Feature

The Development of Tokyo's Rail Network

Haruya Hirooka

Tokyo as Megalopolis

As an introduction to Tokyo's complex railway system, let's look first at how Tokyo developed into today's megalopolis.

In 1995, the population of Tokyo-to (an administrative area of 23 wards (or boroughs) plus some 27 neighbouring cities) was 11,773,605, making it one of the world's biggest cities at the time. But Tokyo is actually much bigger if we define it not as an administrative area but as the Tokyo Metropolitan Area (TMA) extending to cities such as Yokohama and Kawasaki in neighbouring prefectures. Metropolitan centres in other parts of the world, too, include surrounding areas that are under the administration of other local government entities. Tokyo is no exception but the area it draws toward its centre is far larger than that of other world metropolises.

Academics do not always agree about how the area encompassing a large city should be classified. In Japan, a 'greater city' is considered to extend to include the daily commuting distance. In 1995, the population within this Greater Tokyo Commuting Zone totalled 31,987,117 or 2.7 times more than the population of Tokyo-to.

This zone is almost circular with a radius of 50 km centred on JR East's Tokyo Station, which is located in the city centre. If we exclude regions where the public transport system does not permit easy daily commuting, the area within this rough circle is 10,117 km^2. This is less than one third the area of greater New York, which covers 33,020 km^2. However, Tokyo's population is about 1.5 times larger than New York's, meaning that its population density is 4.5 times higher. London and Paris are smaller than New York, making Tokyo the world's largest metropolitan region at this time. Actually, until 1965, greater New York's population was higher than that of the TMA. However, their relative positions reversed over the next 30 years as New York's population remained relatively stable while Tokyo's was increasing dramatically.

Figure 1 shows the extent of the TMA transport network. The city centre exerts a gravitational pull. Adjacent to the centre are sub-centres, sub-sub-centres, and other commercial urban cores. A predominant feature of this megalopolis is its extensive network of railways and expressways serving the huge population. As John Michael Thomson pointed out in *Great Cities and Their Traffic*, if a metropolis is to have a dominant city centre, it must have a well-developed railway network that creates transit corridors within the city proper. London, Paris, New York and Tokyo all meet this requirement.

When we examine Tokyo's railway network against this backdrop, it is true that Tokyo's subways do not extend as far as subways in New York, London and Paris. But Tokyo's subways carry far more passengers. In addition, suburban lines operated by JR East and the private railways have developed very extensive links to Tokyo's centre—suburban residents in New York, London and Paris do not have such substantial links; the lines from Tokyo's suburbs carry a considerable proportion of all railway passengers in the metropolis (Tables 1 and 2).

Table 1 Subways in World's Four Major Cities

	Route-km	Number of lines	Number of stations	Rolling stock (number of cars)	Annual number of passengers
New York (1996)	393.2	29	481	6,141	1,170 (million)
London (1995)	392.0	12	261	3,922	784
Paris (1995)	316.5	17	359	4,342	1,380
Tokyo (1997)	248.7	12	235	3,155	2,640

Source: *1998 Annual Report on Urban Transportation* published by Institute for Transport Policy Studies

Table 2 Shares of Various Transportation Modes

Fiscal 1996

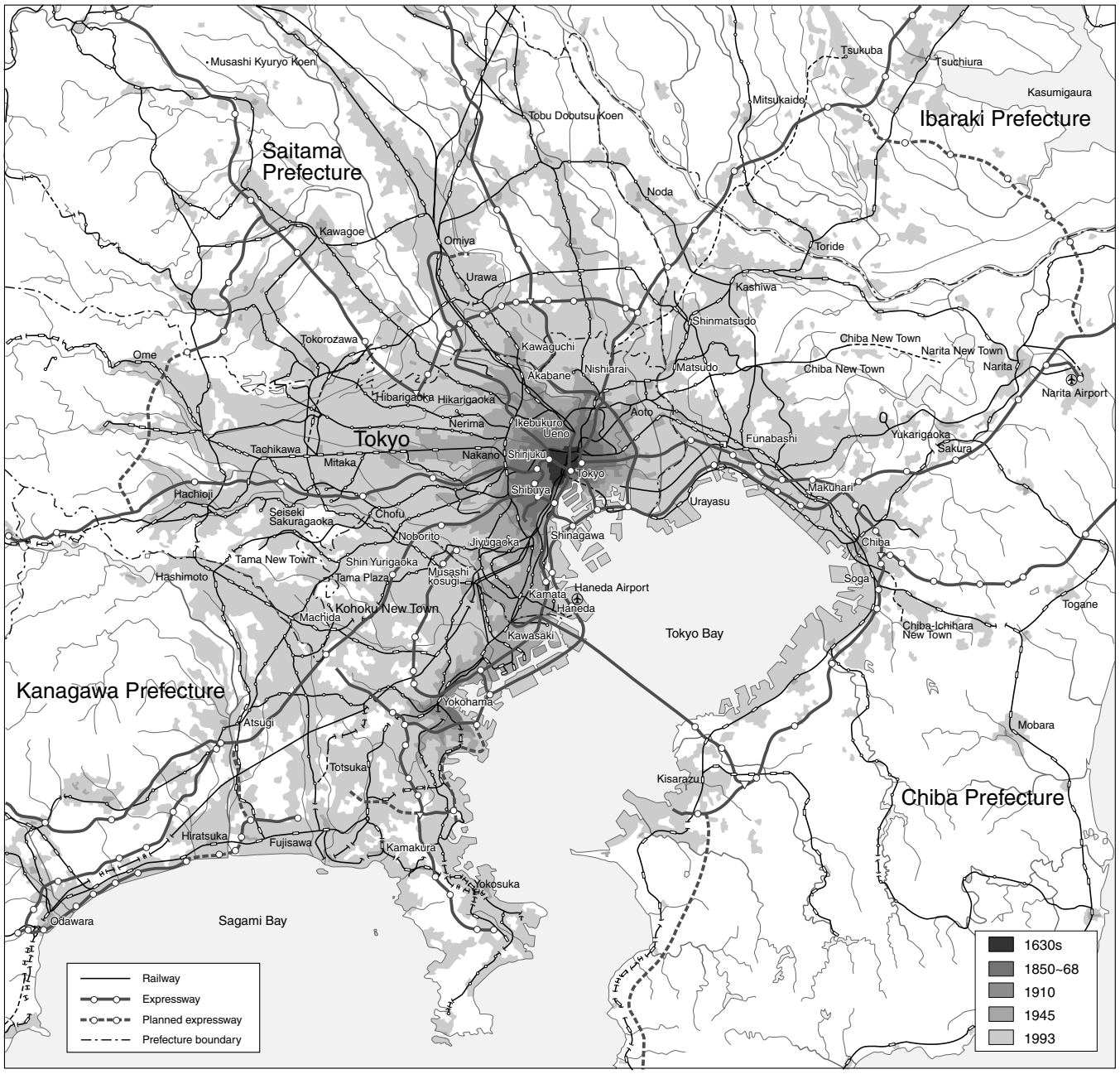
	JR	Private railways	Subways	Rail total	Trams	Buses	Automobiles
Distance (route-km)	876.4	996.2	270.4	2,143.0	17.2	10,996.7	
Passengers in Tokyo's central 23 wards (million)	3,520	2,852	2,541	8,913	40	633	2,078
Passengers in TMA (million)	5,452	4,974	2,671	13,098	40	1,972	8,354

Source: *1998 Annual Report on Urban Transportation* published by Institute for Transport Policy Studies

Railways—The Backbone of Tokyo

As I mentioned, the population of the TMA surpassed that of greater New York after 1965, but the distribution changed dramatically too. From 1970 to 1995, there was a considerable population decline in Tokyo's 23 wards; a 40% drop in the three central wards, a 33% in another eight, and a 10% drop in a further eight. On the other

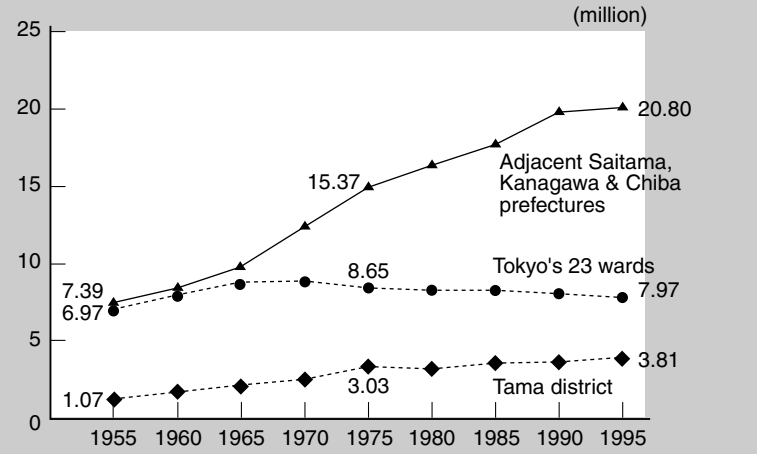
Figure 1 Tokyo Metropolitan Area Transport Network



hand, the population in three adjacent prefectures of Saitama, Kanagawa and Chiba jumped from 6.97 million in 1955 to 20.80 million in 1995. Likewise, the Tama district which is within Tokyo-to but outside the 23 wards, saw its population rise from 1.07 million to 3.81 million during the same time period. This indicates a population shift—at least at night—to the suburbs. However, the daytime working population continued to increase until 1990, so Tokyo has not experienced the so-called inner-city crisis of some European cities. Figures 2 and 3 show population curves and changes in distribution over the last four decades or so.

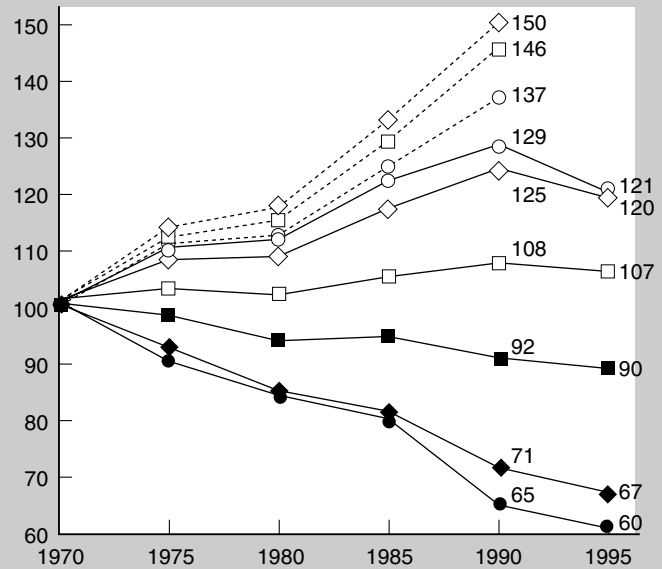
One result of this move to the suburbs is tremendous tidal flows of commuters travelling between home and work or school from the three neighbouring prefectures and from the Tama district to

Figure 2 Population Increase in TMA



Source: National Land Agency

Figure 3 Office, Day and Night Populations of Tokyo's Wards (1970 Population index: 100)



Notes: (1) 3 central wards: Chiyoda, Minato and Chuo
(2) 8 central wards: Above 3 wards and Shinjuku, Shibuya, Bunkyo, Taito and Toshima
(3) Office workers = Total of workers in specialized and technical fields, managerial staff, and office workers as classified by national census
(4) 1995 figures include passengers of unknown ages

Source: Compiled by Metropolitan Areas Development Bureau of the National Land Agency using National Census data of Management and Coordination Agency

Tokyo's 23 wards, especially to the city centre. The daily figures are enormous; in 1995, the commuting population was 650,000 from the Tama district, 970,000 from Kanagawa Prefecture, 1,050,000 from Saitama Prefecture, 870,000 from Chiba Prefecture, 80,000 from Ibaraki Prefecture, and 70,000 from other prefectures. This makes a total of 3,690,000 commuters every working day!

Commuters travel up to 65 km to the three central wards (Fig. 4). Indeed, more than another 31,000 commute from even further away by shinkansen. Because of these great distances, commuting time for one quarter of workers and students travelling to the central three wards is at least 90 minutes one way, or more than 3 hours each day.

The vast numbers of commuters use the public transportation system at the same time each morning and evening, so railways must provide tremendous capacity to satisfy the demand. As I will explain later, postwar improvements in Tokyo's railway network have involved continued effort and huge investments, creating a transit system with immense capacity (Table 3). Although the system can handle the demand, there is congestion at times but studies show that there is a limit to what can be done to alleviate this congestion.

Table 3 lists the major lines forming the extensive railway network that serves the TMA. However, the only lines carrying passengers to the city's centre are JR East's Yokosuka, Tokaido, Keihin Tokohu, Chuo, Keiyo, and Yamanote lines. All the other lines terminate at massive stations such as Shinagawa, Shibuya, Shinjuku, Ikebukuro and Ueno on the circular Yamanote Line. If all passengers disembarking at these stations were to transfer to JR trains entering the city's centre, the congestion would be unimaginable and the transfer stations would not be able to handle the extra load. This problem has been avoided to some extent by through operations of suburban

trains to the city's centre on subway lines and underground railway lines built after WWII (Table 4 and Figure 5). This solution, more than any other, made Tokyo's railway system the efficient marvel it is today. It enables hundreds of thousands of passengers to travel from the suburbs to the city centre without making a difficult and time-consuming transfer at the Yamanote Line.

Development of Tokyo's Rail Network

The TMA railway network has shown remarkable development down through the decades to the present. Figure 6 shows this evolution, demonstrating how the expansion of Tokyo's centre, sub-centres, and commercial districts was directly related to the construction of metropolitan railway lines.

Japan's first railway line was opened in 1872, some 42 years after the first Liverpool & Manchester railway began operations in Great Britain. It was short—a mere 29 km from Shimbashi to Yokohama and used British technology and rolling stock.

The Meiji government of the time initially decided to develop a state railway system, but two factors intervened. First, the government lacked the necessary capital. Second, the private sector was eager to invest in the new technology. As a result, the government changed its policy, permitting private businesses to build and operate railways and even offering financial assistance. This public–private cooperation resulted in a network of private lines covering 4674 km by 1900. This was 3.5 times longer than the government railways' lines, which extended only 1325 km.

The 1906–07 nationalization of major trunk lines belonging to 17 private railway companies reversed this situation almost overnight, causing a sudden expansion of the government railways' network at the expense of the private railways.

Table 3 TMA Railway Transport in 1996 (one way)

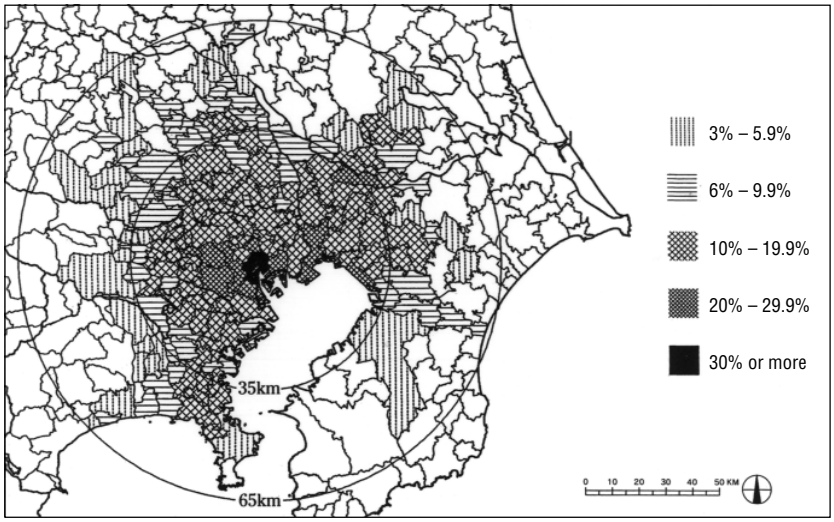
Railway Line	During peak hour			During day		
	Number of trains	Number of cars	Number of passengers	Number of trains	Number of cars	Number of passengers
From southwest						
JR Yokosuka Line	11	143	39,590	108	1,364	136,930
JR Tokaido Line	19	247	74,460	139	1,603	208,480
JR Keihin Tohoku Line	24	240	81,150	279	2,790	284,670
Odakyu Line	29	272	74,330	375	3,303	305,047
Tokyu Toyoko Line	27	216	55,752	327	2,616	242,556
Tokyu Den'en Toshi Line	28	280	76,592	230	2,300	287,405
Keihin Kyuko Line	27	264	51,600	293	2,046	174,677
From west						
JR Chuo Line (rapid service)	30	300	95,580	275	2,750	366,170
JR Chuo Line (all stations)	23	230	32,190	255	2,550	175,140
Keio Line	30	300	70,787	356	3,126	271,215
Keio Inogashira Line	28	140	30,560	296	1,480	135,822
Seibu Shinjuku Line	26	240	59,333	324	2,794	232,156
From northwest						
Seibu Ikebukuro Line	29	266	71,552	358	3,068	280,358
Tobu Tojo Line	27	270	60,423	333	3,262	247,152
From north						
JR Keihin Tohoku Line	24	240	81,740	279	2,790	310,180
JR Saikyo Line	19	190	63,300	187	1,870	224,230
Tobu Isezaki Line	44	368	82,354	440	3,136	252,156
From northeast						
JR Joban Line (rapid service)	10	150	46,150	107	1,460	145,900
JR Joban Line (all stations)	22	220	74,990	168	1,680	180,880
From east						
JR Sobu Line (rapid service)	18	234	64,200	141	1,801	186,257
JR Sobu Line (all stations)	26	260	84,660	241	2,410	302,600
JR Keiyo Line	17	164	43,500	180	1,710	157,140
Keisei Line	18	132	28,020	239	1,600	99,080
Keisei Oshiage Line	19	152	32,610	208	1,608	72,650
Loop lines						
JR Yamanote Line	24	264	90,060	323	3,553	339,330
JR Musashino Line	11	88	26,940	115	898	86,610

Source: *1998 Annual Report on Urban Transportation* published by Institute for Transport Policy Studies

A second railway construction boom lasted from the 1910s to the mid-1930s. The government railways' trunk network was basically completed, so it shifted its efforts to laying branch lines. The private sector built new lines (many electrified) to serve cities and adjacent districts. The basic configuration of Japan's railway network as it exists today—with the exception of the shinkansen—was established by the mid-1930s.

Japan first adopted railway technology in Tokyo, so it was natural for Tokyo to be the central hub of a trunk-line network radiating to every part of the country. These trunk lines naturally determined the

Figure 4 Commuting Ratio to Tokyo's Three Central Wards



Source: Population Census of Management Coordination Agency

directions in which commercial districts expanded within the city and out toward neighbouring areas. In addition, the development of private railways gave impetus to the expansion of Tokyo's suburbs. As a result, Tokyo and its surrounding districts developed more rapidly than other parts of the country.

Table 5 shows the growth of Tokyo's railway lines, which had basically been established by the 1930s. The postwar high-economic growth period and Tokyo's further expansion promoted even more development along the rail corridors. This population growth led to increased demand, which in turn prompted railways to run longer trains at shorter headways. When these measures proved unable to cope with increased ridership, other steps were taken, such as quadrupling tracks and constructing overpasses. More subway lines were also built during and after the 1960s to carry the growing number of commuters disembarking from the suburban railway lines. These efforts gave the TMA its interconnected transit system described above.

TRTA–Tokyu through trains at Naka Meguro Station. TRTA's Series 3000 leaving for Tokyu's Hiyoshi Station (left), Tokyu's Series 7000, leaving for Kita Senju via TRTA Hibiya subway line (middle), and another Series 7000 bound for Tokyu's Shibuya terminal (right). (Photographed in August 1964 by Satoshi Kubo)

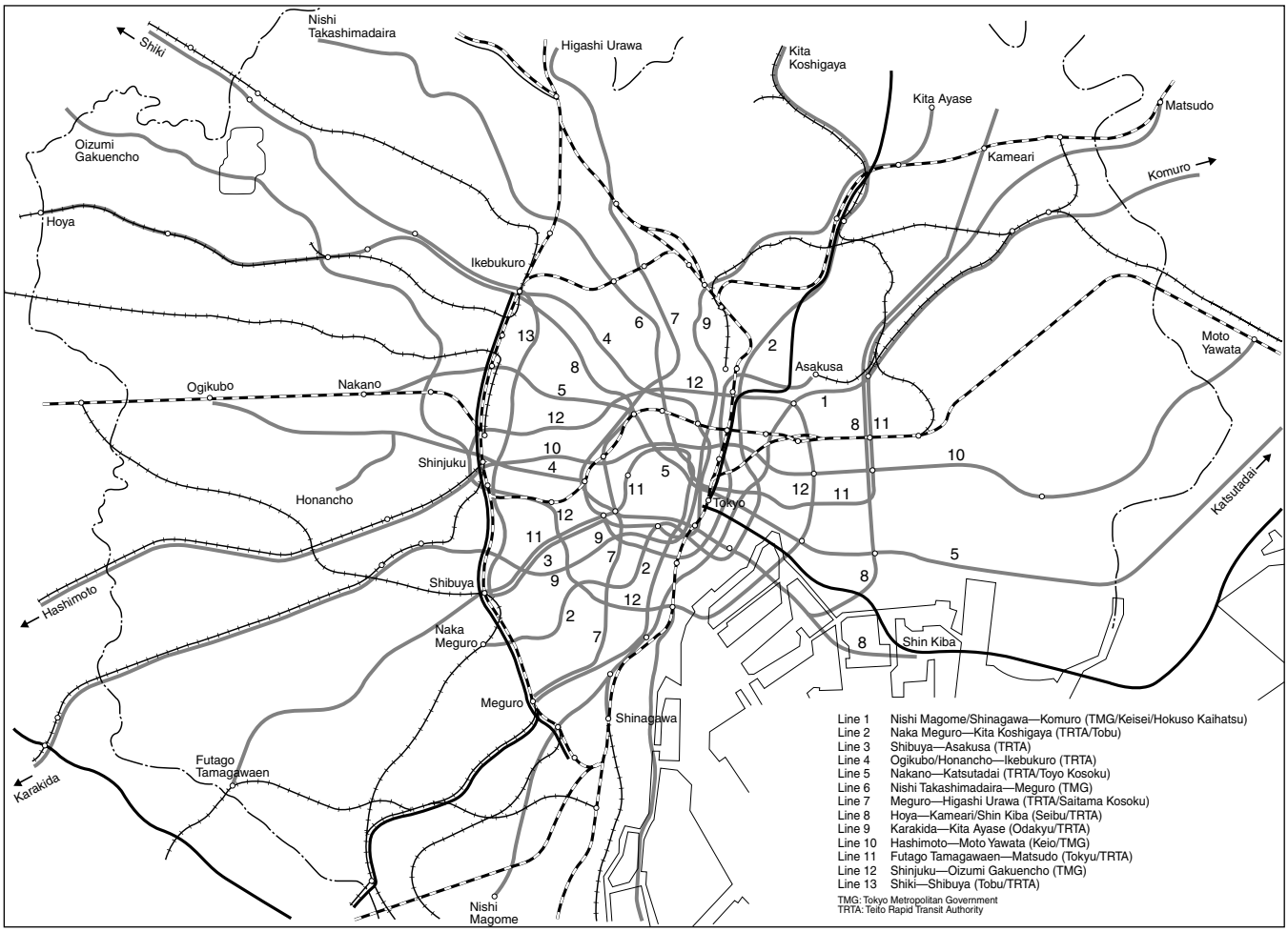
The first public transportation system in the commercial centre was started in 1882 in the form of a private company operating horse-drawn carriages on rails. Ridership was high. Then, in 1903, the same company started Japan's first tramway line from Shimbashi to Shinagawa. Other tramway lines were soon built by different companies. The three tramway companies were amalgamated in 1906 to form Tokyo Railway (*Tokyo Tetsudo*), which subsequently became publicly owned in 1911, reflecting the then worldwide trend towards government control of tramway operations.

Trams formed the backbone of Tokyo's transit system from the 1910s to the 1950s. Ridership was high, and the network extended in many directions. But the trams did not run on private right-of-way and had to share the increasingly congested roads with cars in the 1950s. As road congestion caused increasing timetable problems, passengers began abandoning trams at the very time that the tramway companies' operating costs were rising. The inevitable deficits led to the decision to abandon tram operations in favour of buses and subways. By the late 1960s, Tokyo had only one remaining tramway line.

Today, there are calls to revive the tram concept as light rail. But this will only work if the lines have exclusive right-of-way, and if demand warrants the investment.

Here, it is worth mentioning the efforts in Tokyo to construct elevated lines over roads and waterways for exclusive use by monorail and new transportation systems.

Figure 5 1985 Master Plan for Tokyo Rail Network Expansion



Cars and taxis carry relatively few people in the city centre and sub-centres, because population densities and traffic congestion are high, and because the few available parking spaces are very expensive. However, the car is assuming greater importance in the nearby Tama district and in neighbouring prefectures (Table 2).

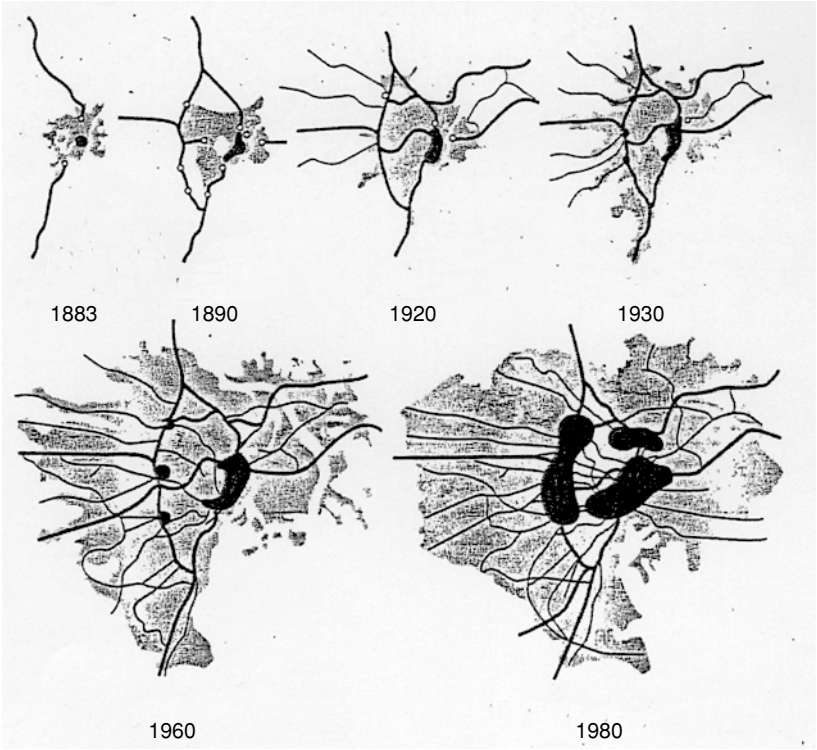
Financing Rail Improvements

Very high land prices in the city centre and surrounding commercial areas make it impossible for the railways to obtain cheap land for further development. It is

Table 4 Suburban Railway–Subway Through Operations

Suburban Railway	Subway
Keihin Kyuko Line	Toei Asakusa Line
Keisei Oshiage Line	Toei Asakusa Line
Tokyu Toyoko Line	Eidan Hibiya Line
Tokyu Den'en Toshi Line	Eidan Hanzomon Line
Odakyu Line	Eidan Chiyoda Line
Keio Line	Toei Shinjuku Line
JR Chuo Line	Eidan Tozai Line
Seibu Ikebukuro Line	Eidan Yurakucho Line
Tobu Tojo Line	Eidan Yurakucho Line
Tobu Isezaki Line	Eidan Hibiya Line
JR Joban Line	Eidan Chiyoda Line

Figure 6 Development of Urban Rail Network and Expansion of Tokyo



Source: *Research Report on Tokyo's Development into Multi-centric Metropolis* by Tokyo Metropolitan Government, 1959

JNR's newly opened Musashi Koganei EMU Depot on Chuo Line in western suburb of Tokyo. As the number of commuter trains increased around Tokyo, many new depots had to be built during the 1960s and 1970s. (Photographed in December 1961 by Satoshi Kubo)

exceedingly difficult to obtain land at all—and any successful purchase involves much expense of time and astronomical amounts of money. These problems can be avoided to some extent by building elevated lines and by building underground, but construction costs rise in proportion to difficulty. The postwar economic boom exacerbated these problems.

Conditions were more favourable to railway construction from the 1880s to 1930s—the golden decades for railway investment—when a considerable proportion of total investment was spent in railways. This spending both stimulated the economy and helped develop the social infrastructure. In those days, rail investment prepared for future growth. On the other hand, postwar railway investment has usually been a (futile) attempt to catch up with spiralling demand caused by high economic growth and rapid urban sprawl. In many cases, the high cost has negatively affected the railway companies' finances.

During the 1910s and 1920s, private railway companies invested considerable sums in construction of metropolitan and suburban lines. An examination of their capital procurement practices during these decades shows that:

(1) When raising capital, the companies depended to a great extent on increasing capitalized stock. They had few retained earnings to draw on.

(2) Because they had little of their own equity, the companies borrowed capital. For example, they issued corporate bonds and secured loans through railway foundation mortgages. Bank loans formed only a small part of borrowed capital.

(3) The companies greatly increased the value of fixed assets used for non-railway-related business, and the value of their investment securities. In other words, they invested in railways while expanding their investments in other business sectors as well.

These facts show that railway companies disposed of a considerable percentage of

their profits through payment of dividends, and that their retained earnings were negligible. This trend was even remarked on before 1913. Railway investment could not be self-financed through retained earnings, and any increased profits were eaten up by paying out more dividends. Stocks rose in value, increasing the ability of shareholders to underwrite new investments in stocks. This in turn created positive signals that prompted further investment.

For its part, the government introduced a system of subsidies that stimulated the private railways to further development. The Light Railway Subsidy Law of 1911 provided government subsidies to new private railway companies for 5 years after their establishment. The size of subsidies depended on profits, but was limited to a ceiling of 5% of construction costs. The 5-year limit was raised to 10 years after the law was amended in 1914.

These subsidies were a boon for railways. For example, the Tokyo Yokohama Electric Railway (now Tokyu Corporation) enjoyed government subsidies for 11 years—the subsidies were of great help during the 6 years it took the railway to go from start-up to profitability (before depreciation). During this period, the company was only just able to continue paying 6.6% dividends. In another example, the Odakyu Electric Railway started receiving subsidies in 1929, and was able to turn a profit and pay dividends of 5%.

Subways became the focus of most new railway construction in metropolitan areas after WWII. Subway construction is immensely expensive and some funds were raised by contributions from local governments, but most were in the form of borrowed capital from other sources. As a result, the costs of this borrowed capital weighed down operations for many years.

In 1962, the government introduced a new subsidy system for subways to lighten their debt load, ensure stable operations, and promote further construction. These subsidies were small at first, only covering part of the interest on loans. Gradually, the subsidies and subsidy ratios were raised over time, and the payment system was modified to the subway operators' advantage. At present, subsidies can amount to as much as 70% of all eligible construction costs, and payment can be made as one lump sum during the fiscal year when construction is undertaken. The national and local governments share these subsidies equally, but even with these generous pay outs, all the nine publicly operated subway companies in Japan, except the Teito Rapid Transit Authority (Eidan), suffer deficits each year, and their accumulated debt is continuing to mount.

Major private railways in the metropolitan region continue to operate lines that were built before WWII. Since the war, they have improved rail services mainly by operating more and longer trains. This has involved purchase of more rolling stock and lengthening of platforms. Other steps to increase basic capacity have included building elevated track in certain areas, quadrupling tracks, and constructing short new track sections to permit through operations to subway lines. This new infrastructure has required very large investments, with most of the capital being external loans at relatively high interest rates. Another problem is that the investments are aimed at alleviating congestion, not generating much new revenue, so construction tends to drag on.

To deal with these problems, in 1986, the government introduced a law to facilitate investment in infrastructure for specified urban railways. Under this law, fares can be adjusted an extra amount upward by adding an amount to the fare increase determined according to the conventional rate-base method. This extra is set aside in an untaxed reserve account at a designated financial institution, forming a surplus for each specified railway. Funds in this reserve are then used to pay construction costs. One condition is that the reserve cannot exceed 25% of the

Table 5 Growth of Tokyo Rail Network and Population

Decade	Track length (km)	Population of Tokyo's 23 wards (10,000)	Track-km per 10,000 people	Population of TMA (10,000)	Track-km per 10,000 people
1880	26.9	100	0.26		
1890	235.8	140	1.68		
1900	562.5	180	3.13		
1910	720.2	200	3.60		
1920	887.7	217	5.71		
1930	1,242.2	207	7.70		
1940	1,432.6	677	2.64		
1950	1,491.0	583	3.42		
1960	1,530.1	831	2.27		
1970	1,699.3	884	1.92	2,147	0.79
1980	1,873.5	835	2.24	2,584	0.72
1990	2,025.5	816	2.48	2,865	0.71
1995	2,143.0	796	2.69	3,198	0.67

Notes: (1) Track length: Total length of government railways, JNR, JR, major private railways, subways, monorails, and new transportation systems, at decade end
(2) Population: Data from *Japanese Economic Statistics, Japan—100 Years of Facts and Figures*, and *Metropolitan Traffic Report* of Japan Statistical Research Institute

construction costs that the fund is intended for. In this way, passengers pay a higher fare up front, and this extra revenue is used to increase rail capacity and decrease congestion, which ends up benefiting the passengers. Another advantage for passengers is that fares should increase upwards to a lesser degree in the future, since the railways will not need to borrow and pay interest on as much capital.

However, unlike publicly supported railway companies, the private railways operate under the premise that they will pay shareholders a dividend of 10%. No railway companies in other cities of the world operate like this.

Before the 1987 privatization and breakup of the Japanese National Railways (JNR), the management took a number of important steps to improve capacity. Some tracks were quadrupled, and passenger and freight lines were separated. Some new lines initially planned as freight lines became passenger lines. Typical examples are the Musashino Line, a circular suburban line around Tokyo, and the Keiyo Line from Tokyo Station to Soga in Chiba Prefecture along Tokyo Bay. After the JNR privatization and breakup, the JR group of companies have attempted to ensure profitability by adopting the principle that investment in construction should remain within the bounds of depreciation expenses involved in such construction. Investments by the JR Group are mainly for upgrading station buildings and rolling stock, increasing the number of passenger trains, raising comfort levels, achieving greater efficiency, and raising competitiveness.

Conclusion

The collapse in the early 1990s of Japan's so-called Bubble Economy marked the start of a long and continuing recession characterized by the country's first negative growth since WWII. There is still little sign of recovery and it seems likely that growth will remain negligible for some time. In addition, it appears that development potential in the Tokyo and metropolitan region had reached its maximum by the early 1990s, and that the expansion days are over. The number of rail passengers increased each year after the war until 1994 but has slowly declined since then. Railway operators are beginning to realize that they can no longer assume that ridership and profits will continue to rise.

And yet many passengers using the metropolitan railway system must endure crowded trains and a long commute. They want these problems addressed. If railways cannot improve the situation using their own financial resources, public subsidies are necessary. But the national and local governments are hamstrung by mounting debts, and have little room to manoeuvre.

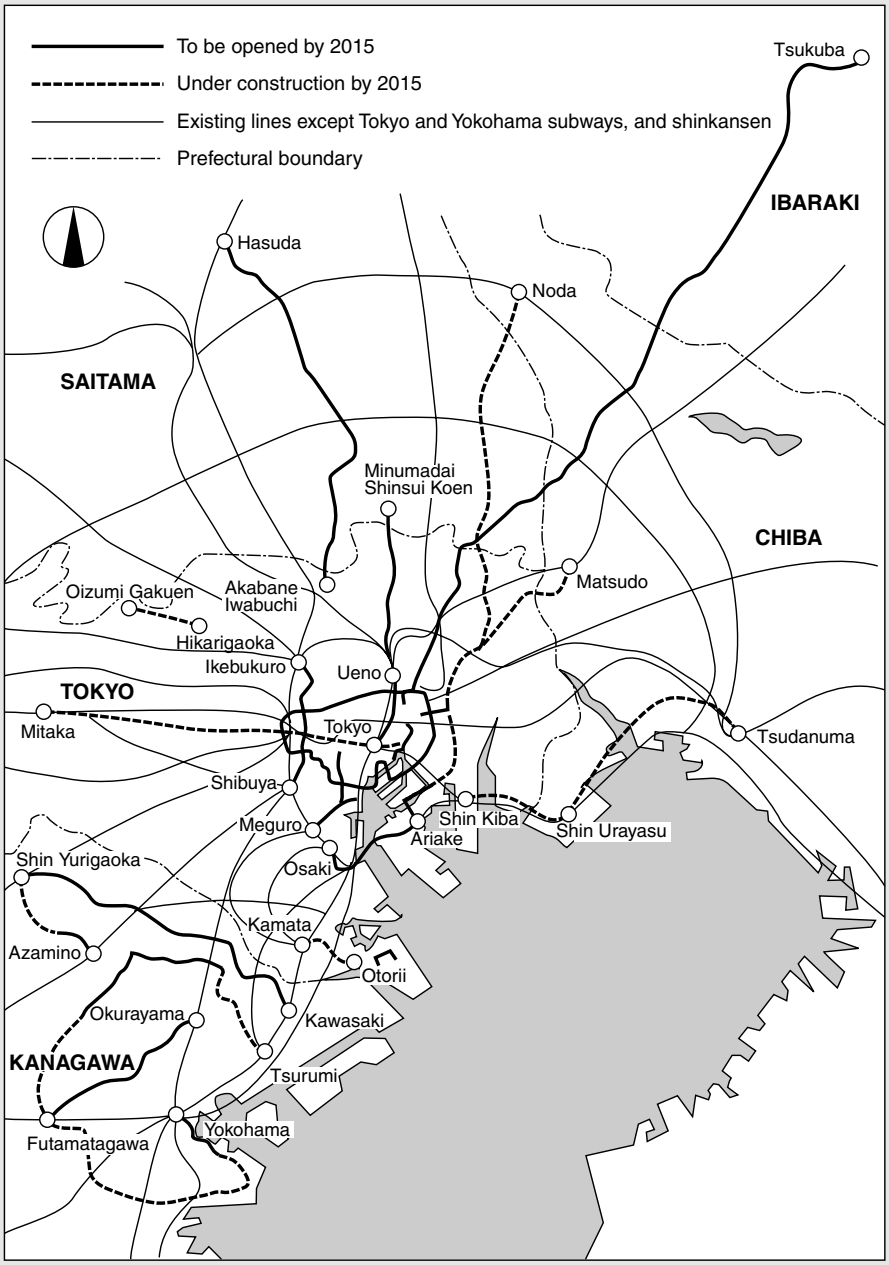
Furthermore, subways will soon find it physically impossible to construct new lines. The solution should be found not only through better rail services but also through comprehensive metropolitan planning that promotes dispersal of certain government functions to other regions, and the return of some residents to the city centre. But such measures would undoubtedly mean that railway companies would have to stop trying to boost revenues by increasing ridership from the distant suburbs. And the end result could be that the railways will have less incentive to invest heavily in measures to increase capacity. ■

Haruya Hirooka

Professor Hirooka is President of Tokyo Junior College of Transport. He graduated from the School of Economics at the University of Tokyo in 1950 and taught for many years at Hosei University where he is now Emeritus Professor. His extensive publications include *Citizens and Transport* (1987, in Japanese), and he is also the editor of *Modern Transport Economy* (1997, in Japanese) and *Cities and Transport* (1998, in Japanese).

New Master Plan for Tokyo's Urban Rail Network

New Rail Expansion Master Plan for Tokyo Metropolitan Area (Recommended by Transport Policy Council, January 2000)



On 27 January 2000, the Transport Policy Council (an advisory body to the Minister of Transport) submitted a report, recommending a major revision of the 1985 master plan to expand Tokyo's urban rail network.

This new master plan covers 426 km of railway sections of which 233 km are entirely new (including new lines and extension or quadrupling of existing lines), as well as sections currently under construction. The plan also includes some monorails and automated guided transit systems. Notable new sections include: 1. A new double track between JR East's Tokyo and Ueno stations enabling trains from the Tohoku, Takasaki and Joban lines to reach Tokyo Station; 2. Extension of the TRTA Yurakucho subway line to Noda (Chiba Prefecture) via Kameari on the JR East Joban Line; 3. Construction of Saitama Kosoku Railway to Hasuda (Saitama Prefecture), connecting to TRTA Namboku subway line at Akabane Iwabuchi; 4. Extension of the JR East Keiyo Line from Tokyo Station to Mitaka on the Chuo Line; 5. Construction of a new line from the Odakyu Electric Railway's Shin Yurigaoka Station to JR East Kawasaki Station to provide a mass transit system to Kawasaki for residents of north Kawasaki.

The report recommends completion of urgent sections by 2015 with construction of remaining sections to start by the same year. Passenger crowding, which is currently at an average of 183% of capacity, should be eased to 151% if all proposed sections are completed.

The total construction costs are estimated at ¥7.2 trillion with ¥4.7 trillion of this being for the 233 km of new sections. However, the number of rail passengers in the Tokyo Metropolitan Area has been decreasing in recent years as a result of the stagnant economy and the aging population. Consequently, rail operators are reluctant to make further infrastructure investments. The Council expects the government to arrange new financing, but the central and local governments are both facing serious deficits, making the whole situation much more difficult than in 1985. ■

T. Suga