# Commuter Railways

## — Can congestion be relieved?

Hitoshi Ieda

The Greater Tokyo metropolitan region has a population of about 27 million and spreads over a radius of 45 km. 15 million people commute every day and 6.9 million of these commuters work or study in the Tokyo central 23 wards. Commuter railways including monorail (total length in Greater Tokyo: 2070 km) are used by 71% of all commuters and by 91% of commuters visiting the 23 wards. Unlike other great cities in Japan or abroad, Tokyo depends on railways to a large extent. In other words, Tokyo has developed with railways. On one hand, railways play a very important role in Tokyo, on the other hand they have many problems attributed to large transport volume, such as congestion during rush hours and poor passenger service facilities, especially for the elderly and the weak. The congestion during rush hours is one of the severest problems of Tokyo traffic facilities. This is often referred to as a symbolic problem of "rich companies" and "poor workers" when more importance is attached to work than to the quality of life. This article describes the causes of rush-hour congestion and how to solve the problem.

## 1. Reality of Rush-Hour Congestion

### What does 160% Target Congestion Ratio Really Mean?

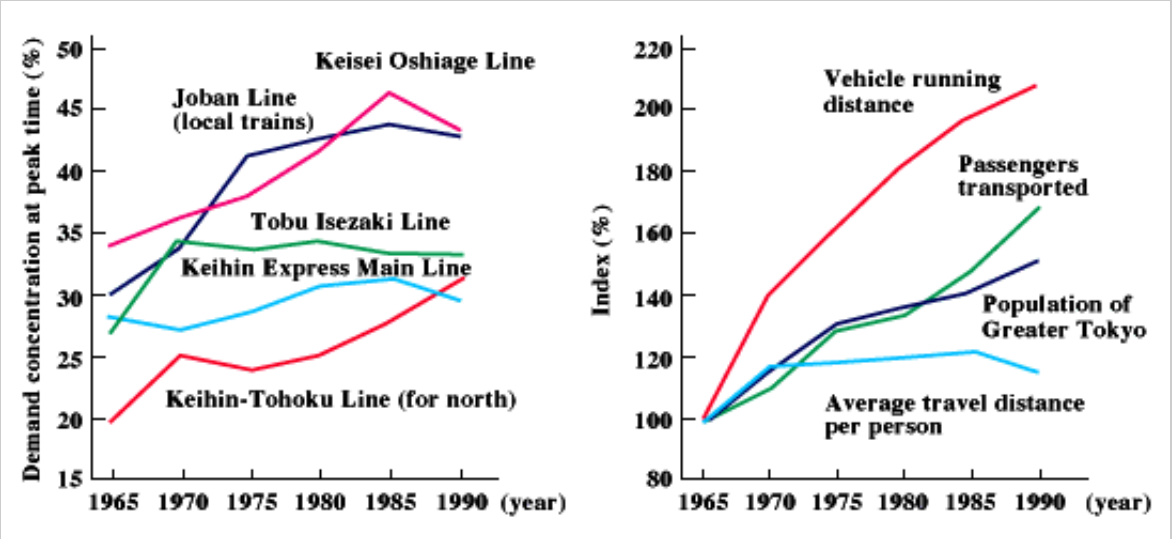
Congestion ratio is used to express the state of rush-hour congestion. It is the ratio of the number of passengers to the train capacity. For a standard train serving the Chuo Line, a congestion ratio of 100% means that approximately three passengers "stand" in 1 m2 of floor space; 200% means approximately 7 passengers, and 250% means approximately 9 passengers. Most of the main commuter lines in Tokyo show a congestion ratio of 200% or higher in rush hours. These figures reveal how terrible the Tokyo rush-hour congestion is. Against this background, 150% (180% at present) has been set as the target for solving the congestion problem. However, at 150% to 180%, 5 to 6 passengers still "stand" in 1 m2 of floor space, which is far from a comfortable ride.

### Transport Capacity Continues to be Reinforced but...

Have no measures been taken against congestion? Yes -- in Greater Tokyo, the vehicle running distance, or transport capacity, has been al most doubled compared to 1975, while the population and passenger volume are 1.5 times that in 1975. Therefore, the congestion ratio has apparently been improved as a whole (Figure 1). In addition, air-conditioning is being introduced increasingly on trains and subways, relieving discomfort to some extent. However, passengers still feel that the hardship of commuting has not been relieved.

The reasons for this are twofold. First, commuting time to offices or schools has increased due to residential sprawl. Second, traffic demand is concentrated in specific time zones.

**Figure 1 Trend of Transport Volumes, Traffic Capacity and Peak-Time Concentration**



On some lines, the towns are mostly dormitory towns for distant offices or schools, resulting in a high concentration of traffic demand at specific times. Although overall congestion has been relieved, the congestion at peak demand is not always relieved. Such a phenomenon not only adds to the congestion at peak demand but also leads to surplus facilities in the off-peak time, lowering the investment efficiency. Third, comfort is becoming more important to Japanese, and hatred of congestion is growing.

### Congestion Cost and Loss

How severe is the congestion? Some people think that commuter congestion is proof of the vitality of Japan, and others that it is more shameful than the infamous "rabbit hatch" houses.

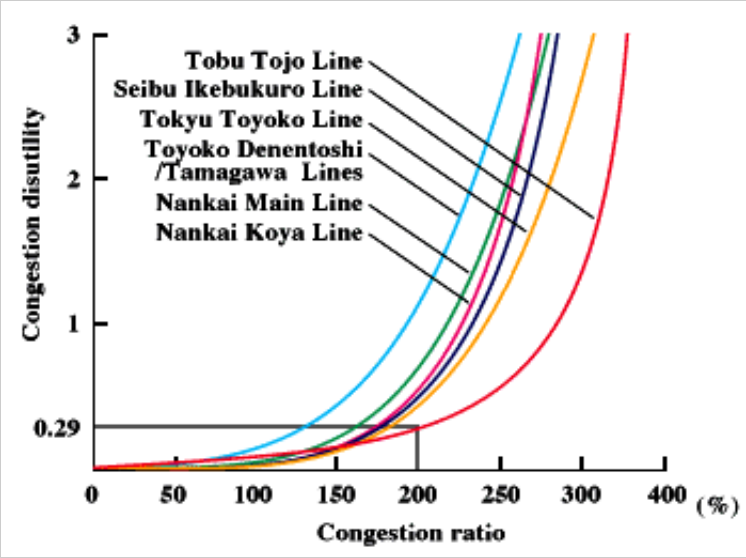
To clarify how users evaluate the trade-offs between discomfort due to congestion and lost time, I analysed the actions taken by users to avoid congestion and formulated congestion evaluation curves.

The congestion evaluation curves for various lines (Figure 2) show that riding a train with a 200% congestion ratio for 10 minutes is equivalent to riding an uncrowded train for 13 minutes. Namely, a passenger suffers a loss of 3 minutes when riding a train with a 200% congestion ratio for 10 minutes. By multiplying the congestion loss converted into time by a value for converting the value of time into money, we can evaluate congestion in money terms.

In Figure 3, congestion loss per service kilometer is totalled over 30 years using a 6% annual rate of depreciation for plant. The figures show to what extent plant investment to relieve congestion can be justified socioe-conomically. Compared with the construction cost of a subway (approximately \20 billion per kilometre), congestion loss is by no means small from the socio-economic viewpoint. If congestion can be relieved by investment, congestion loss will change to a benefit.

Reinforcing the transport capacity of commuter railways tends to be regarded as an investment that does not pay from the financial viewpoint.

**Figure 2 Congestion Evaluation Curves**



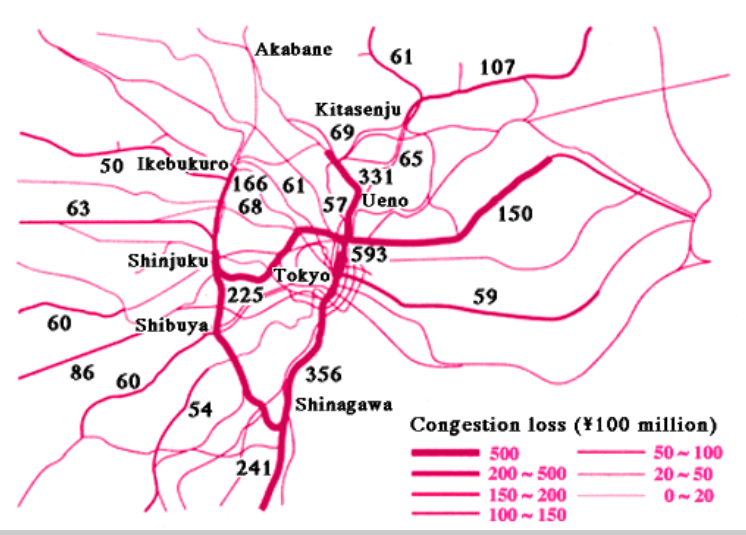

However, evaluation of five major private railways in the Kanto district which are now reinforcing transport capacity by widening to 4-track lines shows it to be a superior investment from the viewpoint of users' benefit. In other words, it is an investment with high socio-economic effect.

## 2. Various Measures to Relieve Congestion

### What measures would effectively relieve rush-hour congestion?

Figure 4 summarises the long- and short-term measures that can be considered from both the supply and demand sides, including reinforcement of transport capacity by constructing new lines and widening to 4-track

**Figure 3 Congestion Loss of Commuter Railways in Greater Tokyo (30-year total per service kilometer at 6% rate of depreciation)**



lines. First, let's examine the long-term measures. Figure 5 shows the lines planned for reinforcement stipulated in the report submitted by the Council for Transport Policy in 1985. In addition, widening to 4-track lines and long trains are being used to reinforce transport capacity.

## 3. Land Acquisition Problems

Long-term measures are accompanied by large-scale construction work. This raises the question that railway land is very difficult to secure and that purchase prices for railway land tend to soar. The problem of railway land leads to direct increases in the amount of money required, as well as to an increase in time-dependent costs, such as increased interest due to prolonged construction terms or delayed opening.

Recently, various measures have being taken to solve the problem of land, in addition to the conventional method of purchasing land. For example, readjustment of land along railways is used in parallel with railroad construction to secure land for tracks, stations and squares in front of stations (Metropolitan Subway Shinjuku Line, New Joban Line, etc.). In addition, wide roads are constructed when a new town is developed so that part can be used as railway land when a railway is built (Chiba New Town); existing lines are moved underground (Seibu Shinjuku Line), roads are reinforced and subways are constructed under them (Metropolitan Subway No.12 Line), the underground of private railways (not public enterprise or joint venture of local government and private business) is used (New Tamagawa Line), and rolling stock yards are utilised in three dimensions to provide land for parks and buildings (Metropolitan Subway No.12 Line).

In addition, urban subways are being constructed under roads by using many curved sections or (as new stations tend to be constructed deep underground to connect existing lines) in the deep underground where the indemnity is comparatively low, avoiding use of underground private land which requires high indemnity. The linear motor cars used by the Metropolitan Subway No.12 Line in Tokyo and the Tsurumi Ryokuchi Line in Osaka have a low floor height above rail level, so the cross-sectional area of tunnels can be small, greatly reducing the construction cost. In addition, they are non-adhesion type railways with excellent gradeability and curve performance, making free route design possible. On the other hand, restriction of ownership of deep underground private land (40 m or deeper) is being investigated to promote reinforcement of the social infrastructure.

## 4. How to Secure funds for Reinforcing Railways

**Business Incentive to Investment**

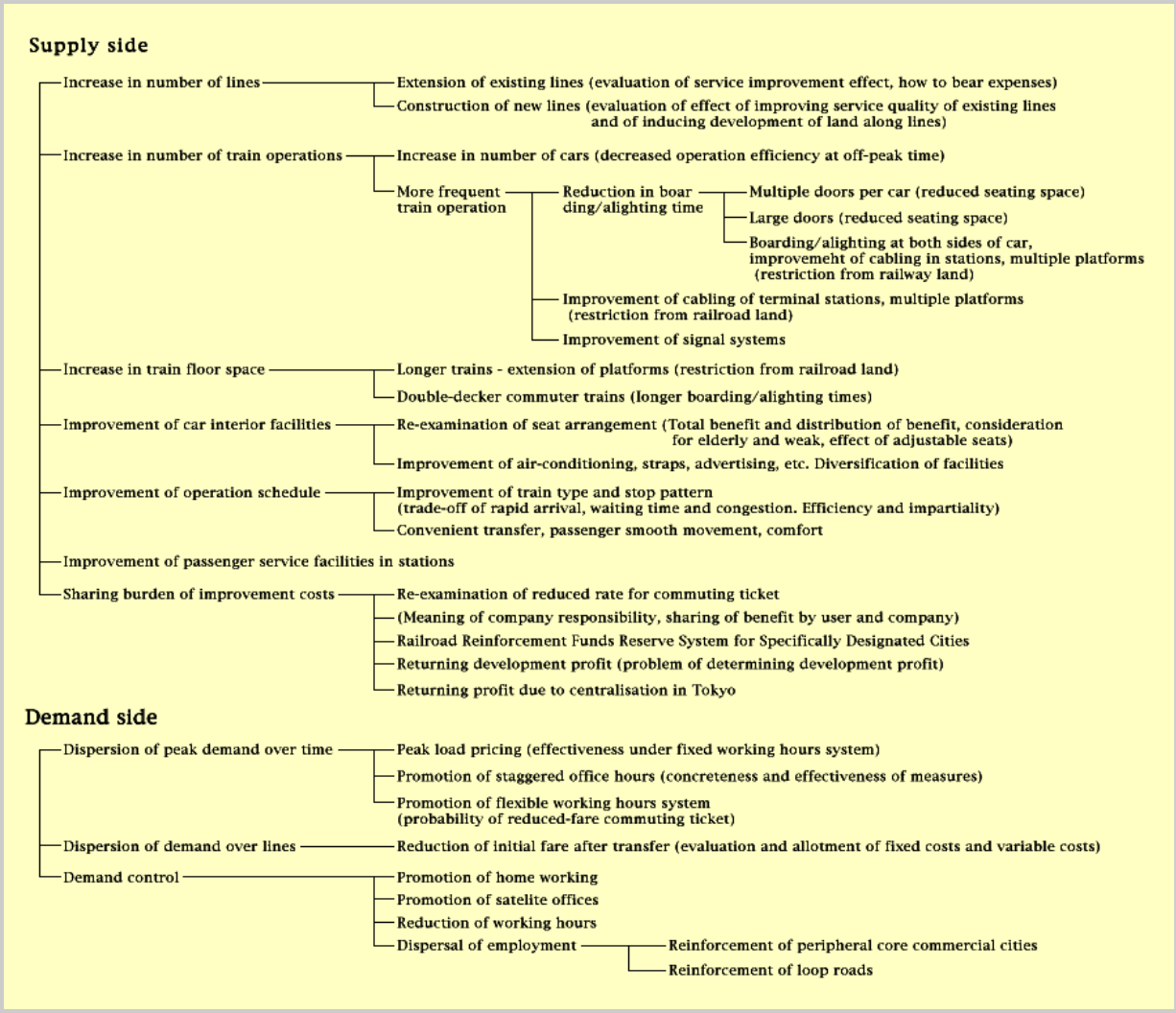
In addition to railroad land, how to raise the funds for reinforcing railways is one of the severest problems. Reinforcing transport capacity by widening to 4-track lines or extending station platforms to relieve congestion does not basically lead to an increase in the number of passengers (or transportation income). Therefore, they are hardly an incentive to investment, from the railroad point of view (pursuit of profit).

In the *Railroad Reinforcement Funds Reserve System for Specifically-Designated Cities* established in 1986, in order to complete the planned construction works for reinforcing transport capacity within 10 years, part of the construction cost is included in the fare to increase income, and the increase in income (exempted from taxation) is reserved to raise the appropriation ratio of own funds with no interest payment burden, thus reducing interest paid as well as preventing fares from soaring after completion. It is a system to induce businesses to invest by a kind of social contract. Based on the system, five major private railways are progressing with their reinforcement plans, which will be completed in 1997. But this system has a limit, and it is necessary to secure new funds for reinforcement from the viewpoint of

**Table 1 Sample Evaluation of Transport Capacity Reinforcement Projects of Five Major Private Railways in Tokyo Metropolitan District (1986)**

| Line | | Length (km) | Construction cost (¥100 million) | Congestion ratio | | Required time (per km) | |
|---|---|---|---|---|---|---|---|
| | | | | Present (%) | After completion (%) | Present (minutes) | After completion (minutes) |
| Tobu Isesaki Line | Kitasenju - Kitakoshigaya | 17.3 | 840 | 192 | 161 | 1.647 | 1.358 |
| Seibu Ikebukuro Line | Ikebukuro - Shakujiikoen | 10.6 | 2538 | 208 | 151 | 1.592 | 1.431 |
| Seibu Shinjuku Line | Seibu-Shinjuku - Kamishakujii | 12.8 | | 196 | 152 | 1.875 | 1.477 |
| Keio-Teito Keio Line | Whole line | 37.9 | 632 | 182 | 176 | 1.768 | 1.689 |
| Keio-Teito Inogashira Line | Whole line | 12.8 | | 178 | 166 | 1.875 | 1.875 |
| Odakyu Odawara Line | Shinjuku - Izumi-Tamagawa | 14.4 | 2563 | 208 | 166 | 2.310 | 1.741 |
| Tokyu Toyoko Line | Shibuya - Hiyoshi | 13.6 | 2108 | 202 | 162 | 1.911 | 1.765 |
| Tokyu Mekama Line | Meguro - Tamagawaen | 7.5 | | 171 | 161 | 2.250 | 1.625 |

**Figure 4 Commuter Railways Improvement Measures**




| Average passengers | | Benefit in congestion time | | Benefit of relieved congestion (¥100 million) | Benefit of relieved time (¥100 million) | Ratio of benefit of relieved congestion to benefit of reduced time (%) | Annual total benefit (¥100 million) | Total benefit of each company (¥100 million) | Depreciation period of construction cost (years) |
|---|---|---|---|---|---|---|---|---|---|
| In peak-demand hour (10,000 people) | Concentration ratio (%) | Relieved congestion (seconds) | Reduced time (seconds) | | | | | | |
| 8.2 | 33.5 | 11.2 | 17.3 | 34 | 299 | 10.3 | 333 | 333 | 2.5 |
| 7.7 | 25.9 | 16.4 | 19.7 | 29 | 124 | 19.1 | 153 | 468 | 5.4 |
| 6.4 | 27.5 | 16.6 | 23.9 | 29 | 287 | 9.2 | 326 | | |
| 6.6 | 27 | 2.8 | 4.7 | 15 | 179 | 7.7 | 194 | 197 | 3.2 |
| 3.2 | 22.4 | 3.3 | 0 | 3 | 0 | 100.0 | 3 | | |
| 7.7 | 25.5 | 23.9 | 34.1 | 58 | 603 | 8.7 | 661 | 661 | 3.9 |
| 6.0 | 23.3 | 14.3 | 8.8 | 25 | 125 | 16.9 | 150 | 213 | 9.9 |
| 1.3 | 24.5 | 10.1 | 37.5 | 2 | 60 | 3.4 | 62 | | |

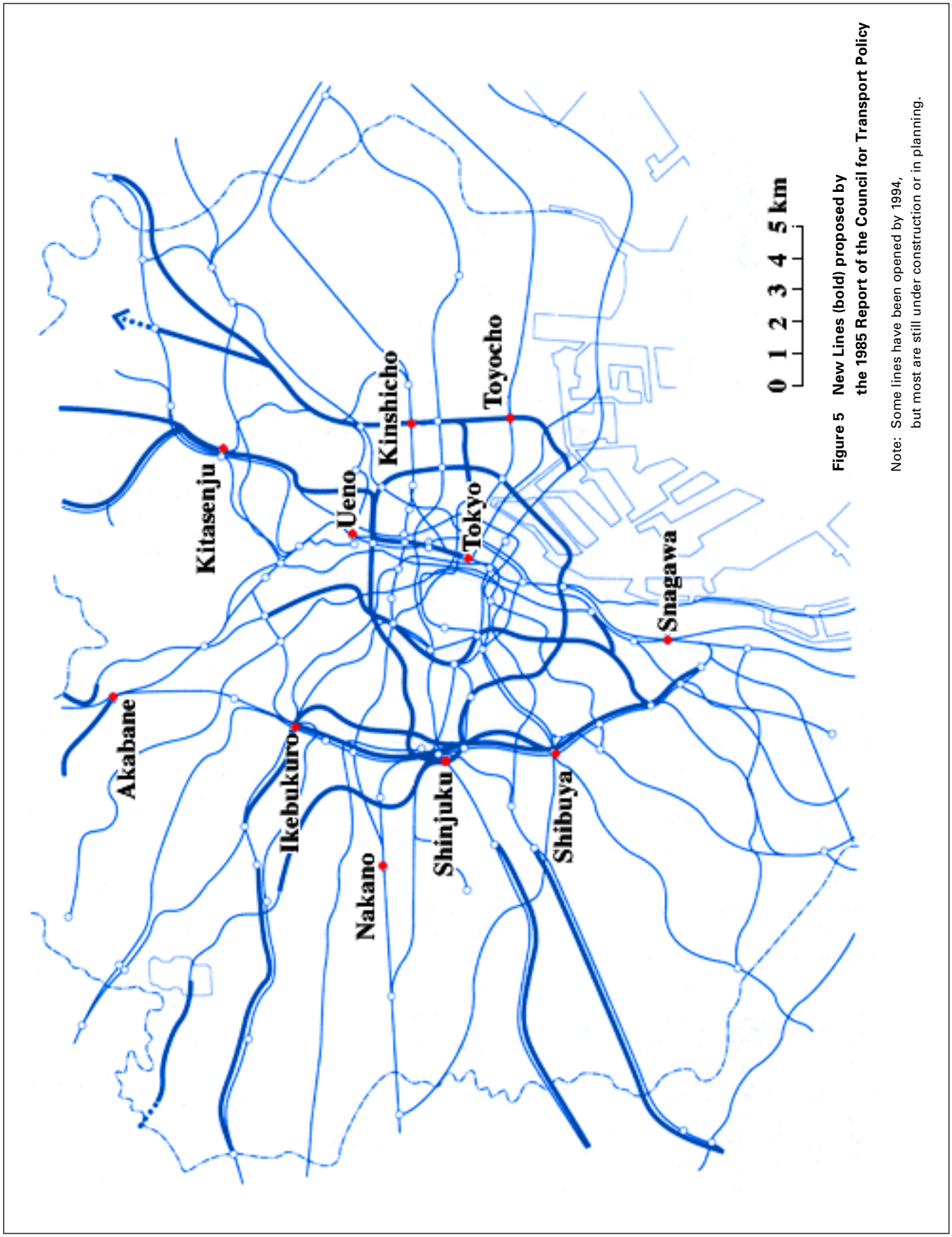



**Figure 5** New Lines (bold) proposed by the 1985 Report of the Council for Transport Policy

Note: Some lines have been opened by 1994, but most are still under construction or in planning.

■ Rush-hour crowding at Tokyo Central
*(T.Yakita)*

social need, or relieving congestion.

**The Benefit Principle**

The first solution to consider is raising the users' burden by increasing fares. During the morning rush hour, most passengers use commuter tickets. The reduction is about 5% for workers and about 80% for students. Although the running cost per capita after depreciation of assets is actually lower in peak times than in off-peak times due to economies of scale, the fact that passengers using railways in off-peak times must buy costly tickets cannot be neglected. It seems necessary to re-examine the fare system for commuter tickets so that benefit and burden can be balanced in appropriating the funds for achieving comfort, after reaching a social consensus about which level of comfort to achieve.

On the other hand, in Japan, most of the expense of commuting is borne by employers. In Tokyo, the money expense of commuting is borne by the employer, while the physical and mental cost is borne by the employee. Under such cost allotment, companies in central Tokyo enjoy the "profit of concentration" (the economy of concentration). Of course, part of the "profit" is returned to commuters through their income as employees. However, because labour share is lower in Japan than in foreign countries, companies may bear the additional investment cost for relieving congestion in the form of the increased burden of the commuting ticket (or commuting allowance) so as to share part of the physical and mental cost.

Second, companies may bear some burden through taxation, a representative system being the traffic tax enforced in France. This system taxes companies (with 10 or more employees) in Paris or in the suburbs of Paris according to the total wages paid, and uses part of the collected funds to reinforce the transport capacity of public traffic facilities, such as railways.

Third, part of the income from gasoline tax, e.g., may be used to reinforce or operate urban railways. This system is used by traffic authorities in various German cities. The merit is lowering the burden of road traffic. However, because the substitutability of railways and road traffic is very low in Tokyo, and because road systems are not yet sufficiently advanced, this system is not practicable for Japan today.

In addition to these solutions, if railways are regarded as fundamental infrastructure for urban areas, the tracks, like roads, could be partly financed by the public sector. From the viewpoint of practicability, this may begin with the public sector bearing part of the fare.

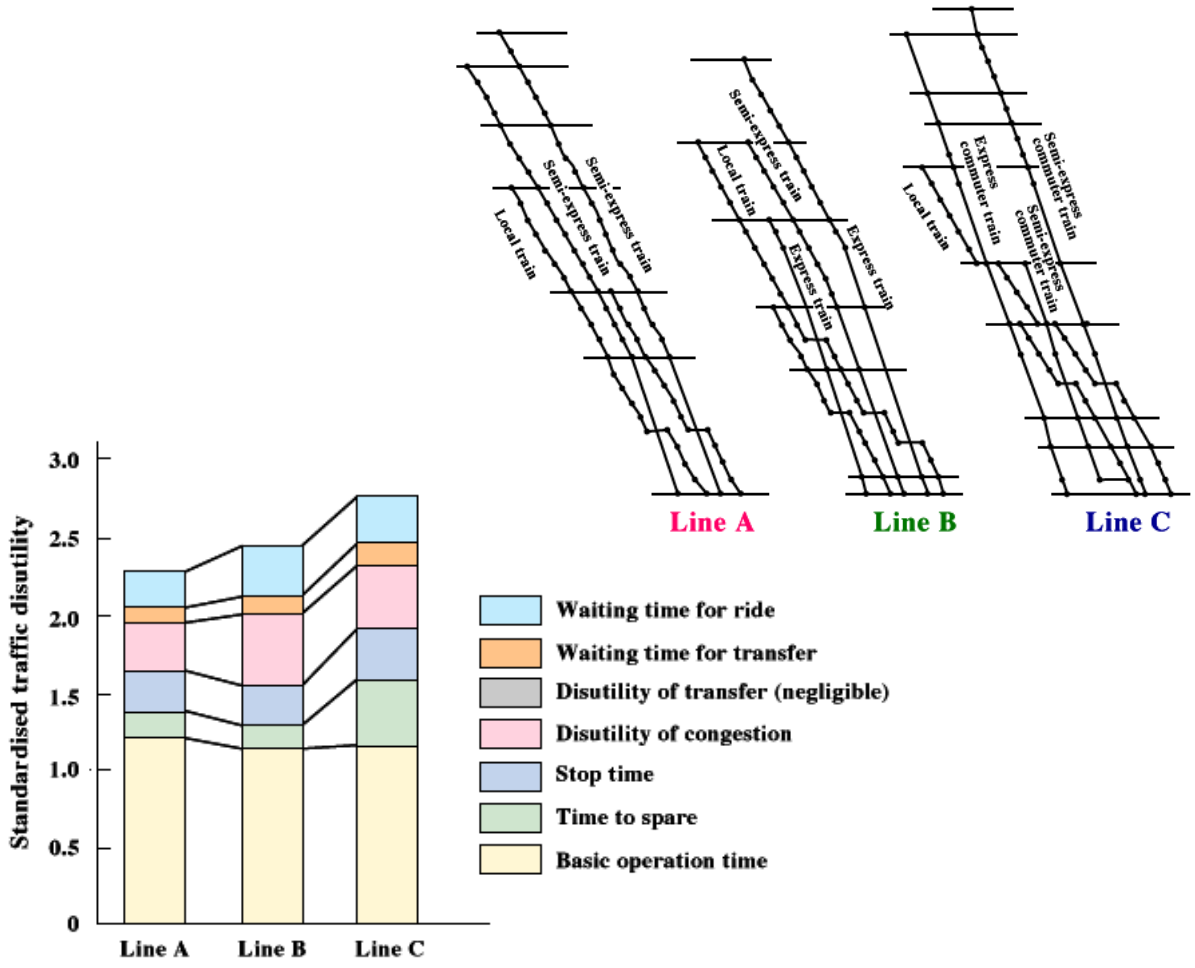
**Returning of Development Profit**

Reinforcement of railways not only results in greater convenience to the users and increases the income of the railway business, it also leads to greater convenience for areas along the lines, especially near stations, increasing the value of land, vitalising commerce, and relieving traffic congestion on roads near the lines. Thus, reinforcement of railways has various economic benefits. Such benefits are particularly great when a new line is constructed. If part of the benefit (development profit) is returned to reinforcement of railways, development of new lines can progress according to the degree of necessity.

However, although the classic integration of land development and railroad reinforcement can be seen in the Tokyu, Hankyu and other lines, railway businesses have made it a rule to progress with construction of railways by their own responsibility, using part of their transportation income. This was a natural course when railways (especially freight railways) dominated the transport market and took pride in their high profitability. However, it is not easy to appropriate the huge funds from transportation income in today's climate of severe competition. To supplement the shortage, various public subsidies are available, such as the subsidy for subway construction, and the subsidy of the Japan Railway Construction Corporation for construction of private railways. A fund reserve system backs up these subsidies, and the establishment of the national *Railways Reinforcement Funds* in 1991 was a great first step but it is still not enough.

There are two methods for returning development profit: the determinative method to measure and collect individual development profit, and the non-determinative method which allows self-governing bodies to participate in the construction of new lines based on the concept of the existence of development profit and the local self-governing bodies' taxation authority (such as real estate tax). For the former method, a system to accurately measure the scope and amount of benefit has not yet been established. Therefore, the latter method is increasingly employed. For example, local governing bodies participate in and offer funds for joint ventures with private businesses established to reinforce railways (New Joban Line, Nanboku (north-south) Line of Teito Rapid Transit Authority (Saitama section), Coastal Rapid Transit Railway, etc.). Alternatively, self-governing bodies establish railways reinforcement funds using part of real estate tax and enterprise tax (Sendai City and Fukuoka City). Development profit can also be returned by transferring the railway land developed in a new town at base price or by offering

**Figure 6 Operation Schedule and Traffic Disutility**




railway land by readjusting land in parallel with railway reinforcement. The possibility of other methods developing and spreading in the future is not low, but this system is now progressing little-by-little.

## 5. Short- and Middle-Term Measures to Relieve Congestion

### Can Peak Demand be Leveled?

Frankly speaking, rush-hour congestion cannot be relieved substantially without taking the above-mentioned long-term measures. However, we should still take short- and middle-term supplementary measures. First, how can we mitigate the concentration in a specific time zone which is one of the core problems of rush-hour congestion?

Each user does not think that his or her action may lead to additional congestion. A market affected by congestion in this sense is subject to "externality", and the free action of users does not lead to optimisation. In such cases, demand control can be justified.

A representative control is peak load pricing, which sets higher fares at peak loads than at off loads to disperse the peak demand thus relieving congestion and reducing transportation cost. Demand control has been introduced on railways of various cities, such as Washington, Frankfurt and Hong Kong. But in Japan, the"value of service principle" is emphasized too strongly compared with the "cost burden principle" and "market demand response", so demand control has not yet been introduced. While peak-load pricing is based on free time choice by users, office hours are still firmly fixed in Japan. Therefore, this method of demand control does not seem very effective. Railway companies are now examining commuting tickets for staggered office hours and reduced fares for flexi-time commuting tickets.

### Improvement of Rolling Stock and Their Operation

The transport capacity of railways depends greatly on track facilities and rolling stock and operation. Increasing car floor space by using double-decker construction, improving signal apparatus and operational security devices, and shortening train opera-

tion intervals by reducing stop times at stations using multiple or large door cars all lead to greater transport capacity. Increasing the number of train operations by devising better operation schedules is also being proposed.

To relieve rush-hour congestion, both reduced congestion ratio and time are important. Details are omitted here, but a computer system for investigating which operation schedule is "good" for users from the viewpoint of total benefit and impartiality, including congestion, rapid arrival, convenient transfer and waiting time, has been developed and used by some private railways (Figure 6).

In addition, introduction of no-seat cars on the Yamanote Line has stimulated studies of how many seats are best from the users' viewpoint. There is room for devising better rolling stock and operation, and active progress is anticipated in these fields.

The extreme over-centralisation in Tokyo has been questioned for many years. It has caused the problem of external diseconomies represented by rush-hour congestion and the problem of local imbalance which prevents balanced development of national land. If the external diseconomies are financed by the bodies enjoying the benefits of centralisation and if the funds raised are used to reinforce traffic facilities, the former problem can be solved.

There is an opinion that the cost of centralisation is already paid for in the form of high land prices in t he heart of Tokyo, but the questions till exists that the funds collected are not returned through reinforcement of traffic facilities to the users who actually (physically) bear the cost of centralisation (congestion loss). It seems necessary to establish a system which evaluates the effect of office development in the heart of Tokyo on traffic infrastructures whenever a development is planned and makes the developer bear part of the expenses for reinforcing traffic facilities (traffic assessment).

The second problem should be discussed at the level of the reinforcement of main means of transportation or local policy. In Greater Tokyo, the development of peripheral core commercial cities such as Omiya, Urawa and Tachikawa is now in progress in an attempt to disperse businesses centralised in central Tokyo over the entire region. Reinforcement of lines to access these cities, their station facilities and loop lines connecting these core commercial cities are important parts of this concept.

With the exception of the Musashino Line which was constructed as part of the large-scale JNR reinforcement plan framed and executed in the 1960s and 1970s from the viewpoint of the macroeconomy or the entire metropolitan region, such as the *5-Aspect Strategy* and *Separation of Passengers and Freight plans*, no line in Greater Tokyo has sufficient functionality as a loop line. It is necessary to reinforce such lines despite low current demand from the viewpoint of developing peripheral core commercial cities. ■

**Further Reading**


Hitoshi Ieda
*Computer-aided Evaluation System of Train Operation Schedule –IEDIS–*
Japanese Railway Engineering, No.117, pp6-9, 1992.3

Hitoshi Ieda
*An Evaluation Model of Commuter Train Operation Schedule and Its Applications*
The 6th World Conference on Transport Research Collection of The Joint Section No.9, 1992.7

Hitoshi Ieda, Hideo Nakamura
*The Revitalization of Railways –Experience of the Japan Railway Corporations–*
International Conference for Public Transport System, 1993.9

Hitoshi Ieda, Kunihiko Nagai
*The Prospects and Problems of Speed up on Intercity Railway Lines in Japan –In Comparison with European High Speed Trains–*
THE INTERNATIONAL CONFERENCE ON SPEEDUP TECHNOLOGY FOR RAILWAY AND MAGLEV VEHICLES, pp13-18, 1993.11

Hitoshi Ieda
*What is expected & required for the privatization of Public Transport Management ?*
2nd Annual Conference of the Transportation management Association of the Philippines, 1994.2



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Dr. Ieda was born in Tokyo in 1955. After graduating in civil engineering from the University of Tokyo, he joined the Japanese National Railways in 1978. Since 1984, he has been an associate professor of civil engineering at the University of Tokyo. His main interest is in traffic planning and transport policy, and he has been involved in various research and policy-making activities in both the public and private sectors.