A SYUDY OF OPTIMUM RAIL TRACK ACCESS ALLOCATION BETWEEN FREIGHT AND PASSENGER TRAIN IN JAPAN

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ABSTRACT

This study reveals that the current rail track access allocation (slot allocation) system in Japan cannot maximize social surplus and causes deadweight loss, especially in congested sections. Deadweight loss is estimated with an actual case in this study. The problem is due to a specific rail way company having priority access to rail tracks and that company acts to maximize profits under the situation. This study concludes that a neutral body is required to adjust slot allocation.

Keywords: Rail track access, Slot allocation, Vertical separation, Deadweight loss

INTRODUCTION

Background of this study

To further progress open access in the EU and to develop railways, the EU established Directive 91/440 in 1991. Through this directive, the EU has separated train operations division from infrastructure (track) operation and introduced the competition principle into railways. Initially, separation (vertical separation system) caused a lot of problems. It took about 20 years since the directive was introduced for the EU to solve these separation problems and progress to open access. As Nash (2009) indicates, separation in particular seems to have had some good effects on rail freight.

On the other hand, most railways in Japan are operated under a non-separation system in which a railway company has both train operation and infrastructure divisions. However, we can see some vertical separation systems in railways in Japan. The goals of the system differ from the EU case and do not introduce the competition principle. Figure 1 shows the type of vertical separation systems in railways in Japan.

As the figure shows, the major aims of the system are to construct new lines or to maintain existing lines. This is one of the characteristics of vertical separation systems in Japan.

The system introduced for rail freight was caused by the "privatization and breaking up of the Japanese National Railways (JNR)"(JNR revolution) in 1987, in particular, breaking it up by regions. Since the JNR revolution, JR Freight (JRF) has operated freight trains (In Japan, most freight trains consist of container trains. Reflecting this fact, a "freight train" means a container train in this study), using rail tracks owned by JR passenger companies (six companies) and paying access charges to the companies.

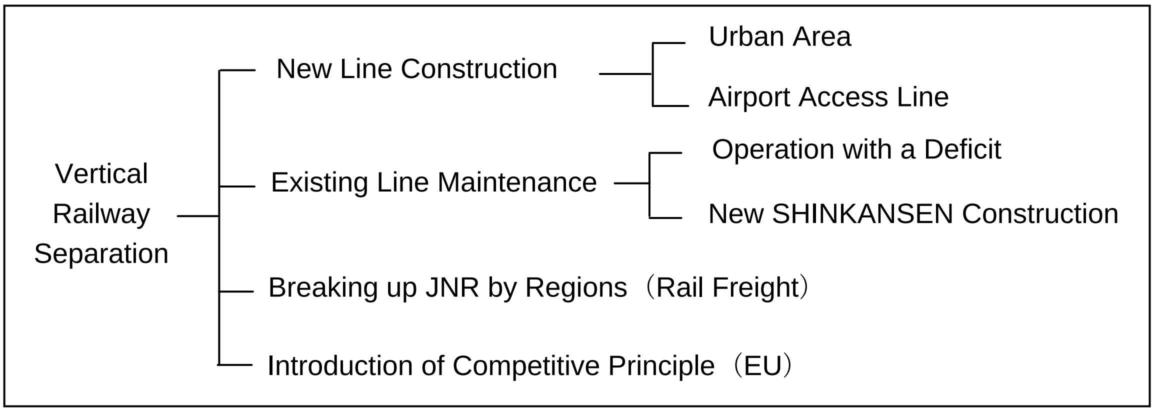

Figure.1 － Type of Vertical Railway Separation in Japan

Aim of this study

We can now see some problems concerning rail freight in Japan. Of these, rail track access allocation (slot allocation) is a serious problem, because it might inhibit the supply of JRF directly. The inability to make free decisions on supply quantity leads to serious profit problems which could endangers JRF's existence.

Intercity transport density in Japan is high compared to other countries, especially in large urban areas (e.g. Tokyo, Osaka and Nagoya) and their surrounding areas. Given this situation, there is a strong possibility of conflicts arising between a rail track provider and a user. Rail track is not owned by a natural infrastructure company such as DB Netz (Germany) and ProRail (Netherlands), but by JR passenger companies which both operate trains and own rail track. Therefore, JR passenger companies actually have a priority right for slot allocation and JRF is at a disadvantage in allocation. Besides, there is no arbitration system to resolve conflicts（There is an arbitration system for rail track slot allocation in the UK）. These facts cannot lead to an adequate slot allocation that maximizes social surplus.

This study investigates slot allocation between passenger train and freight trains with a surplus analysis, and considers the optimum slot allocation that maximizes social surplus and the allocation policy. In particular, the study emphasizes the situation described below. That is, when different independent railway companies use the same rail track and a railway company has a priority right, social surplus will not be maximized in a congested area.

OUTLINE OF SLOT ALLOCATION PROBLEM

Relationship between rail track's lender and borrower

Under "Railway Business Act (1986) ", railway companies are now divided into the three groups below.

G1. First Class railway company
G2. Second Class railway company
G3. Third Class railway company

The first class railway company owns rail track and operates trains(e.g. JR Passenger companies and major urban private railway companies (Odakyu railway)). A Second Class railway company is a railway company that has no rail track and operates trains (e.g. JRF). In such a case, the railway company accesses rail track owned by other railway companies and pays an access charge. A third Class railway company (e.g. Kansai Rapid Railway Co.,Ltd) is a company that owns rail track and provides track access to a first class or second class railway company. A third class railway company does not operate trains.

Regarding slot allocation, a second class railway company has the two relationships with railway companies described below. At all events, a second class railway company has to be a receiver of access.

（Borrower）　　　　　　　　（Lender）
A: Second Class railway company － First Class railway company
B: Second Class railway company － Third Class railway company

In case A, different and independent railway companies use the same rail track. We can see a competitive relationship (especially, in congested areas) between railway companies using rail track. Therefore, conflicts between second class and first class railway companies occur. Under the conflict, the first class railway company has an advantage in slot allocation, because it owns the rail track and has the final say. In contrast, the second class railway company has a disadvantage and can have slots they want taken away. That is one of focus of this study.

In case B, we can see a complementary relationship. The case mainly applies to new line construction in urban areas. Pure private railway companies engage in railway businesses in urban areas in Japan. Traditionally, these companies constructed rail track and operated trains using their own resources. However, it is not easy now for these companies to develop new lines using their own resources, because traffic volume has decreased (profits decreased) and construction costs have increased in recent years. Given this situation, vertical separation was introduced as a tool to reduce the cost burden on private railway companies and to develop and construct new lines. Under the style of separation, the public sector constructs rail track (third class railway company) and private railway companies cover only the running costs of train operations (second railway company). Thus, there is relative relationship between a second class railway company and a third class railway company in case B. The two companies also own assets together with high asset specificity, thereby, they have a highly complementary relationship.

Slot allocation problem

The relationship between JRF and JR passenger companies form part of case A. That is, there is strong possibility of conflict over slot allocation arising. We cannot see official and concrete conflicts between companies now. But there is a good likelihood that the conflict will occur. In fact, the occurrence of slot allocation conflict was viewed with suspicion in the "Discussion Session on Basic Problems for JRF's Complete Privatization" (1997) and "Financial Results (2002) of Board of Audit of Japan". Also, the access charge for freight trains was viewed with suspicion in "Price Stabilization Policy Convention" (2001). Besides, the "Price Stabilization Policy Convention" (2002) pointed out the conceptual problem of different access charges for JRF and JR passenger companies.

Meanwhile, we can see now that JRF cannot increase the number of freight trains. Figure 2 shows the number of container trains and container wagons per day moving between Kanto (areas around Tokyo) and Kyushu. Figure 3 shows transport volume (ton) at each point. As shown in figure 3, most freights train in Japan run on the Tokaido line and Sanyo line (Tokyo-Nagoya-Osaka-Kyushu). The section picked up in Figure 2 is the main route for rail freight transport. In most of the section, projected freight train capacity growth has been reached and trains with 26 freight wagons can be operated.

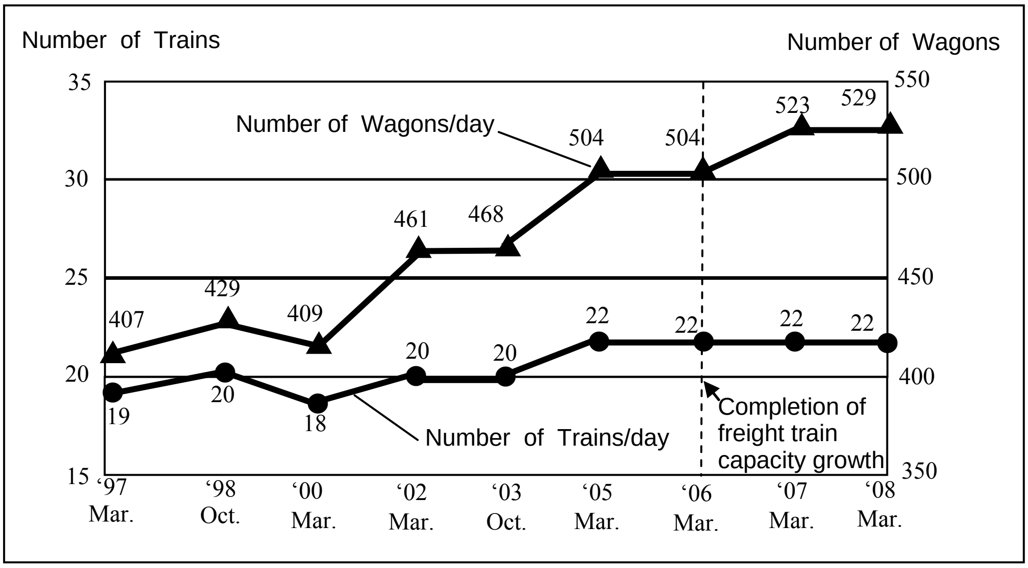

Figure.2 — Process of container trains and container wagons moving between Kanto and Kyushu

* number of trains and wagons is the figure at Kanmon Tunnel

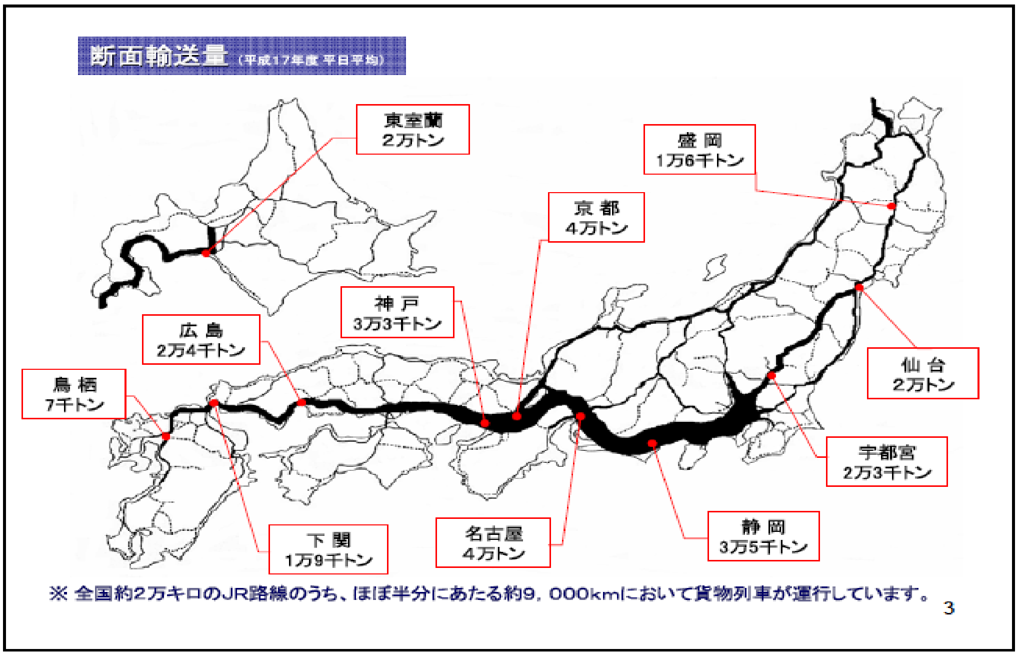

Figure.3 ― JR Freight’s transport volume at each points
Source: Naohiko Ito “Current sitiation and issues of rail freight” (JR Freight’s material)

However, the main goal of the project was to increase the number of wagons per train. The number of trains could not increase under the project. However it is impossible to further increase the number of wagons per train because of the road-bed intensity（maximum weight per freight train is 1300 t）. Therefore, if JRF wants to increase supply capacity in the section, it has to increase the number of trains. Generally, demand in the section is potentially high, because the section is long (ca. 1000 km) and a lot of people live along it. Considering that environment and labor-related problems will become more acute in the future and demand for rail freight will grow further, how the number of trains is increased will become import. If we change the number of trains, we will face slot allocation problem.

ANALYSIS OF OPTIMUM SLOT ALLOCATION

Outline of the analysis

In this section, optimum slot allocation that maximize social surplus is analyzed under certain conditions. In the analysis, the conditions below are set.

C1. Passenger company operates only passenger trains and freight company operates only freight trains.
C2. Passenger trains and freight trains use the same rail track.
C3. Rail track is owned by passenger company and the company has priority right to access rail track

Under the conditions above, this study describes demand curves of passenger trains and freight trains on the same figure (Figure 4,5, and 6). In these figures, the vertical axis represents fare and cost of passenger trains and freight trains. The horizontal axis represents slot capacity. Optimum slot allocation is analyzed with the surpluses of passenger company and freight company. Optimum slot allocation that maximizes the total surplus (passenger company's surplus and freight company's surplus). Also, the hypothesis below is formulated in the analysis.

H1. Marginal costs (MC) of passenger train and freight train are the same (>0) and fixed regardless of the number of trains.
H2. Fares of passenger trains and freight trains equal to MC (assuming regulated fares)
H3. Fix costs stay flat (Short-term model)

The analysis is carried out under two situations; non congested case (slot capacity>demand of passenger trains and freight trains) and congested case (slot capacity<demand of passenger trains and freight trains).

Non congested case

Figure 4 shows the surplus situation in the non congested case. In the case, passenger trains are supplied at 0Q1 and freight trains are supplied at 0'Q2. And we can see here that the consumer surplus of passenger trains is ΔABE and that of freight trains is ΔCDF. In the short-term model, social surplus (ΔABE+ΔCDF) is maximized and there is an optimum distribution of resources arises. If different independent railway companies access the same rail track, even in non congested case, the needs of these companies may be crossover. But, in fact, it is easy to adjust these needs. Accordingly, the emergence of conflict can be ignored in this case.

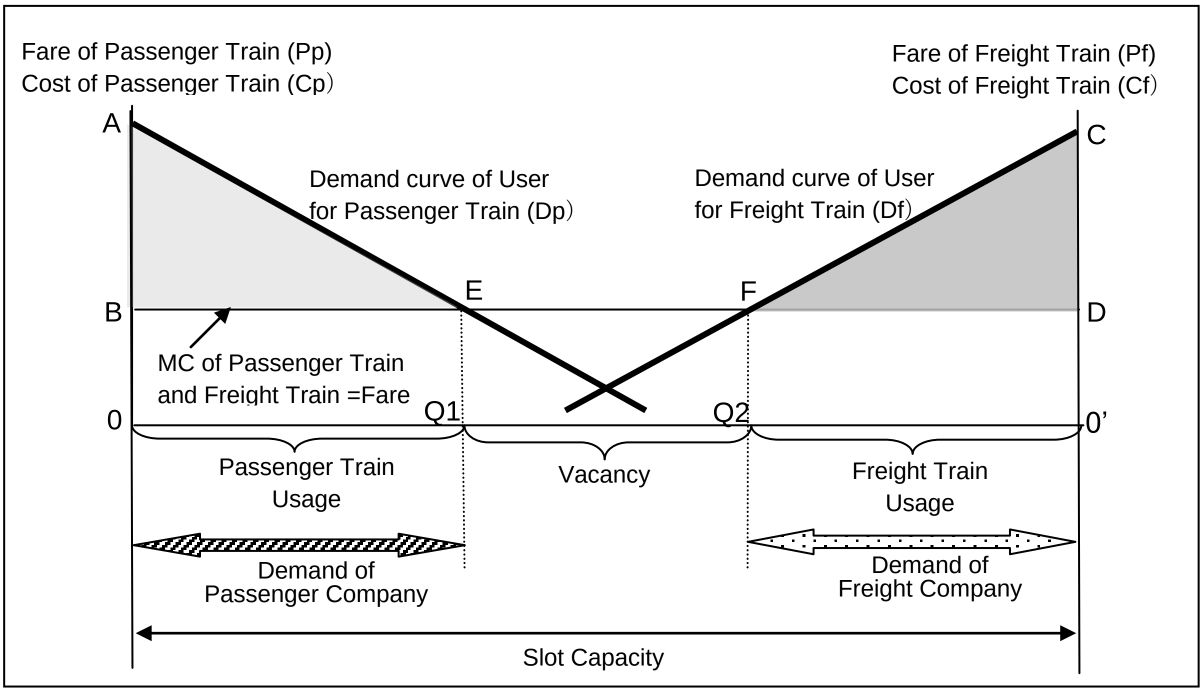

Figure.4 — Social surplus in non congested case

Congested case

Figure 5 shows that demand by passenger trains and freight trains exceeds slot capacity and the passenger company has priority right to access rail track; that is, the freight company can use only the rail track remaining after the passenger company has had access. Passenger trains are supplied at 0Q2 and surplus ΔAFB arises. On the other hand, the freight company wants to supply freight trains at 0'Q1 and surplus □CHFD arises. However the freight company has to accept the level at 0'Q2 because the passenger company has the priority right. In this case, the fare of the passenger company is set at the level 0B. Because freight trains are under-supplied, the fare of freight trains rise to the level 0'I.

As just described, if the passenger company exercises it priority right, freight trains which are in higher demand than passenger trains are not provided. As a result, the social surplus does not reach the maximum level and deadweight loss arises (ΔHGF). Thus, if different independent railway companies access the same rail track and only a specific company has priority right to use it, there is strong possibility that social surplus will not be maximized in the congested case. That is, the existing slot allocation system in Japan involves a strong possibility that the optimum slot allocation is not achieved.

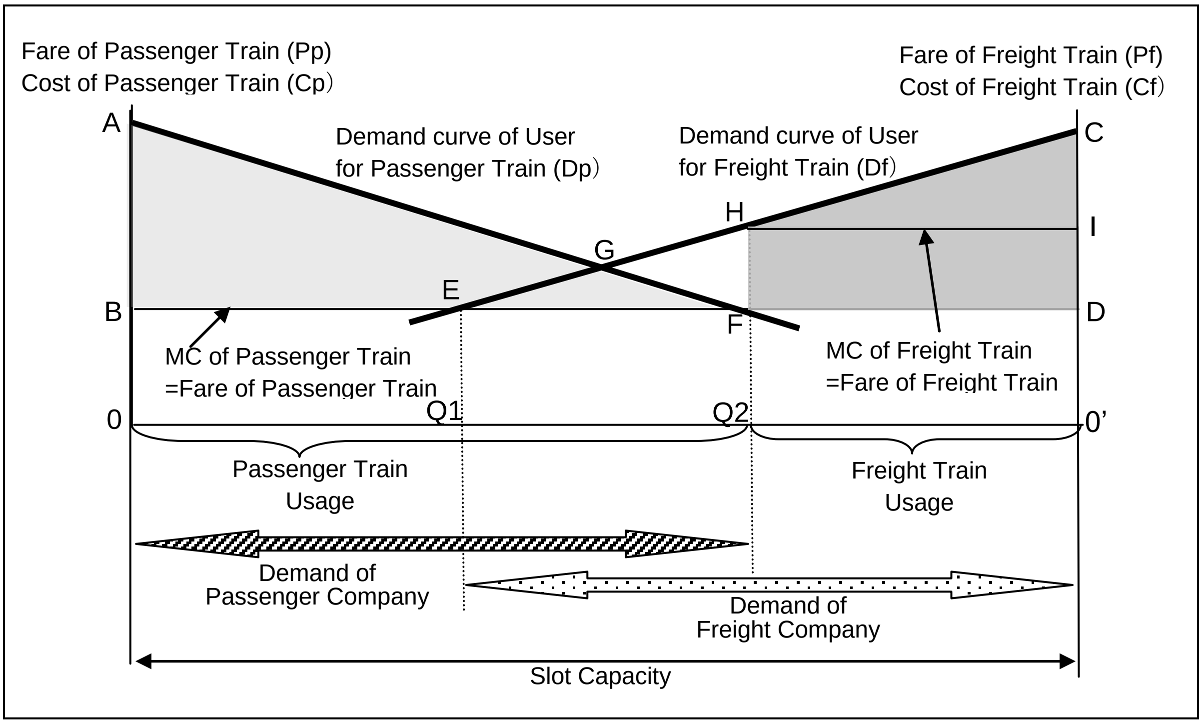

Figure 5 – Social surplus in congested case

Measures to maximize social surplus in congested case

To maximize the social surplus in the congested case, it is best to allocate slots for passenger trains and freight trains at Q*. To achieve the slot allocation at Q*, a neutral body (e.g. government) has to intervene in slot allocation and monitor it to maximize social surplus. Figure 5 shows the result when a neutral body intervenes in slot allocation and allocates optimum slots, and social surplus is maximized.

Meanwhile, if slots are separated at Q*, total demand (passenger company's demand + freight company's demand) exceeds slot capacity and fares of passenger trains and freight trains can be kept equal to MC. In this situation, the fare of passenger and freight trains moves to JK from BD (Passenger Train) and from HI (Freight Train). Raising fares can be regarded as a congestion charge. Using income from the charge, we can consider that the charge applies resources to expand slot capacity in the section.

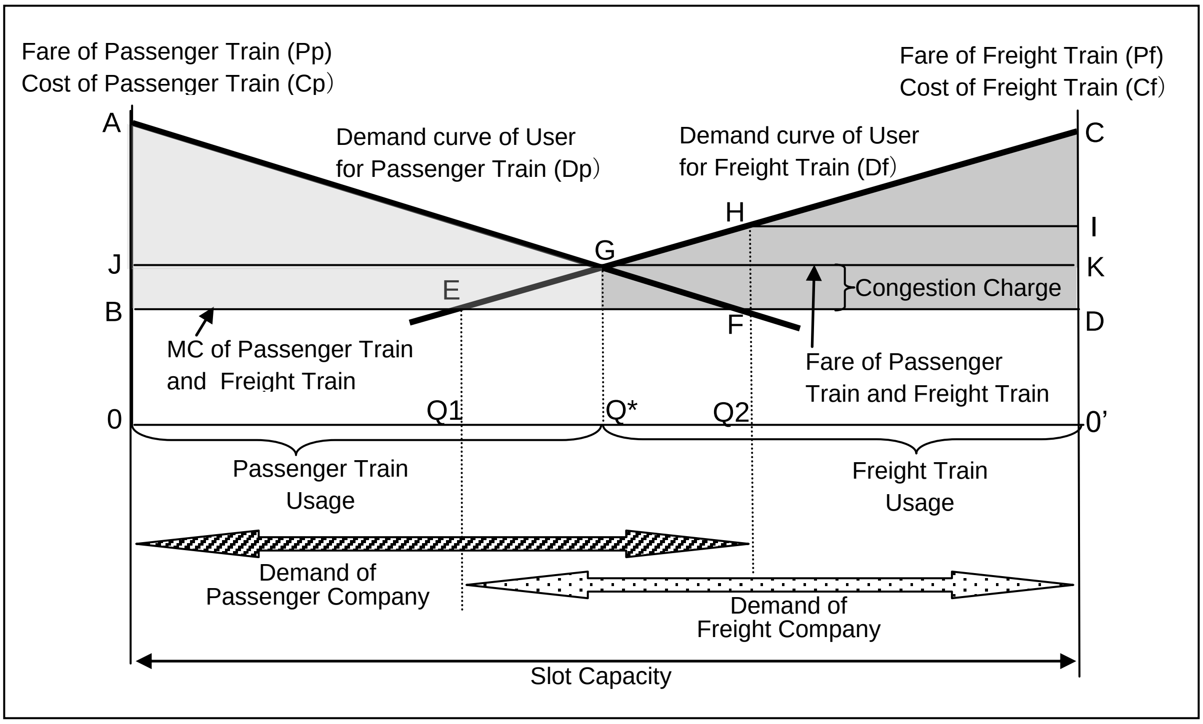

Figure.6 – Optimum slot allocation in congested case

LOSS ESTIMATION OF SOCIAL SUPLUS IN THE CONGESTED CASE

Specification of congested case

Based on the theory described above, this chapter estimates the loss of social surplus in the congested case with an actual section of track. Before beginning the estimation, we need to find the congested section. From interviews with JRF, it was clear that the area around Nagoya has been recognized as congested section for passenger trains and freight trains for a long time.

In the section, as Figure 7 shows, passenger and freight trains access the same rail track and the structure of rail track around the city is double track (Around Tokyo and Osaka, freight trains run on an exclusive track or on quadruple track). Also, a lot of trains are operated because many people live round the area. Therefore, this area has a strong possibility of being a bottleneck. Reflecting the facts, the section between Gifu and Owariichinomiya is picked up as an actual congested section in this study.

Total number of trains (per hour) and slot allocation between passenger trains and freight trains in the section were researched. Table 1 shows actual slot allocation between Gifu and Owariichinomiya. As a result, the maximum number of trains per hour (one direction) is 14, which is the maximum number (slot capacity) in the section. We can see congested case on the three time period; 7:00-7:59, 8:00-8:59, and 14:00-14:59. Regarding estimating surplus and deadweight loss, the situation (time period) 7:00-7:59 is focused on.

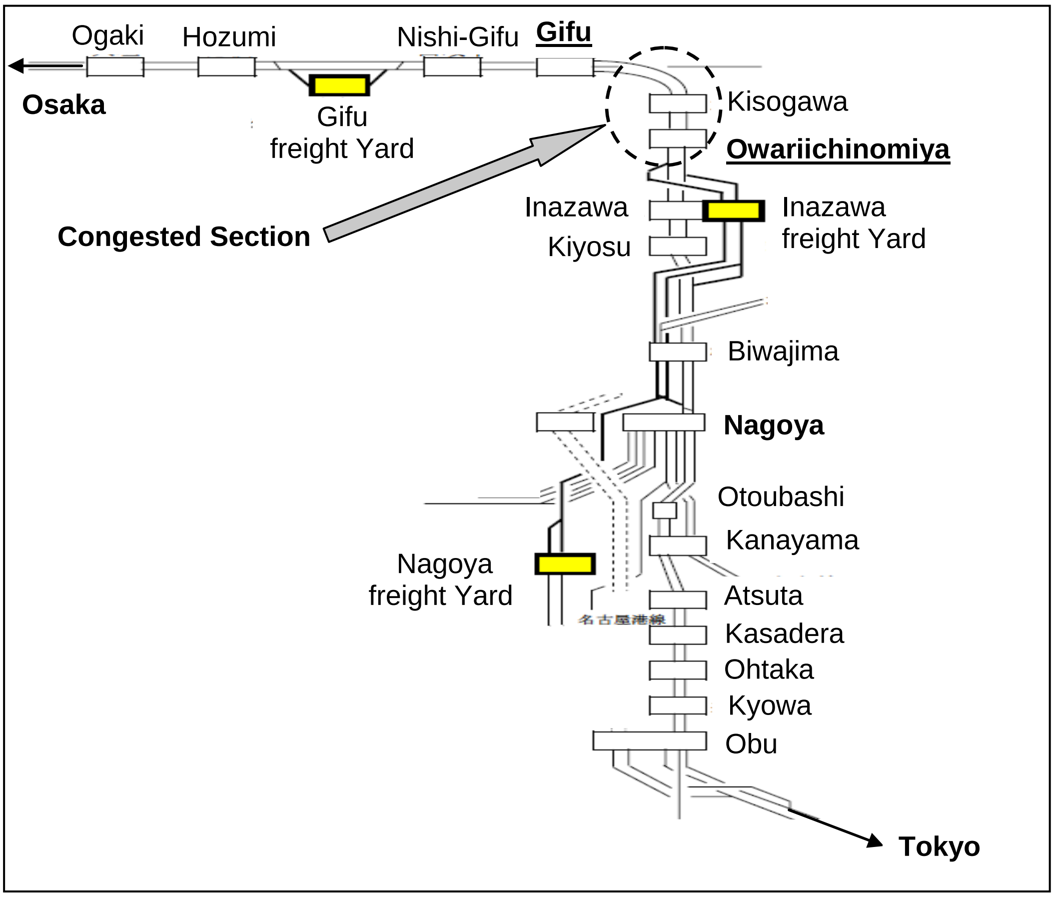

Figure.7 ─ Rail track structure around Nagoya area

Table I – Slot allocation situation between Gifu and Owariichinomiya

	0:00–0:59	1:00–1:59	2:00–2:59	3:00–3:59
Total Number of Train	7	7	6	0
– Number of Freight Trains	5	6	3	0
– Number of Passenger Trains	2	1	3	0
Average Time Interval between each Train (minute)	8.6	8.6	10.0	60

	4:00–4:59	5:00–5:59	6:00–6:59	7:00–7:59
Total Number of Train	2	6	11	14
– Number of Freight Trains	2	3	6	2
– Number of Passenger Trains	0	3	5	12
Average Time Interval between each Train (minute)	30.0	10.0	5.5	4.3

	8:00–8:59	9:00–9:59	10:00–10:59	11:00–11:59
Total Number of Train	14	13	11	13
– Number of Freight Trains	0	3	2	2
– Number of Passenger Trains	14	10	9	11
Average Time Interval between each Train (minute)	4.3	4.6	5.5	4.6

	12:00–12:59	13:00–13:59	14:00–14:59	15:00–15:59
Total Number of Train	10	11	14	13
– Number of Freight Trains	2	2	5	2
– Number of Passenger Trains	8	9	9	11
Average Time Interval between each Train (minute)	6.0	5.5	4.3	4.6

	16:00–16:59	17:00–17:59	18:00–18:59	19:00–19:59
Total Number of Train	13	12	11	12
– Number of Freight Trains	4	2	1	2
– Number of Passenger Trains	9	10	10	10
Average Time Interval between each Train (minute)	4.6	5.0	5.5	5.0

	20:00–20:59	21:00–21:59	22:00–22:59	23:00–23:59
Total Number of Train	10	12	10	9
– Number of Freight Trains	1	2	3	4
– Number of Passenger Trains	9	10	7	5
Average Time Interval between each Train (minute)	6.0	5.0	6.0	6.7

Outline of Estimation Method

There are a lot of methods for estimating surplus. One method is to estimate the MC curve and demand curve, and then to take the area framed by the curves. On the other hand, like Romilly (2001) and Mizutani (2003), we can see the way that actual transport volume and actual fare levels are considered as equilibrium points and regress the equilibrium points for each year. Using this method, the demand curve is derived from the result of the regression analysis and a surplus arises with the demand curve.

The number of trains becomes the unit of rail tracks in this study. Therefore, the MC curve of freight trains is estimated and the demand curve is derived with actual transport volume, actual fare level, and elasticity of demand to fare. With two curves, the areas of surpluses are found and deadweight loss.

Estimation of MC

It is difficult to estimate each freight train on a specific section and at a specific time. Therefore, in the study, the average MC of freight trains is estimated. The MC is regarded to be the MC in the section and the time zone. Based on theoretical framework above, the MCs of passenger trains and freight trains are dealt with at the same level. The estimation of MC proceeds along the steps below.

At first, Total cost (TC) function is formulated below.

$$TC = e^{\alpha} \cdot Q^{\beta 1} \cdot L^{\beta 2} \cdot K^{\beta 3} \cdot E^{\beta 4}$$

Q: Transport Volume（ton-km）　L: Labour cost　K:Capital cost
E:Energy cost　α, β1, β2, β3, β4:Parameter

$$\ln TC = \alpha + \beta_l \ln Q + \beta_2 \ln L + \beta_3 \ln K + \beta_4 \ln E$$

Ton-km of JR Freight is used as Transport volume. Also labour cost, capital cost, and energy cost are defined below.

Labour cost: Payroll number × Man-hour (railway industry) ×Domestic average wage
Capital cost: (Fixed asset ×Yield rate of government bonds (10 years) +Rental payment + Depreciation cost) / Corporate goods price index
Energy cost: Consumption volume of electricity×unit price of electricity + Consumption volume of fuel ×unit price of fuel

Costs are deflated at the 2000 level and each date is prepared for 15 years (1987-2006) Based on the formula above, each parameter is estimated by the ordinary least square method (OLS). Values in brackets are t-value.

$$\ln TC = 0.28 + 0.01 \ln Q + 0.16 \ln L + 0.50 \ln K + 0.29 \ln E \quad \cdots\cdots\cdots\cdots (1)$$

(0.59)　(0.52)　(35.0)　(14.9)　(24.4)

R^2=0.99

As MC rises from differentiating TC with respect to Q,

$$MC = \partial TC / \partial Q$$
$$= e^{\alpha} \cdot \beta_l \cdot Q^{(\beta 1-1)} \cdot L^{\beta 2} \cdot K^{\beta 3} \cdot E^{\beta 4}$$
$$\ln MC = \alpha + \ln \beta_1 + (\beta_1 - 1) \ln Q + \beta_2 \ln L + \beta_3 \ln K + \beta_4 \ln E \quad \cdots\cdots\cdots\cdots (2)$$

By substituting the values of each parameter which are estimated in formula (1) and each factor price into formula (2), we find that MC equals to 0.02 yen. Concerning factor prices in this study, based on statistical data, factor price of labour cost (labour cost/ton-km) is set at 1.06 yen: factor price of capital cost (capital cost/ton-km) at 2.42 yen: factor price of energy cost (energy cost/ ton-km) is set at 0.64 yen.

Estimation of Slope of Demand Curve

The formula below is defined as the demand function of a freight train.

Q=f(PF, AD, GDP)

PF: Fare of freight train (Service Price index for companies)

AD: Average transportation distance

GDP: Growth rate of real GDP

$$Q=e^{\gamma} \cdot PF^{\mu 1} \cdot AD^{\mu 2} \cdot GDP^{\mu 3}$$

Based on the formula, the regression formula is set up and each parameter below becomes apparent with OLS. Values in brackets are t-value.

$$lnQ=\gamma + \mu_1 lnPF + \mu_2 lnAD + \mu_3 lnGDP$$

$$=18.43 - 1.72 lnPF - 0.57 lnAD + 0.23 lnGDP$$

(1.44) (-0.86) (-2.1) (0.39)

R^2=0.75

From the results of the estimation, the slope of the demand curve (price elasticity of demand) is “-1.72.” As result the slope of the demand curve for passenger trains, we cannot see changes of passenger train fares in recent years. So, it is difficult to estimate the demand for passenger trains. Therefore, in the study, the slope of the demand curve for passenger trains was derived from an existing study and Kaneko (2002) was selected as that existing study. According to the study, the slope of the demand curve for passenger trains in urban area is in the range between -0.15 and -0.25 (according to Oum et al (1992) and the slope of the demand curve for passenger trains is in the range between -0.1 and -0.6. Also, in Yamada al. (1996), the range is estimated at between -0.15 and -0.25(commuter pass user) or -0.3 and-0.9 (non commuter pass user)). Based on Kaneko (2002), this study uses “-0.2” as the halfway point between -0.15 and -0.25.

Fare per train

Concerning fare per one train, in the study, the amount of income per one train is regarded as the fare per one train. Generally, income of on-rail (train fare) and of rail (truck fare: origin-terminal and terminal-ending) comprises the income of a freight train. The income of one of freight train is calculated below. From the interview, it appears that the average truck transport fare (one shipping) is about 10,000 yen. As a result, we can see 1.063 million yen as the income of one freight train.

(Operating income/number of freight trains)+(number of containers shipped)

=(151,663 million yen/227,030 trains)+(4483,347 containers×(10,000 yen×2))

=1.063 million yen/train

JR central company (JRC) owns the rail track in the section between Gifu and Owariichinomiya. The fare per one passenger train is derived from the formula below.

Operating income (JRC: except Shinkansen)/number of passenger trains
=0.14 million yen/train

Estimation of deadweight loss in congested case

Before beginning the estimation, we need to plot actual point regarding fare per one train and slot allocation (12 passenger trains and 2 freight trains) of passenger train and freight train (Figure 8). Concerning MC, MC is to be 0.02 yen in the calculation above. Then MC is set to zero in the estimation.

Based on two points, demand curves of passenger train and freight train are estimated with the process below.

Elasticity of demand to fare (η)

$$\eta = \frac{p}{x}\frac{dx}{dp}$$

$$\downarrow$$

$$\frac{dp}{p} = \frac{1}{\eta}\frac{dx}{x}$$

$$\int \frac{dp}{p} = \frac{1}{\eta}\int \frac{dx}{x}$$

$$\int \frac{dp}{p} = \int \frac{1}{\eta}\frac{dx}{x}$$

$$\ln p = \frac{1}{\eta}(\ln x + C)$$

$$\ln p = \frac{1}{\eta}\ln x + \frac{1}{\eta}C$$

$$\ln p = \ln x^{\frac{1}{\eta}} + C'$$

Then exponent function is derived below

$$e^{\ln p} = e^{\ln x^{\frac{1}{\eta}} + C'}$$

$$p = e^{\ln x^{\frac{1}{\eta}}} \times e^{C'}$$

$$p = x^{\frac{1}{\eta}} \times C''$$

Here we can take inverse demand curve and demand function

$p = Cx^{\frac{1}{\eta}}$ ・・・inverse demand function $\quad\quad$ $x = cp^{\eta}$ ・・・・ demand function

$$\frac{p}{x^{\frac{1}{\eta}}} = C$$

p : Fare per one train (0.14 million yen-passenger train, 1.06 million yen-freight train)
x :Slot allocation (12 passenger trains, 2 freight trains)
η : Elasticity of demand to fare ("-0.2" - passenger train, "-1.72" -freight train)

Elasticity of demand to fare (η) of passenger train and freight train is set stay.

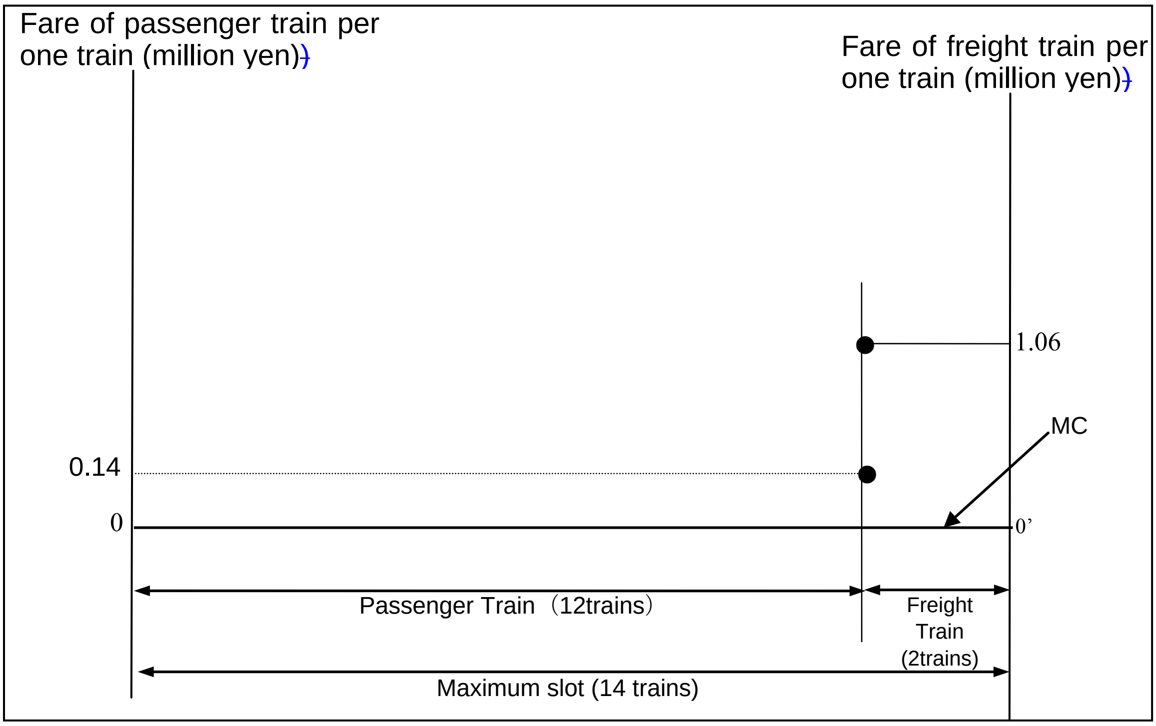

Figure.8 — Estimating deadweight loss (1)

With the formula above,

Passenger train

$$\frac{0.14}{12^{\frac{1}{-0.2}}} = C$$

$$C = 34836.48$$

Freight train

$$\frac{1.06}{2^{\frac{1}{-1.72}}} = C$$

$$C = 1.59$$

Based on the value C, change of value x and value p is calculated with numerical analysis. As a result of the analysis, optimum point become to the slot allocation of 8.9 passenger trains and 5.1 freight trains.

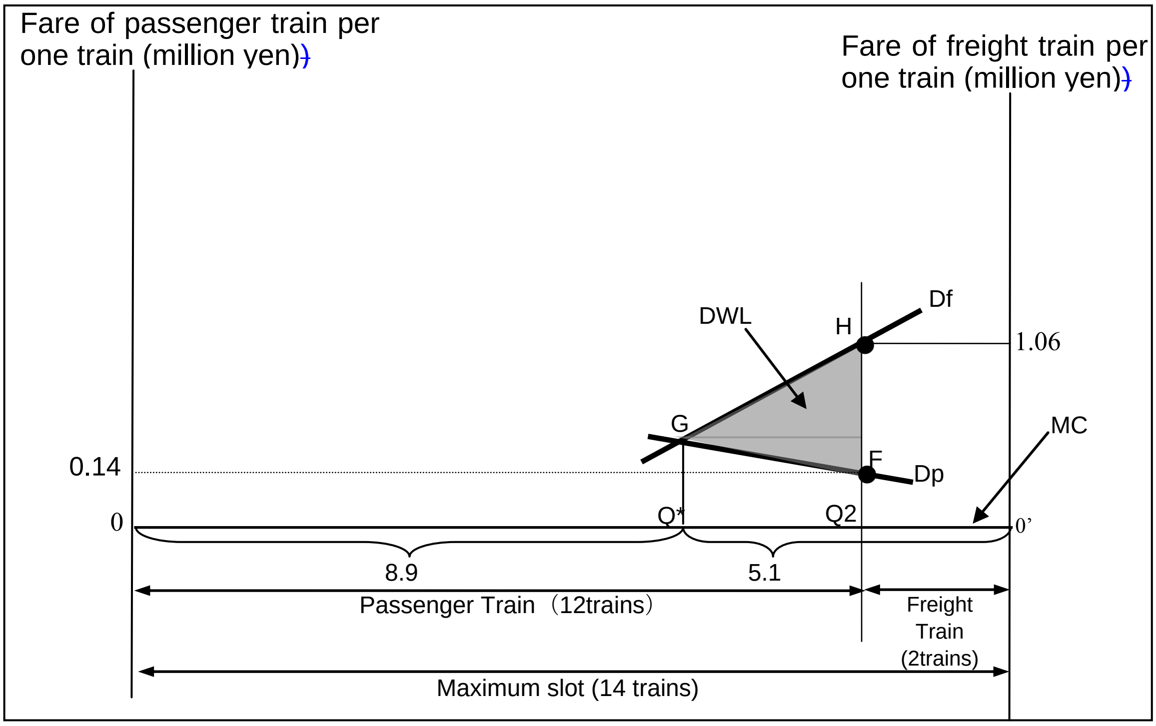

Figure.9 – Estimating deadweight loss (2)

Considering the result, deadweight loss (DWL) is estimated below.

$$B^R = \int_0^{x^R} D^p(x)dx + \int_0^{x^m - x^R} D^f(x)dx$$

$$B^* = \int_0^{x^*} D^p(x)dx + \int_0^{x^m - x^*} D^f(x)dx$$

$$B^* - B^R = DWL = \int_{x^m - x^R}^{x^m - x^*} D^f(x)dx - \int_{x^*}^{x^R} D^P(x)dx$$

Or

$$DWL = \int_{x^*}^{x^R} D^f(x) - D^P(x)dx$$

B^R: Surplus without slot adjustment
B^*: Surplus with slot adjustment
$D^p(x)$: Inverse demand function of passenger train
$D^f(x)$: Inverse demand function of freight train
x^R: Actual number of passenger train (=10)
x^m: Maximum slot number (=14)
x^*: Optimum number of passenger train (=8.9)

As a result of calculation above, deadweight loss is 1.46 million yen.

Conclusion

In generally, privatization and separation of the JNR is recognized to be an example of successful railway revival. In particular, passenger services have been improved and many Japanese judge the results to be a success.

Meanwhile, the JNR revolution provided a vertical separation system for JRF which operates freight trains without having rail track. Under the system, JR passenger companies do not consider the demand for JRF and the companies act in their own interests to maximize profits (This is rational behaviour for the passenger companies). As a result, there is a strong possibility that optimum slot allocation will not be achieved in the system, particularly in congested sections. That is one of the serious problems regarding rail freight in Japan. This can be recognized as a social problem, because it remains possible that social surplus is not maximizes under the system.

The cause of the problem is that slot allocation is decided only between JR passenger companies and JRF. Establishing an optimum slot allocation would require a neutral body to intervene in the allocation. Concerning slot allocation at airports in Japan, a neutral body intervenes in the allocation with various factors being considered. We can think of slot allocation decided only between two companies to be a characteristic of railways.

If environmental problem and labour problems increase more in the future and demand for rail freight increases, the allocation problem would obviously become serious. It has been about 20 years since the JNR revolution, however, the slot allocation problem still remains. While service-improving levels of passenger trains represent the “light” created by the JNR revolution, slot allocation of freight trains is one of “shadow” created by the revolution.

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