MODELING OF INVESTMENT BEHAVIOR OF URBAN RAILWAY OPERATORS UNDER SOCIAL PRESSURE MINIMIZATION SCHEME

Toshiyuki OKAMURA
Research Associate
Graduate School for International Development and Cooperation,
Hiroshima University
1-5-1, Kagamiyama, Higashi-Hiroshima,
Hiroshima, 739-8529, Japan
Fax: +81-824-24-6922
E-mail: tokamura@ipc.hiroshima-u.ac.jp

Hitoshi IEDA
Professor
Transport Research and Infrastructure Planning Lab (TRIP), Dept. of Civil Eng., Univ. of Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo,
113-8656, Japan
Fax: +81-3-5841-8506
E-mail: ieda@trip.t.u-tokyo.ac.jp

Abstract: Private railway operators in Japanese metropolises have invested in their railway facilities in order to improve and develop their existing railway network, however, these projects are not so attractive for operators because of the fare regulations and low elasticity of the demand which results from their regional monopolistic supply. To explain the behavior of these railway operators, this study proposes operators' investment behavioral model (Social Pressure Minimization Investment Model {SPMin Model}) and verify the using investment data during past thirty years.

1. INTRODUCTION

Railways have a large share of total passenger transport in Japanese large cities. In these cities, private sector has a big role in passenger railway services. The private companies manage most of the network both in length base and passenger volume base with little amount of subsidy including capital costs. Their commercial based management and their efficiency bring huge benefit to whole population and economic activities in the area.

The most significant issue in the railway systems is over-congestion problem in commuting hours. Although railway operators have invested in their facilities, load factor in peak time is still high (approximately 8 passengers stand in $1m^2$ on vehicle in the most congested section). Projects in their railway facilities to improve their level of service is planned and launched by each private operator. This means that, in order to solve this problem, it is needed that railway operators including private ones continue to improve their level of service, particularly to relief congestion in peak time, by their own decision under commercial based operation scheme.

In spite of the importance for investment, railway operators in the metropolitan area do not have large motivation to invest in their existing lines for improvement because of the following reasons.

1) <u>Low elasticity of demand</u>: The improvement of LOS (Level Of Service) does not directly mean the increase in passengers and profit at least in short term. The railways have already occupied a monopolistic share of commuter trips of their own franchising operation areas for a long time. This means that the demand is somewhat non-elastic in terms of the improvement of the existing network.
2) <u>Fare regulations</u>: Raising fare for improvement projects is not actually realized for operators. The fare is regulated so that it can compensate for their supply cost and pre-determined reasonable profit ("fair return"). Operators are not able to put the monopolistic fare and, as a rule, they can not reserve their profit for investment in advance. Loan is the only available fund for their projects in principle.
3) <u>Project risk</u>: Even if their projects are profitable ones, operators hesitate to launch large projects because of the difficulty of raising fare and the risks for delay for completing projects.

In Japanese metropolitan area, considering that the demand will not increase so much, or will make negative growth, railway operators will have less motivation for investment in future. What will be able to push operators to invest in their projects for improving there level-of-service? To deal with this problem, it is needed to study investment behavior of private railway operators. In this reason, the authors propose the basic concept of investment behavior model under break-even fare regulations and low demand elasticity market, and suggest how we should develop the quality and the quantity of the urban railway systems in future.

This study models investment behavior of urban private railway operators by introducing the original concept under fare regulations and low demand elasticity market. Research items of this paper are follows.

1) To propose and to formulate the "Social Pressure Minimization Investment Model" (SPMin model) explaining operators' investment behavior under break-even fare regulations and low demand elasticity market.
2) To make operators' cost sub-models for the items to explain the actual behavior.
3) To verify the SPMin model by confirming consistency between following two results; operators' behaviors reproduced in SPMin model by theoretical approach, and observed behaviors of actual operators.

2. DEVELOPMENT OF 'SOCIAL PRESSURE MINIMIZATION INVESTMENT MODEL (SPMin Model) '

2.1. Basic Scheme of SPMin Model

Considering the market condition shown in chapter 1, the authors propose a concept of investment behavior of urban railway operators as follows. The authors name the following concept as 'Social Pressure Minimization Investment Model (SPMin model)'.

Basic concept of operators' investment behavioral model;

Social Pressure Minimization Investment Model (SPMin model)

We assume that level of passengers' utility is configured by level of fare and level-of-service. Then, railway operators are revealed to social pressure provided by various kinds of passengers to raise their level of utility. In this situation, railway operators decide their investment level, which is represented by their level of fare and level-of-service, in such a way that passengers' utility perceived by operators is maximized (in other words, in such a way that passengers' pressure perceived by operators is minimized) under break-even fare constraint.

Under fare regulations and a low demand elasticity market, this kinds. of business are socially regarded as *public service*. In addition, the private railway operators also manage subsidiary business. Their subsidiary business is important for their management because its net profit is of the same order as that from railway business. If they make light of investment in railway facilities and become notorious for their low service level, they will lose their confidence and they will lose their profit from their subsidiary business which are in competitive market even if the profit from railway business does not decrease. This means that maintaining their reputation in railway divisions will connect to keep and increase their total profit and they will make effort to satisfy "*social pressure*" from railway passengers.

2.2. Basic Concept and Valuables

$c_0 \equiv C(s_1|s_0)$; Cost for investment including interest of loans (yen/year)
C: Investment Cost function
$f_1 \equiv F(f_0, c_0, D)$; Fare level per kilometer after investment (yen/km)

F: Fare function

$u_i \equiv U_i(s,f)$; Utility of passenger i perceived by operators

U: Perceived Utility function

$u = \sum_i \alpha_i * u_i(s,f)$; Utility of total passengers perceived by operators

where

s_0, s_1 ; Service level before and after improvement projects.
The s is measured in time in this study, therefore, its value gets smaller in higher LOS.

f_0, f_1 ; Fare level before and after improvement projects.

u_{i0}, u_{i1} ; Utility of passenger i perceived by operators before and after improvement projects.

D ; Travel demand (passenger km).

α_i ; Parameter

Now the SPMin model stated above can be written as follows.

Operators choose their point of fare and service, which would be achieved by investment, where U(s,f) is maximum and where satisfies fare regulation condition $f_1 \equiv F(f_0, c_0, D)$ *and* $c_0 \equiv C(s_1|s_0)$

2.3. Assumptions of Functions

(a) Basic conditions and assumptions

1) Railway operators plan and launch their projects by themselves.
2) Investment which this study deals with is for improvement projects in existing lines.
3) Demand is non-elastic in terms of improvement of existing network.
4) Fund for improvement is operators' revenue only from their fare income.
5) Operators have to keep break-even fare constraint.

(b) Investment Cost Function; $c_0 \equiv C(s_1|s_0)$

The cost c is defined as the actual cost for investment which certain operator pays per year. In this cost function, it is assumed that the cost is proportional to the increase of LOS, and that marginal cost gets higher as the increase of LOS.

$$\frac{\partial c}{\partial s} < 0 \quad \frac{\partial^2 c}{\partial s^2} > 0 \tag{1}$$

(c) Fare Function; $f_1 \equiv F(f_0, c_0, D)$ (This represents break-even fare regulation.)

The fare f is defined as the fare per passenger kilometer. The cost c is assumed to be covered by increase of fare.

$$f_1 = f_0 + c_0/D \tag{2}$$

The author assume that demand is not elastic and assume that D is not changeable. Then equation (3) is derived from equation (1), (2).

$$\frac{\partial F}{\partial s} = \frac{1}{D}\frac{\partial C}{\partial s} < 0 \quad \frac{\partial^2 F}{\partial s^2} = \frac{1}{D}\frac{\partial^2 C}{\partial s^2} > 0 \tag{3}$$

$\frac{\partial F}{\partial s}$ does not depend on f_0, therefore, F of different operators can be drawn as parallel curves for horizontal axis direction (figure 1).

The points on the curves F are the sets in which operators can choose as investment points. In this sence, F can be named as "**Service-Fare Frontiers**" (**SFF**) of operators.

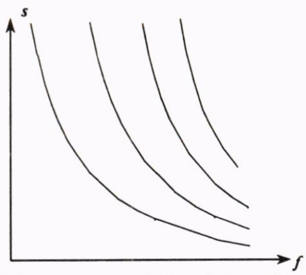


Figure 1. The characteristic of fare function (**Service-Fare Frontier**)

(d) Perceived Utility Function ; $u=U(s,f)$

The characteristic of utility function is shown in figure 2.

It is assumed that the disutility of passengers increases in proportion to the increase of fare (for example, the social reluctance to 40% fare increase is more than twice of that to 20% increase), and that the disutility also increases in proportion to the reduction of LOS. Equation (4) is derived from the assumption shown above.

$$\frac{\partial u}{\partial f}<0 \quad \frac{\partial^2 u}{\partial f^2}<0 \qquad \frac{\partial u}{\partial s}<0 \quad \frac{\partial^2 u}{\partial s^2}<0 \tag{4}$$

Assuming that the passengers' requirement to the improvement of LOS per marginal fare rise will increase in proportion to the fare level, the indifference curves which represent $U(s,f)$ will be drawn as concave to the origin (figure 2).

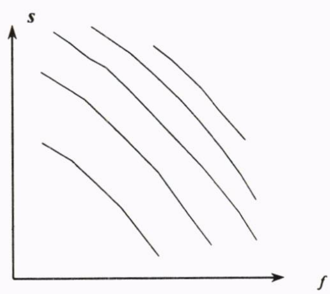


Figure 2. Indifference curves of $U(s,f)$

2.4. Operators' Decision for Investment Level under SPMin Model

We will consider two operators, O_A and O_B at time t_1. In figure 3, we draw their SFF, A_1A_1' and B_1B_1', and indifference curves of u. A_1 and B_1 represent the points of the operators at time t_1 when operators do not expend at all for investment from time t_0 to t_1. In the SPMin model scheme, the investment point of railway operator on the s-f plain is the point where u is maximum on its fare-service frontier. That is, investment level achieved by operator O_A at time t_1 is A^*_1 and its service level and fare level are s^*_A and f^*_A respectively.

From the part shown above, behavior of operators can be represented as follows.

Operators located in arbitrary point (s_0,f_0) at time t_0 can invest in its facility when equation (5) is satisfied at t_1.

$$-\frac{\partial F}{\partial s}\bigg|_{s_0,f_0} < \frac{\partial u/\partial s}{\partial u/\partial f}\bigg|_{s_0,f_0} \tag{5}$$

And equation (6) is satisfied at the point where investment is done.

$$-\frac{\partial F}{\partial s} = \frac{\partial U/\partial s}{\partial U/\partial f} \tag{6}$$

In figure 3, the operator locates at B_1 is not able to invest any more because of the following condition at t_1.

$$-\frac{\partial F}{\partial s} \geq \frac{\partial U/\partial s}{\partial U/\partial f} \tag{7}$$

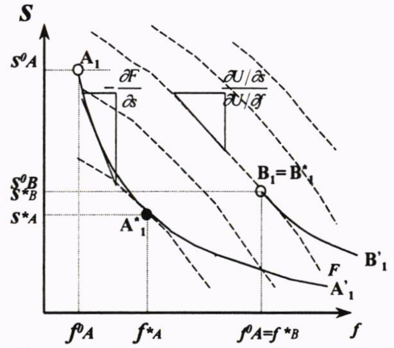


Figure 3. Operators decision for investment level under SPMin model scheme.

In this model, $-\frac{\partial F}{\partial s}$ can be called "*marginal cost for LOS improvement per passenger km*"

and $\frac{\partial U/\partial s}{\partial U/\partial f}$ can be called *"Passengers' Willingness-to-Pay perceived by operators"*. In addition, service level s is given in a time unit, therefore, a unit of $\frac{\partial U/\partial s}{\partial U/\partial f}$ is "value of time" and $\frac{\partial U/\partial s}{\partial U/\partial f}$ can be called *'Passengers' Value of Time which perceived by operators'*.

The authors, then, name $\frac{\partial U/\partial s}{\partial U/\partial f}$ as **'Perceived Value of Time' (PVT).**

3. INVESTMENT BEHAVIORS THROUGH THEORETICAL APPROACH

This chapter shows various behaviors of railway operators derived from SPMin model on theoretical base.

3.1 'Perceived Value of Time' at Invested Points

In chapter 2, the authors introduce a concept of passengers' utility perceived by operator. We can observe "PVT (same as Perceived Willingness-to-Pay for investment)" by calculating "marginal cost for LOS improvement" at investment-launched point because these two values are same at the point.

Then, if operators behave under SPMin model, and if market situation of operators is not so different, the following behavior can be observed.

> *The values of "marginal cost for LOS improvement" at investment-launched points have little difference between operators, in other words, 'Perceived Values of Time' at investment-launched points have little difference between operators. (behavior 1)*

From the basic concept of the SPMin model, operators can invest when equation (5) is satisfied. If the model is correct, the following behavior will be observed.

> *In the case when "marginal cost for LOS improvement" is larger than "Perceived Value of Time", operators do not invest any more, in other words, investment-launched point is on the end of SFF curve. (behavior 2)*

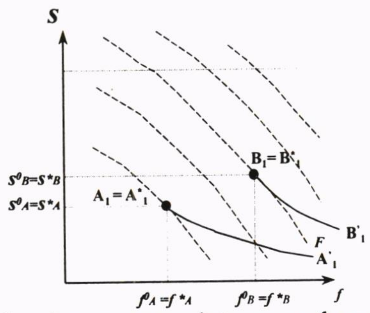


Figure 4. The case when investment points are on the end of Service-Fare-Frontier curves

3.2 Investment Behavior in Constant f_0 and Constant s_0

We will discuss the case that there are two operators, O_A and O_B, whose levels of fare are the same f_0 and whose levels of service are different. In this case, investment points of the operators are A_1^* and B_1^* respectively (Figure 5) and maximum fare level after investment is apparently $f^{*A} > f^{*B}$. Therefore, equations (8) and figure 5,6 are derived.

$$\Delta f^{*A} \equiv f^{*A} - f_0 > f^{*B} - f_0 \equiv \Delta f^{*B}, \quad |\Delta s^{*A}| \equiv |s^{*A} - s_0| > |s^{*B} - s_0| \equiv |\Delta s^{*B}| \qquad (8)$$

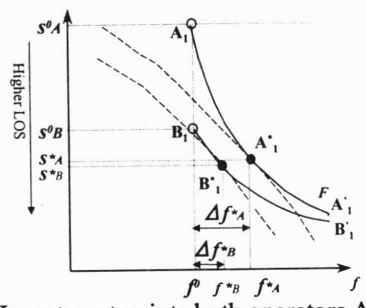


Figure 5. Investment points both operators A, B whose fare is constant f_0

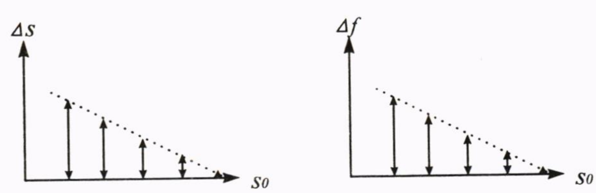


Figure 6. Investment level launched by operators A, B on s_0-Δs, s_0-Δf plain

From the part shown above, the investment behavior can be derived as follows.

If the present LOS of operators are lower, the operators will invest their projects with higher LOS increase and higher fare increase. (behavior3)

We can also discuss the case that there are two operators whose levels of service are the same s_0 and whose levels of fare are different (Figure 7). Same as the former case, the investment behavior can be derived as follows.

If the operators' levels of fare are lower, the operators will invest their projects with higher LOS increase and higher fare increase. (behavior4)

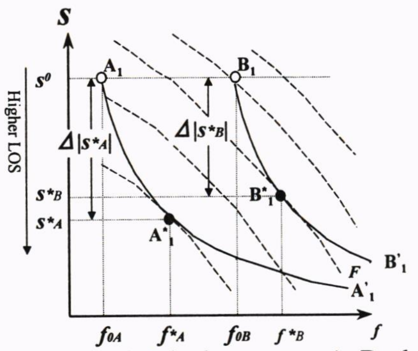


Figure 7. Investment points both operators A, B whose LOS is constant s_0

3.3 Investment Behavior in Large Scale Project

We will discuss the case when operator invests in a project which needs huge cost. In this case, the fare function – which is configured by level of fare and LOS – is uneven before and after investment point. This shows the situation that only infrastructure is developed and fare has already raised, and service level has not changed yet (figure 8). The points between B^*_1 and A^*_1 will not be selected by operators as a investment launched points because equation (5) is not satisfied on the range.

From the part shown above, the investment behavior can be said as follows.

Possible investment domain (Service-Fare-Frontier) has a gap on the fare function when operators invest in infrastructure with large amount of cost. (behavior5)

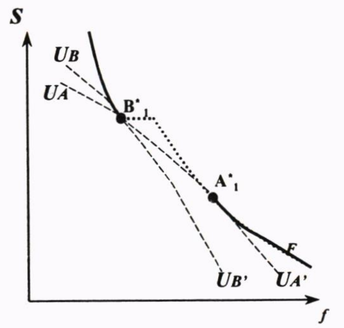


Figure 8. Investment behavior in large scale project

If operators are permitted to raise their fare to reserve their profit for large project in advance, Service-Fare-Frontier can be shown at figure 9 and operators will behave as follows.

> *In the case when operators can raise their fare to save funds for investment in advance and, from this reason, can restrain the margin of fare increase at investment completion point, operators can invest easily.*

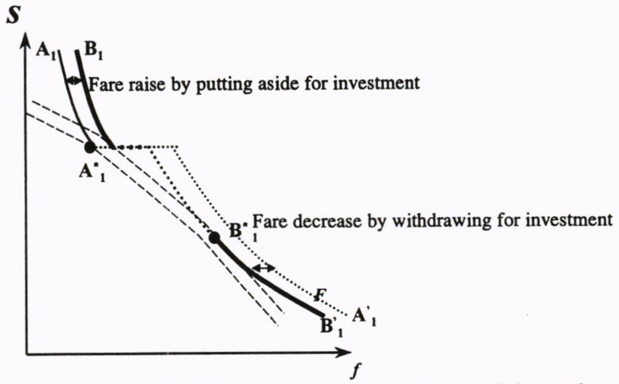


Figure 9. Investment behavior under fare pre-raising rule

4. CALCULATION OF SERVICE-FARE FRONTIERS

4.1. Structure of the Cost Sub-Models

The main objective of this modeling is to calculate level of fare from LOS data for the purpose of calculating SFF of railway operators. In order to be able to derive the Frontiers, the cost models are formulated to use only data which are controlable valuables of operators. The main input of the whole system is a 'targeted service levels' of operators and the output is a level of fare per passenger kilometer. The structure of the models is shown in figure 10.

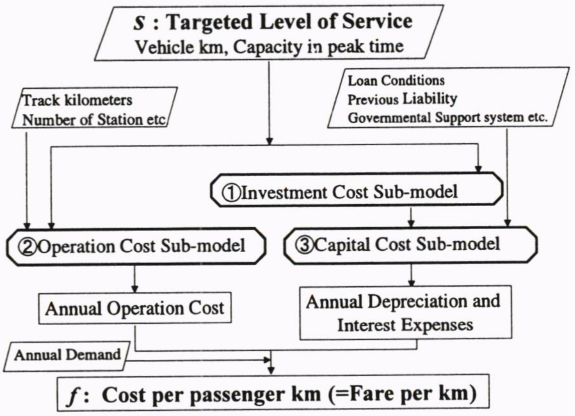


Figure 11. Structure of cost sub-models

This system has three main sub-models shown as follows.

(a) Investment Cost Sub-model

Main input : Supplied level of service at time t_n which is planed at time t_0.
Output : Operator's total investment cost which is needed from t_0 to t_n.

(b) Operation Cost Sub-models

Main input : Supplied level of service at t.
Operator's fundamental operational data (track km etc.) at t.
Output : Operator's annual expenses for railway operation at t.

(c) Capital Cost Sub-models

Main input : Operator's total expenses for investment before t.
Loan condition ,accounting rules etc..
Output : Operator's annual expenses for depreciation and interest expenses at t.

4.2 Formulation and Estimation of the Cost Sub-Models

(a) Investment Cost Sub-models

These sub-models cover investment cost which is directly connected to the projects contribute to improvement of the quality in existing lines. The reason is that this research focuses mainly on the market where the demand is non-elastic. Investment for safety and construction of new lines are not included in this model.

Investment cost K is formulated and estimated as follows. The data used for model estimation are of 6 major private operators in Tokyo and Osaka from 1967 to 1992.

$$K=Kv+Kr \tag{9}$$

$$Kv = r_v/r_p*153.5*[Nv(t_n)-Nv(t_0)]$$

$$Kr = e^{0.9810}\cdot[Np(t_n)-Np(t_0)]^{0.5118}\cdot L^{0.379}\cdot(Vkm/l)^{0.7957}\cdot \exp(N_{line})$$

Unit: million yen/(t_n -t_0) (1996 price)

where

Kv: Investment cost for rolling stocks from t_0 to t_n. (Replaced vehicles are not included)

Kr: Investment cost for infrastructure from t_0 to t_n.

Nv : Number of rolling stocks, $r_v(t_n)$: Vehicle price index (1996=1.0)
$r_p(t_n)$:Consumer's price index (1996=1.0)
Np :Capacity in peak hour in the busiest section (persons per hour)
Vkm : Vehicle kilometers (10 thousand kilometers per year)
l : Operation kilometers, N_{line} :Numbers of 4 track sections

(b) Operation Cost Sub-models

Operation cost C is formulated as the sum of the following five cost items. The costs are formulated and estimated as follows. The data used for model estimation are of 12 major private operators in Tokyo and Osaka from 1967 to 1997.

$$C=Cr+Cv+Cd+Ce+Cm \tag{10}$$

$$Cr = e^{-4.297}\cdot L^{0.9415}\cdot(Vkm/L)^{0.9242} \quad \text{(Track maintenance cost)}$$

$$Cv = e^{-4.348}\cdot Nv^{1.0588}\cdot(Vkm/Nv)^{0.4852} \quad \text{(Vehicle maintenance cost)}$$

$$Cd = r_d/r_p\cdot e^{-3.1238}\cdot Tkm^{0.9438}\cdot(Vkm/Tkm)^{0.0736} \quad \text{(Driving cost)}$$

$$Ce = r_e/r_p\cdot e^{-6.331}\cdot Vkm^{1.221}\cdot(l*10/Nst)^{-.5539} \quad \text{(Power cost for vehicles)}$$

$$Cm = r_d/r_p\cdot e^{-2.858}\cdot(Np/Nst)^{0.5568}\cdot Nst^{1.032} \quad \text{(Management cost)}$$

where

L: Track kilometers(km), Tkm: Train kilometers (10 thousand km per year)
Np: Number of passengers (10 thousand persons per year), r_d: Personal cost index (1996=1.0) , Nst: Number of stations, r_e :Electric cost index (1996=1.0)

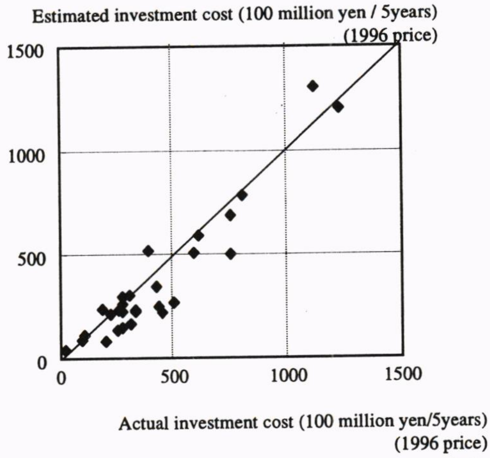


Figure 11. Fitness of Investment cost model.

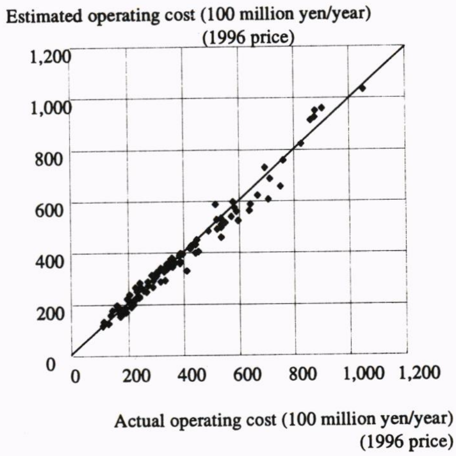


Figure 12. Fitness of Operation cost model.

(c) Capital Cost Sub-models

a) Depreciation

Operator's annual depreciation is calculated by following assumption.

- All expenses for investment are subject to depreciation.
- Expenses for investment are depreciated from the year when the expenses occur.
- All expenses are depreciated by constant rate for 30 years.

Then, depreciation can be calculated. The fitness of them are shown in figure 13.

b) Interest expenses

Operator's annual interest expenses are calculated by following assumption.

- The amount of loans borrowed at time t is assumed to be equal to investment expenditure minus depreciation and deposit.
- The loans are assumed to repay by actual loan systems and rules.
- Interest expenses at time t is a sum of the interests which originated from past borrowings

Then, annual interest expenses can be calculated. The fitness is shown in figure 14.

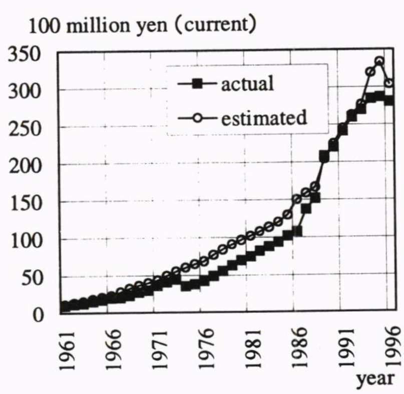


Figure 13. Fitness (annual depreciation)
(example; Tobu railway)

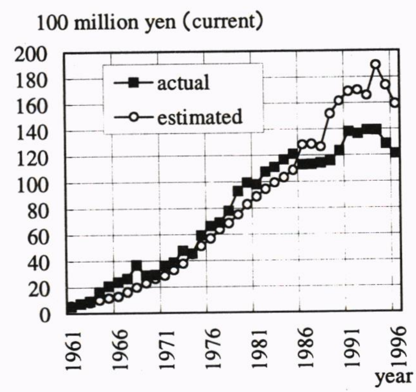


Figure 14. Fitness(annual interest expenses)
(example; Tobu railway)

4.3 Calculation of Operators' Service-Fare Frontiers

We define level of fare and LOS for calculation of Service-Fare Frontiers.

1) Level of Fare
We define operator's fare level as follows.

Fare level: The sum of annual operation cost (derived from Operation cost sub-model) and annual capital cost (derived from Capital cost sub-model) divided by total passenger kilometers. (unit: yen/passenger/km)

2) Level of Service
We define operator's service level as follows.

Level of Service: 'Congestion disutility index' derived from average load factor at the busiest section during peak one hour.

Congestion disutility index is calculated by equation (11). (Shida, et al. 1989)

$$s = 0.01 \times \{exp(1.97 \times R) - 1\} \qquad (11)$$

S: service level (congestion disutility index per one minute ride) R: load factor

5. VERIFICATION OF 'SPMIN MODEL'

5.1 Perceived Value of Time at Invested Points in Actual Situation (Verification 3.1,3.3)

In this section, the authors calculated SFF of 9 of 13 major private operators in Tokyo and Osaka from 1972 to 1992 by using the Cost Sub-models.

Figure 15 shows the Perceived Value of Time at the points where operators invested for improving LOS for their existing lines.

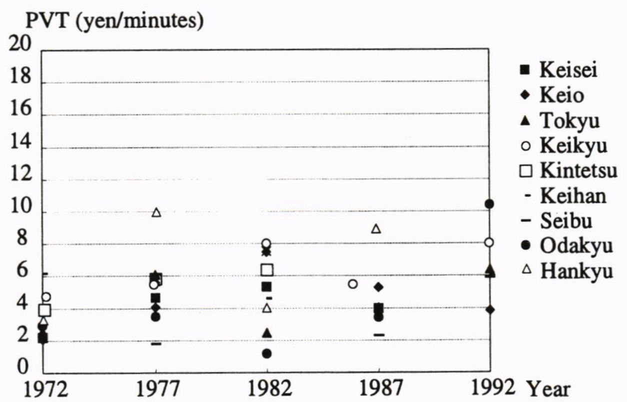


Figure 15. Perceived Values of Time of 9 operators at investment-launched points

In figure 15, most of the values of PVT are within the range from 2 yen/min to 8 yen/min. Consider that the time-value of inter-city transport is said to more than 15 yen / min, it can be said that the PVT of the urban railway have little difference between operators in lower range of value comparing with inter-city transport. This result is same as the behavior by theoretical derivation in 3.1 *(behavior 1)*.

The figure 16 shows the example of calculation of SFF (Service-Fare Frontier). The curves show the SFF in that year and the points show the investment launched point in that year. In figure 16, the investment point in 1987 is pointed at the end of SFF. This means that this operator did not invest in project for improvement of existing lines. In addition, the value of marginal cost for investment in 1987 is the highest of all investment point of this operator. This behavior can be explained that the operator did not invest in the year because all PVT on SFF is less than the marginal cost of investment. This is the same as *behavior 2* which is derived from SPMin model.

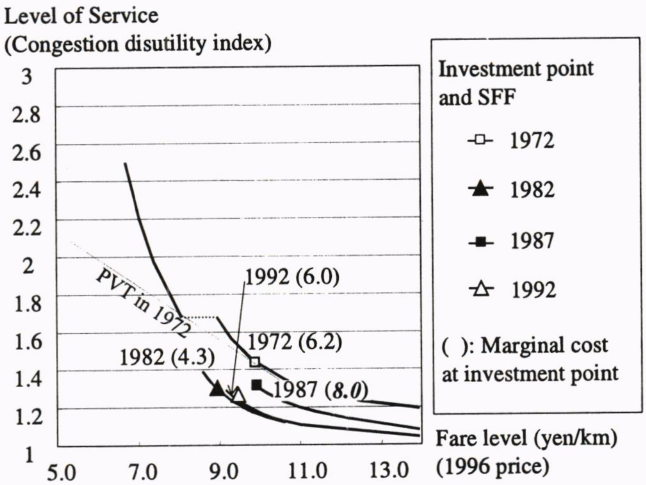


Figure 16. Service-Fare Frontiers and PVT at investment launched points .
(Example: Keihan Electric Railway)

In figure 16, the SFF in 1972 has a gap because of the realization of four tracking projects. The investment behavior in 1972 can be explained that the operator invested in the points where the PVT line contacted to the fare function curve which also contacted to the point before launching four tracking projects. And so, it can be said that the range on the fare function which are located between the points contacted by PVT line were not selected by the operators. This behavior is the same as which is showed in section 3.3 and this proposition is demonstrated in this section.

5.2 Trends of the Relation between Fare Level and Service Level (Verification 3.2)

The authors collect data and calculate level of service and level of fare defined in the previous chapter in the case of 12 major private operators in Tokyo and Osaka area from 1962 to 1992. In order to verify the 'behavior' by theoretical derivation, the following indices are applied.

(i) S^i_t ; Level of service in operator *i* at time *t*. *(t=92,87,82,77,72,67)*

(ii) f^i_t ; Fare level in operator *i* at time *t*. *(t=92,87,82,77,72,67)* (Converted to price in 1996)

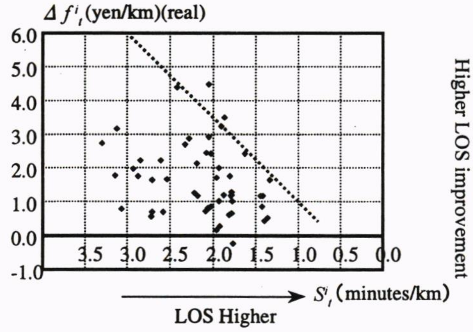
(iii) Δf^i_t ; The amount of fare increase during 5 years in operator *i* at time *t*.

$\Delta f^i_t \equiv f_{t-5} - f_t$ *(t=92,87,82,77,72,67)* (Converted to price in 1996)

(iv) ΔS_t ; The difference of 'level of service' during 5 years.

$\Delta S_t \equiv S_{t-5} - S^i_t$ *(t=92,87,82,77,72,67)*

The authors plot these indices in figures 17 to 20.



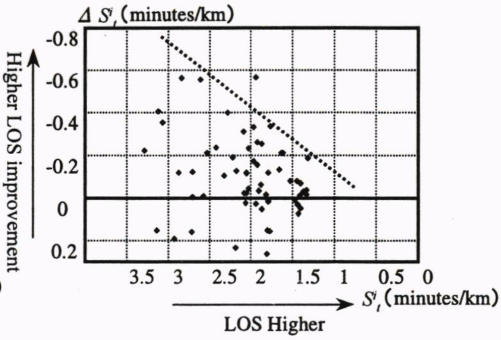
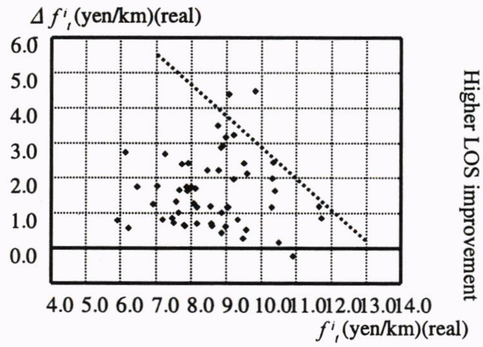


Figure 17. Previous LOS and fare increase. Figure18. Previous LOS and difference of LOS



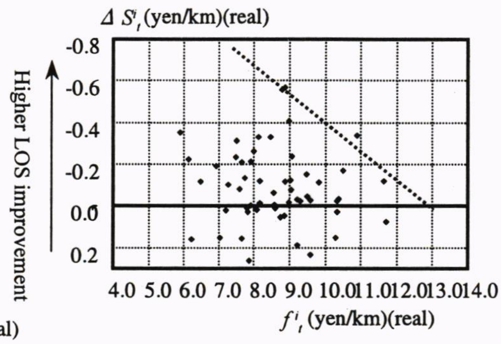


Figure 19. Previous fare and fare increase. Figure20. Previous fare and difference of LOS

Figure 17 and 18 show the upper limit lines where projects have been launched. The lower the LOS before investment is, the higher the maximum fare increase is, and so is maximum increase of LOS. This result is same as the behavior by theoretical derivation in 3.2 *(behavior 3)* and the territory of investment in figure 6 is same as that in figure 16,17. Therefore, the *behavior 3* in 3.2 is demonstrated in this section.

Figure 19 and 20 also show the upper limit lines where projects have been launched. The lower the fare level before investment is, the higher the fare increase and the increase of LOS is, and so is maximum increase of LOS. This result is same as the behavior by theoretical derivation in 3.2 *(behavior 4)*. Therefore, the *behavior 4* in 3.2 is demonstrated in this section.

6. SUMMARIES

This study focused on the behavior of railway operators in Japanese large cities about their investment. The authors propose a concept of investment behavior model of railway operators which have monopolistic market under the break-even fare regulation (Social Pressure Minimization Investment Model). And the authors explain the behavior of the operators by theoretical approach from modeling and analysis of real operators' data of investment.

Then, from theoretical and empirical approaches (in chapter 3 and chapter 4,5 respectively), following behavior can be explained and observed.

1) The values of "marginal cost for LOS improvement" at investment-launched points have little difference between operators, in other words, 'Perceived Values of Time' at investment-launched points have little difference between operators.
2) The case when "marginal cost for LOS improvement" is larger than "Perceived Value of Time", operators do not invest any more, in other words, investment-launched point is on the end of SFF curve.
3) If railway operators' present LOS are lower, the operators will invest their projects with higher LOS increase and higher fare increase.
4) If railway operators' present levels of fare are lower, the operators will invest their projects with higher LOS increase and higher fare increase
5) Possible investment domain (Service-Fare-Frontier) has a gap on the fare function when operators invest in infrastructure with large amount of cost.

REFERENCES

Ieda, H. and Okamura, T. (1997) INVESTMENT CRITERIA FOR THE IMPROVEMENT OF SERVICE LEVEL IN JAPANESE URBAN RAILWAYS, **Journal of the Eastern Asia Society for Transportation Studies vol.2 No.1**, pp339-352

Nakamura, H. (1995) Transportation Problems in Tokyo. **Japan Railway and Transport Review**. East Japan railway culture foundation, Tokyo

Shida, K., Furukawa, A., Akamatsu, T. and Ieda, H. (1989) A Study of Transferability of Parameters of Railway Commuter's Dis-utility Function. **Proceedings of Infrastructure Planning 12**, 519-527.

Japan Transport Economics Research Center (1961..1994) **Annual Urban Transport Statistics**, Tokyo (in Japanese)

Ministry of Transport (1961..1994) **Annual Railway Statistics**, Tokyo (in Japanese)

Ministry of Transport (1994) **Transport economy statistics hand book**, Tokyo.