueno and Aomori. The introduction of many limited express trains using diesel multiple units on the nation's trunk lines was greatly increased in October 1961, marking a turning point in National Railway interurban transport. The Kiha 82 series diesel multiple units, an improved version of those used on the *Hatsukari*, provided the main motive power for these trains. In 1960, the Kiha 35 series diesel multiple unit appeared for frequent service on non-electrified suburban railroads.

A feature common to Japan's development of diesel-hydraulic multiple units in the two decades beginning in 1953 was the use of the DMH17 series 8-cylinder engines. The first engine in the series had a 150 horsepower output that was eventually beefed up to 180. For greater power and economy, development began in 1959 on small, lightweight diesel engines of 300 and 500 horsepower that could be installed under the car floor. The Kiha 181 series limited-express car, equipped with one 500-horsepower engine, first came off the assembly line in 1968. Beginning in the 1970s, improved versions of this engine were mass-produced as standard models: a 12-cylinder 440 horsepower and a 6-cylinder 220 horsepower engine.

In 1972 test-runs began on the experimental Kiha 391 gas-turbine cars powered by aircraft gas-turbine engines modified for railroad use; the goal was high output and light weight. The experiments continued, but they were eventually cancelled because no satisfactory way was found to lower the noise that these engines produce.

In contrast to the rapid development of diesel multiple units, the development of diesel locomotives with high horsepower engines was not easy. Although test-runs were started at about the same time as those for diesel multiple units, there were long delays before the production of a lightweight, reliable engine could be achieved. This delayed the programme for rationalizing the motive power of freight trains and prolonged the use of steam.

The biggest impediment to the development of diesel locomotives in Japan was the requirement that locomotives be suited to the inferior track conditions, made worse by the fact that the tracks were narrow gauge. Moreover, in order to minimize weight increases, diesel-hydraulic locomotion was preferred to diesel-electric power. During the 1950s, the electric-type DF50 (for trunk routes), based on imported German technology, was mass-produced, and the hydraulic DD13 was standardized as a yard-switcher. By the 1960s, America and Europe were producing 3,000- and 4,000-horsepower-class diesel locomotives, but it was not until 1964 that Japan started producing the DD51 diesel-hydraulic locomotive with a 2,200 horsepower output equivalent to the larger steam locomotives (see fig. 3, chap. 5).

Steam Locomotives

The National Railways ended production of new steam locomotives with the last C61 and C62 produced in 1949. In 1946, right after the war, the largest number of steam locomotives were in existence: at the end of that fiscal year (March 1947), there were a total of 5,958 locomotives, a number that gradually declined as the old ones were phased out of service. But the number of kilometres run by these locomotives continued to increase, and by fiscal 1956, the figure had climbed to a postwar record of 286.9 million km.

The pace of electrification began to quicken in 1956, as did the use of diesel multiple units and diesel locomotives, which hastened the phasing out of steam locomotives. The report of the Committee on Motive Power Modernization dated June 1959 forecast the total elimination of the steam locomotive by fiscal year 1975. The last steam locomotives ran in Hokkaido, where they pulled their last general operating train in December 1975 and were retired from yard-switching service in March 1976.

Except for railroads handling a lot of freight traffic like the Tobu Railway or the coal-mine railroads in Hokkaido, almost all ordinary private railroads had eliminated their steam locomotives by 1955. But, because of the delay in developing mid-size diesel locomotives (National Railway DD13 class) for specialized railroads such as those operating within factories, the conversion from steam to diesel was not made until around 1960. Steam locomotives were still being built in Japan for these specialized railroads in 1953.

The first attempts to preserve steam locomotives in running condition were made in the 1970s. National Railway locomotives can be seen in operation at the Umekoji Steam Locomotive Museum in Kyoto and on the Yamaguchi Line in Yamaguchi Prefecture, and, among the private lines, Oigawa Railway operates steam engines in Shizuoka Prefecture.

Expansion of Electrified Lines and the Appearance of Alternating Current

In October 1955, the National Railways set up an Electrification Survey Commission that, after two months of deliberations, created a plan for electrifying 3,300 km of trunk railroads in 10 years.

As for progress in electrifying the country's trunk lines, the National Railways was hurrying to complete electrification between Maibara and Kyoto, the final steam-driven segment of the Tokaido Main Line, so that the entire line would be electrified by the following year. The only other main trunk routes that were electrified were the Chuo Main Line between Tokyo and Kofu, completed prior to World War II, the Takasaki Line (between Omiya and Takasaki), the Joetsu Line (between Takasaki and Nagaoka), and the Ou Main Line between Fukushima and Yonezawa, all of which were electrified after the war. The major motivation for adopting this large-scale electrification plan was to save on the cost of motive power and enhance transport power.

Electrification of the National Railways up until this time had been based on a direct-current 1,500-volt standard, but the practical application of alternating current was now possible, and, subsequently, electrification would be through the use of both AC and DC.

After the Second World War, France's national railway succeeded in electrification using standard commercial frequency electricity, and Japan, too, contemplated electrification based on this method. In July 1953 the National Railways set up a Survey Commission on Electrification Using Alternating Current in order to devise specific plans for AC electrification. At first the idea was to introduce the technology from France and purchase a small amount of materials, but the French National Railways and the manufacturers could not agree on the terms, so Japan went ahead and developed its own technology.

Tests were made of the ground equipment between Sakunami and Kita Sendai on the Senzan Line in September 1954, with testing of the AC electric locomotives beginning the following August. In the tests, a comparison was made between the ED44 locomotive, driven by an AC commutator electric motor, and the ED45, which is powered by an AC-DC conversion, DC series-wound motor featuring a mounted rectifier. The test results led to the adoption of the ED45 system. After two years of testing, including actual test-runs, AC-electric-based operation began in September 1957 on the Senzan Line between Sendai and Sakunami.

The success of the tests on the Senzan Line encouraged the National Railways to go ahead with its plans to use commercial alternating current (single-phase 20,000 volts with frequencies determined by the regional differences in Japan's power supply of 50 hertz [Kanto and northwards] and 60 hertz [Chubu and westwards]) to electrify its trunk lines. The electrification of the Hokuriku Main Line between Tamura and Tsuruga in October 1957 constituted the completion of the first alternating-current electrification of a

Table 2. Progress in electrification (1950–1985)

	National Railways				Private railroads		
Fiscal year	Kilometres operating (A)	Electrified kilometres (B)	(AC-electrified kilometres)	Rate of electrification (B/A × 100)	Kilometres operating (a)	Electrified kilometres (b)	Rate of electrification (b/a × 100)
1950	19,786	1,659	—	8.4%	7,615	5,796	76.1%
1955	20,093	1,961	—	9.8	7,578	6,007	79.3
1960	20,482	2,699	258.7	13.2	7,420	6,034	81.3
1965	20,754	4,228	1,105.9	20.4	7,128	5,875	82.4
1970	20,890	6,021	2,220.8	28.8	6,214	5,383	86.6
1975	21,272	7,628	3,036.1	35.9	5,594	4,902	87.6
1980	21,322	8,414	3,469.5	39.5	5,594	4,907	87.7
1985	20,788	9,109	3,545.1	43.8	5,831	4,943	84.8

Source: For each fiscal year, from both the National Railways Information Systems Department, *Tetsudō yōran* and *Min(shi)tetsu tōkei nempō*.
Note: All statistics are for the end of the fiscal year, 31 March of the following year.

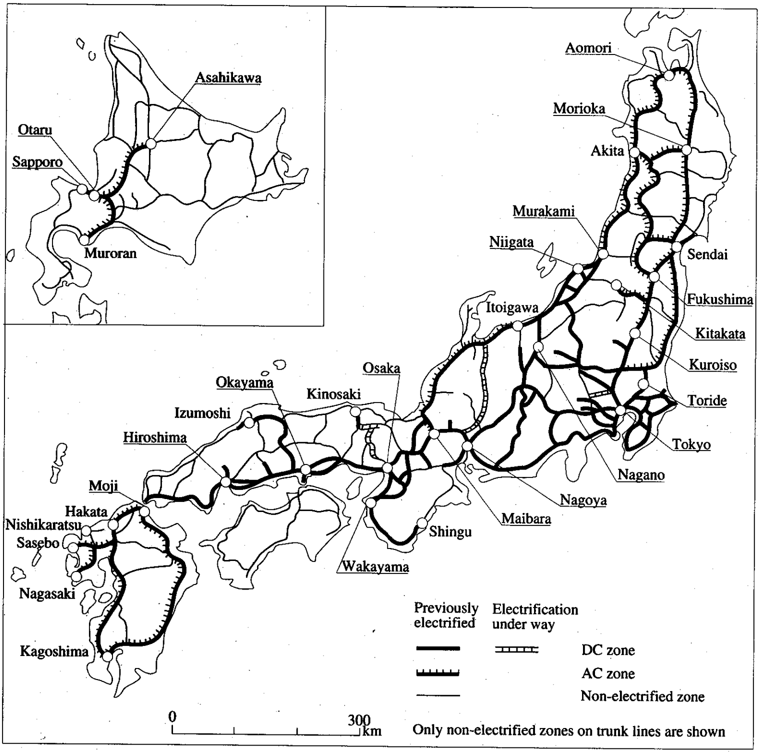

Fig. 1. Zones electrified on the National Railways (as of March 1985)

trunk line. Trains using alternating current started service in the section north of Kuroiso on the Tohoku Main Line in July 1959, in the section north of Toride on the Joban Line, and on the Kagoshima Main Line, in June 1961. The joining of AC zones to DC zones progressed in three stages: from intervening blocks of non-electrified sections in the beginning period, to a system of switching from the ground, and finally to one of switching on board the train – this last being widely adopted subsequently. This resulted in the development of railcars that could operate in both alternating and direct current zones.

The first rectifiers mounted in AC locomotives were mercury rectifiers; they were eventually replaced with silicon rectifiers. Subsequently, thyristors were adopted. In addition to making the entire unit smaller and lighter in weight, thyristors provided generation of DC with greater continuity during the switching from AC to DC. These developments led to the introduction of AC-DC electric multiple units in 1962, which made possible the use of electric trains able to operate over long distances in both AC and DC zones.

Electrification of the National Railways with both AC and DC zones progressed very quickly from the 1960s on. The reader is referred to table 2 and to figure 1, which maps the distribution of electrified lines throughout the country as of the end of March 1985.

The Start of Shinkansen Operations

The beginning of Shinkansen operations was epoch-making not just for Japanese railroad history but for the railroad history of the entire world. At the time the Shinkansen was built, there were doubts about the viability of railroad transport as a result of the great strides made in airline and motor-vehicle transport, which had eaten into the railroad's share of the market. The Shinkansen demonstrated to the world the viability of railroad transport.

The Shinkansen was planned as a means of strengthening transport along the Tokaido Main Line, more than simply adding a new set of tracks to already existing ones; it represented the world's first attempt to maintain a fleet of passenger trains in constant operation at maximum speeds of 200 km/h.

The Shinkansen tracks are international standard gauge, i.e., 1,435 mm. All trains are made up of electric multiple units powered by alternating current of 60 hertz, 25,000 volts. Each unit is 25 m long – except for the front and rear units with operator cabs, which are 25.15 m – and are 3.38 m wide. The first trains consisted of 12 electric cars, but this was later expanded to 16. Automatic train control (ATC) is used for safety during high-speed operation, and the signals indicating speed limit are displayed on the operator panel. Centralized train control (CTC) for monitoring and directing the operations of all trains in the system is at Tokyo Station.

The Tokaido Shinkansen made its maiden run on 1 October 1964; the *Hikari* (stopping only at Nagoya and Kyoto) covered the distance between Tokyo and Osaka in only four hours, and the *Kodama*, with stops at 10 stations along the way, made the same journey in five hours. By November 1965, these times had been reduced to three hours and ten minutes in the case of the *Hikari* and four hours in the case of the *Kodama*. The opening of Mishima Station in April 1969 added another stop on the *Kodama*'s run, thus extending the trip by ten minutes. The *Hikari*'s scheduled speed is 163 km/h and has a rated capacity of 1,400 passengers. There are four to six *Hikari*s running every hour and two to three *Kodama*s (figures are for one direction). Interurban train service of this frequency is rarely seen anywhere and was in operation in Japan by the 1970s. Thus the National Railways demonstrated an ability to compete with motor vehicles and the motorways and subsonic jets with operational ranges of around 500 km.

The success of the Tokaido Shinkansen led to the decision to construct the San'yo Shinkansen, in essence an extension of the Tokaido Line. Construction began in 1967, and the segment between Shin-Osaka and Okayama opened for service in March 1972 and that between Okayama and Hakata in March 1975.

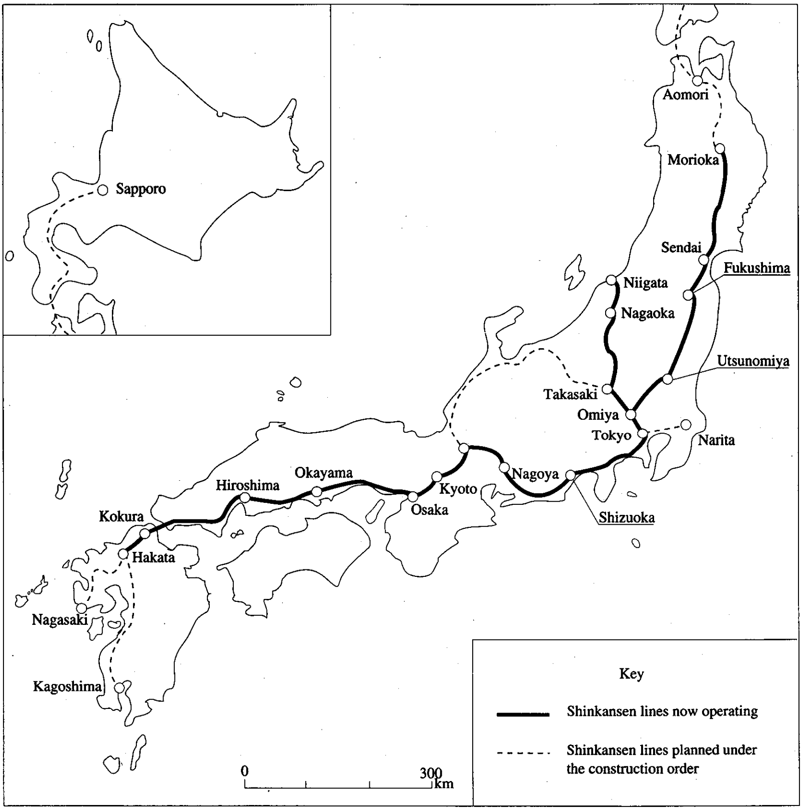

Fig. 2. The Shinkansen rail network

In May 1970, the Law for Building a Nationwide Shinkansen Railroad was enacted, after which construction began on the Tohoku (Tokyo-Morioka) and Joetsu (Tokyo-Niigata) Shinkansen lines. However, difficulties in purchasing land for right-of-way delayed the completion of construction on the final segment between Tokyo and Omiya. The sections from Omiya northwards were opened in June and November 1982, and those between Omiya and Ueno were finally opened for service in March 1985. Following the model provided by the Tokaido Shinkansen, all tracks, rolling-stock, and other above-ground equipment on these lines were built to a running standard of 260 km/h, but by the end of 1985, no trains had exceeded 240 km/h.

The Shinkansen's success was important in getting the European and American officials responsible for railroads to realize that the railroad age has not reached its twilight and that railroading still has a vital role to play in contemporary transport. This role is evident in the eastern United States and western Europe where since the 1970s different kinds of interurban train plans have been implemented for frequent, high-speed service.

Expanding the Urban Underground Railway Network

Above-ground transportation was unable to handle the growing demand for urban transport in the 1950s, and this led to an active push for underground railways in order to provide rapid transit railway service.

Post–World War II construction of underground railways started in Tokyo and Osaka during the 1950s. By 1983, eight city governments were operating underground railways or providing funds to separate organizations (usually direct operation or public corporations) for construction and operation. Table 3 outlines these developments.

In the 1960s the underground railway took over the function of surface public transport, expanded its network beyond the city centre, and thus provided a direct transportation link between the city centre and its peripheries. Links were created between the underground railways and suburban lines so that a train could operate on a through service between two railroad systems. This arrangement is most widely seen in Tokyo, but inter-company through train service also operates in Osaka, Nagoya, and Fukuoka. Another example of contemporary innovation is the Kobe High-Speed Railway, which owns no rolling-stock but operates trains from four private railroad companies on its tracks.

In order to implement a system of interconnecting rail services, the connecting underground railways had to be built against the same standards as those for the existing suburban railroads. In place of a third rail, which was the conventional mode of supplying power, an overhead power-supply system was installed. The tunnel bore was also much larger than it would normally be, in order to accommodate the pantographs. In addition, all suburban railway rolling-stock must be manufactured to the same strict flame-resistance standards as the underground cars. Because gauge and rolling-stock specifications of interconnecting railways had to be identical, it sometimes happened that gauge and carriage sizes differed even within the same company. One example is the Tokyo Metropolitan Transit Bureau, which has tracks of three different gauges: 1,067 mm, 1,372 mm, and 1,435 mm.

The Sapporo underground railway is a notable result of new technological development. Sapporo's Municipal Transit Agency and Kawasaki Heavy Industries jointly developed a guide-rail electric train, an improved version of the system developed for the Paris metro in the 1950s. Car wheels are fitted with pneumatic rubber tyres that ride on a concrete roadbed, the rails serving only to guide the car and keep it on the roadbed. The Paris system uses two guide rails, but the Sapporo system has only one, positioned at the roadbed centre. So far, this system remains unique to Sapporo, the only city currently using it.

Table 3. Development of underground railways in the large cities (1950–1985)

City	Corporation	Date service begun	Kilometres in operation at fiscal year ending							
			1950	1955	1960	1965	1970	1975	1980	1985
Tokyo	Teito Rapid Transit Authority	1927.12.30	14.3	21.5	33.9	71.7	104.9	123.9	131.8	142.1
	Tokyo Metropolitan Transit Bureau	1960.12.4	—	—	3.1	8.8	28.4	39.3	54.9	56.6
Osaka	Osaka Municipal Transit Bureau	1933.5.20	8.8	11.9	16.7	32.1	64.2	70.2	86.1	94.1
Nagoya	Nagoya Municipal Transit Bureau	1957.11.15	—	—	6.0	9.8	27.8	38.1	51.5	60.2
Kobe	Kobe High-speed Railway	1968.4.7	—	—	—	—	7.6	7.6	7.6	7.6
	Kobe Municipal Transit Bureau	1977.3.13	—	—	—	—	—	—	5.7	16.8
Sapporo	Sapporo Municipal Transit Bureau	1971.12.16	—	—	—	—	—	12.1	24.2	31.6
Yokohama	Yokohama Municipal Transit Bureau	1972.12.16	—	—	—	—	—	5.3	11.5	20.5
Kyoto	Kyoto Municipal Transit Bureau	1981.5.29	—	—	—	—	—	—	—	6.6
Fukuoka	Fukuoka Municipal Transit Bureau	1981.7.26	—	—	—	—	—	—	—	13.5

Source: *Min(shi)tetsu yōran* (Outline of private railroads).
Notes: a. Sendai Municipal Transit Bureau constructing (in 1985) 14.4 kilometres of underground in Sendai.
b. All statistics are for the end of the fiscal year indicated (31 March) of the following year.

The Decline of the Tram and the Search for New Middle Weight Transport Modes

As of 1950, 45 towns and cities in Japan were operating electric trams.[1] But inferior mobility made the tram a poor rival for the bus, and one after another, throughout the 1950s and 1960s, the trams were taken out of service.

In the latter half of the 1950s several large cities tested a new tram modelled after the US PCC Car that had indirect control systems, higher output electric motors for faster speeds, improved trucks that reduced vibration and swaying, and more modern-looking car bodies. But, the idea was fixed in most people's minds that trams were an out-of-date means of transport. Policies that might have improved the efficiency and effectiveness of the tram as a mode of transport were for the most part neglected. Another factor working against the tram was that most of the companies operating trams were running buses in the same area, and the prevailing trend was to improve efficiency by scrapping trams in favour of buses only.

There are even now no policies aimed at taking advantage of the tram's special features in urban transit. By 1980, trams survived in only 18 towns and cities, and even then, the track mileage was greatly reduced. Japan has failed to adopt policies such as those in the central European countries to completely improve tram technology, to make the best use of their special features, and to suitably position them in the overall urban transit picture.

However, a search has been on since the 1960s for a transportation mode with capabilities somewhere between the bus and the high-speed electric train and that would be cheaper to construct than trains are.

One is the monorail. Japan has introduced monorail technology through licensing arrangements for the West German ALWEG straddle-type, the French Safége suspension type, and the American Lockheed straddle-type. Most run on rubber wheels over a concrete roadbed. But, despite the fact that Japan has run more monorails in amusement parks and expositions than most countries, very few have been used in mass transit. The most successful is undoubtedly the Tokyo Monorail that began service in 1964 connecting the airport at Haneda with the central Tokyo transit network. As of December 1985, Japan had five monorail lines, three operating, one temporarily closed, and one under construction.

During the 1970s, many manufacturers were researching new transit systems that use the most advanced electronics technology to provide high-frequency, fully automated operation. One system considered effective for urban mass transit is the medium weight tram – computer-controlled small cars with rubber pneumatic tyres that run on concrete roadbeds and provide short-interval service. The Osaka Municipal Transit Bureau and Kobe New Transit (a public corporation funded by the city of Kobe) began operating trains of this type in 1981, and by December 1985 had five lines in operation.

West German innovations in tram technology during the late 1970s stimulated a fresh look at the tram. One of the most important endeavours was the test-construction, with Transportation Ministry support, of a light electric railcar that far surpassed conventional trams in speed, efficiency, and comfort. The kind of operational and policy-making success Hiroshima has had in exploiting to the fullest the special attributes of the tram has brought about a rebirth of the tram in the form of the "light electric car" and wide recognition of a new, medium weight transport mode. However, these new, light trams are being used in only a few cities, and they are consequently still at the trial-and-error stage.

The Development of Technologies for Operational Safety

Although the long history of the railway in Japan has been fraught with not a few accidents, attempts have always been made to learn from them in an effort to improve safety. The rapid increase in urban transport demand during the 1960s caused the railroads to shorten the intervals between trains, in what was called "dense scheduling." But long-distance express or freight trains running at different speeds on the same track as "dense-scheduled" local trains raises the probability of an accident.

Indeed, in May 1962, a major accident occurred at Mikawashima Station on the Joban Line: the engineer of an outbound freight train ignored a stop signal and crashed into a stop barrier. The locomotive and one freight car derailed and jumped into the path of an outbound train on the adjacent tracks. The second train went off the track and into an in-bound track. A fast-moving in-bound train crashed into the second train, killing 160 people and injuring 296. The accident lent greater urgency to installation by the National Railways of signal-linked automatic train stopping (ATS) units on all lines; this was completed in April 1966. The private railways, however, were slower to adopt ATS. A series of head-on and rear-end collisions on the private lines, however, provoked the Transportation Ministry to order in 1966 16 major companies to install ATS in designated lines within fiscal 1967–1969. The major private lines responded quickly in implementing ATS.

The use of central train control (CTC) started in September 1958 on the Ito Line and then on the Yokohama Line in June 1962. However, full-scale use really began in 1967 on the Dosan Line between Tadotsu and Kochi. The use of CTC allowed for large reductions in operational personnel at each station. The National Railways installed the system on all its lines, with special attention given first to single-track, sub-trunk routes. The major private railroads began to install CTC on their urban lines in the 1970s and, at the same time, two-way radio communications.

But, even with wider ATS use, careless equipment operation and operators going to sleep at the controls caused a series of accidents in the 1960s on national and private railways. In 1968, the Transportation Ministry ordered the railroads to retrain all train operators and the National Railways to beef up its system of operator testing. The retraining consisted of personnel training, counselling, and aptitude testing. The National Railways also installed continuous warning units and devices that would prevent ATS power from being turned off. But, machines alone do not improve safety; the basis is in safety training and the safe operation of equipment.

Improvements in and the Decline of Railroad Ferries

Railroad ferry lines functioned for a long time as important links in domestic transport. The Seikan Line (Aomori-Hakodate) connecting Honshu and Hokkaido and the Uko Line (Uno-Takamatsu) connecting Honshu and Shikoku are particularly important. Due to their importance, they were modernized to accommodate the increasing transport demand of the 1960s.

Seven new boats of the *Tsugaru Maru* class were constructed in 1964–1966 for the Seikan Line. These 8,300 gross ton vessels have a rated capacity of 1,200 passengers and 48 freight cars (each loaded with 15 tons of freight). Their 18-knot cruising speed (previous boats ran at 14.5 knots) shortened the time between Aomori and Hakodate to 3 hours and 50 minutes, 50 minutes less than that achieved previously. This dramatically increased the operating rate, since before, boats could make only two round trips in one day, while the new ones were able to make 2.5 trips. The use of diesel engines, replacing the old steam turbines, reduced fuel consumption, and automation reduced crew size by roughly 40 per cent.

In 1969–1970, three *Oshima Maru* class (4,090 gross tons) non-passenger ferries with a carrying capacity of 55 loaded freight cars and a speed of 18 knots were commissioned and put into service between Aomori and Hakodate.

Four boats of the 3,084-gross-ton *Iyo Maru* class were placed in service on the Uko Line in 1966–1968. The new diesel-powered boats ran at 15 knots, faster than the former 12 knots, to reduce travel time between Uno and Takamatsu to one hour.

Thus, while the latter half of the 1960s was the most prosperous period for railroad ferries, the beginning of the 1970s saw a rapid decline in the importance of ferries as passengers between Tokyo and Hokkaido and between Kyoto-Osaka-Kobe and Shikoku shifted from trains to aeroplanes and as highway transport began to take freight away from the railroads. Motor-vehicle transport constituted the major threat to the railroad ferries.

The Seikan Tunnel now under construction and the three bridges between Honshu and Shikoku will mean the end of ferries, without which it will be difficult for the railroads to play as important a role as they once did.

Note

1. Excepting some suburban and interurban electric-train zones on city streets.