# MACROSCOPIC MODELING OF BUS TRANSPORT MARKET CONSIDERING THE MODAL COMPETITION/COALITION AND ITS APPLICATION TO MANAGEMENT/POLICY ASSESSMENT


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abstract : This paper discusses a model which can be used as an assessment tool when designing transport policy, regarding bus transport in Japanese cities. An original survey of seventeen bus companies, operating in different cities was conducted and a cost model and demand model of high precision were estimated. Applying these models to particular operators, each having their own operating and environmental characteristics, the effect of changing the level of service (in terms of network density and frequency) on profitability and total surplus was estimated. By mapping isovalue curves of profitability and total surplus it is possible to project the direction that service level should be changed in order to improve profit levels or to increase total surplus.

## 1. INTRODUCTION

Public road transport continues to have an important role in the provision of service due to its relative flexibility, efficiency and affordability. However, the role that it is asked to play depends greatly on the conditions under which it exists. Problems accompanying urbanization and growing social awareness has led to the increase of political and social pressures to have public road transport take on the following roles : Promotion of the environmental concerns through the efficient use of fossil fuels; efficient use of limited road space through the reduction of road congestion, and improvement of the general mobility of the citizenry. Needless to say, the achievement of these objectives requires careful consideration of the actual situation facing bus transport and its sustainability.

Bus operators in Japan currently operate in nearly exclusive regions, competing with each other only at limited sections of their routes. However, due to strong competition from personal motorized and non-motorized modes, their situation is far from monopolistic. (Ieda, et.al. 1996). Indeed, many of these operators face difficult financial situations with little expectation of an improvement of them owing to an anticipation of spreading motorization more.

This study is an effort to provide an assessment tool for understanding the interrelationship between the level of service, demand, and government policy concerning bus transport, in determining the profitability (and hence sustainability) of the transport service, as well as user surplus. Within this framework, variations in the operator and his operating environment will affect the so-called cost structure of the operators as well as the level of ridership. In turn, these will affect the profitability of the enterprise, its impact on users. It is beyond the scope of this modeling to predict the turns that will occur in the operating environment, but it is the objective of the model to describe what level of service output is appropriate to a given situation, from the viewpoints of profitability and social welfare. It is thus hoped that this will provide some insight to what sort of government policies are appropriate. In its present stage, some social and environmental issues are partially considered, making this a first step towards a more complete model.

## 2. DEVELOPMENT OF REGIONAL BUS TRANSPORT MARKET MODEL

### 2.1 Special Considerations

The main objective of this modeling exercise is to develop a model of the urban bus transport market which could be easily applied to the evaluation of an existing bus service from the viewpoint of the "improveability" of its level of service, denoted by frequency and network density, with regard to profit and social welfare. In order to satisfy the requirement of ease for application, the model is formulated to use only data which are easy to acquire. In addition, by making it "self-calibrating", meaning that it can account for differences in aspects of the operating environment, it can be more easily applied to different situations. The term "macroscopic" is meant to be interchangeable with this concept of easy usage. Although the assessment of what constitutes "easily available" data may differ from region to region (or country to country), it was deemed that the for the purposes of its application to the Japanese setting, the basic variables that are hereinafter detailed belong to this category.

### 2.2 Structure of the Model

The model is conceived to be of the basic form, as shown in figure 1. It consists of an input block of the input variables describing the following :

<u>Characteristics of operating environment</u>

This includes such aspects as the role of the bus service (trunk or feeder), existing road travel speeds, variables related to the nature of the demand (car ownership rates, possession of a license, population density, etc.). as well as the existing regulations.

<u>Decision on the level of service</u>

This includes the nature of the service variables that an operator may or may not freely modify, as well as the basic features of the operators, whether they are a private or public enterprise, or what make of and how many vehicles do they own, to name a few.

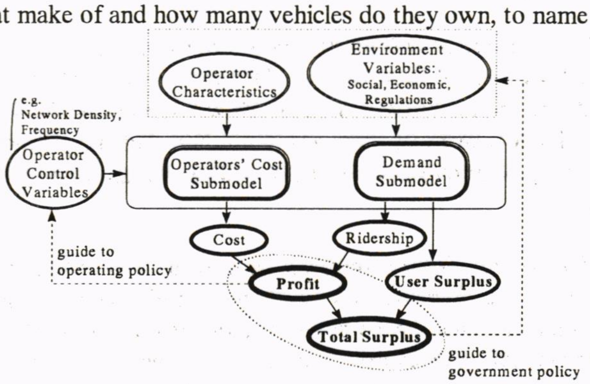


**Figure 1 : Conceptual Structure of the Model**

These input variables are used by the model to estimate ridership and costs associated with a given level of service.

## 2.3 Operators' Cost Sub-Model

The nature of the contributions, or the "path" of the contributions of different variables are assumed to follow the manner shown in figure 2. Basic variables are loosely grouped as Operator Characteristics, Operator Control Variables and Environmental Characteristics. Some of these basic variables are then used to compute the value of another intermediate variables, which are then used in conjunction with the other basic variables as input to the piece-wised equations of the main constituents of the total operators cost. These main portions are assumed to be personnel costs, fuel costs and others. Others includes such things as the depreciation cost of capital.

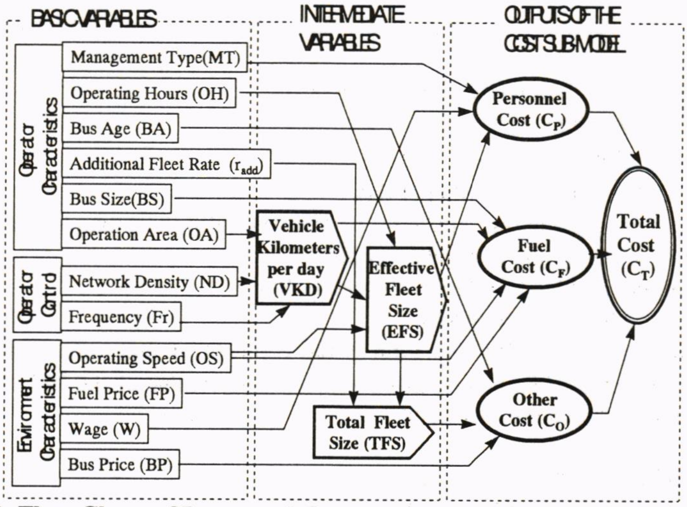


**Figure 2. Flow Chart of Input and Output Variables for the Cost Sub-Model**

Note: Endogenous variables are considered to be only Network Density and Frequency; other variables are considered to be Exogenous due to the strict regulations regarding bus services in Japan.

The so-called intermediate variables shown in Figure 2 for predicting vehicle kilometers operated per day(VKD) and fleet size(FS) are expressed as follows:

$$VKD = 2 \cdot ND \cdot Fr \cdot OA \qquad (1)$$

which is the same a formulation proposed in an earlier work (Ieda etal. 1995). It is assumed that this is an exact expression, as long as the units of measure of the input are appropriate to produce a result in units of vehicle-kilometers. On the other hand, effective fleet size (EFS) was expressed to include other terms describing the operating condition.

$$EFS = \alpha_0 \cdot \frac{VKD}{OH \cdot OS} \qquad (2)$$

where $\alpha_o$ = unknown parameter

The equation for total fleet size (TFS) is of the form:

$$TFS = EFS \cdot (1 + r_{add}) \qquad (3)$$

where $r_{add}$ = rate of additional vehicles over operating or active vehicles

It should be noted that $r_{add}$ is determined by the inspection system currently in place. Operators usually maintain a certain number of reserve vehicles, to be able to maintain services, in the case of accident or need for repairs.

The equations for which the basic and intermediate variables are inputs were estimated separately and respectively for the personnel costs, fuel costs and "other" costs.
Formulation for personnel costs ($C_P$) is of the following form :

$$C_P = \alpha_1 W \cdot EFS^{\alpha_2} \cdot MT^{\alpha_3} \tag{4}$$

where W : wage (yen/man/month)
EFS : Effective Fleet size (buses)
MT : Dummy variable of the management type, 1 if private, 10 if public
$\alpha_i$ : unknown parameters

This equation may also be viewed as an estimate of the required manpower to operate a certain fleet, given that the operator has the characteristic of being managed by a private or public enterprise. The perception is that the public corporation is less efficient (requiring more people to provide the same level of service). Thus MT is a dummy variable of efficiency also. Wage is thus multiplied by this manpower estimate to get the resulting cost.

For fuel costs ($C_F$), the chosen equation form was:

$$C_F = \alpha_4 \cdot FP \cdot VKD \cdot BS^{\alpha_5} \cdot OS^{\alpha_6} \tag{5}$$

where : *FP* : price of fuel (yen/liter)
*VKD* : Vehicle-kilometers run per day
BS : average space in the vehicle for passengers - also indicating the size of the vehicle, its weight or similar variable
*OS*: Average running or operating speed (km/h)
$\alpha_4, \alpha_5, \alpha_6$ : unknown parameters

A converse interpretation of this equation is the estimate of fuel consumption, to run a certain number of vehicle-kilometers, given some characteristics of the bus. Multiplied by the fuel price, this will give the fuel costs.

For other costs($C_O$), it was:

$$C_O = \alpha_7 \cdot TFS \cdot (BP \cdot BA^{\alpha_8} + \alpha_9) \tag{6}$$

where: BP : Price of bus (yen/bus)
BA : Average age of bus (years)
$\alpha_7, \alpha_8, \alpha_9$ : unknown parameters, to be estimated

This function of "other" costs deals most clearly with the depreciation costs, as indicated by the inclusion of the purchase price of bus as well as the present average age of the fleet. Fleet size is the scaling variable.

## 2.4 Demand Sub-model

The estimate of demand is expressed as a density function, which relates the population characteristics and as well as properties of the existing transport systems of the bus and others. Population characteristics that were considered to be of significance are the car ownership rate, license possession rate, as well as the ratio of daytime to nighttime population. Since bus operators in Japan operate in separate regions, properties of the transport system that were considered are primarily those describing the extent of service of other modes, for example, network density and frequency of rail service, as well as the availability of stations(in terms of station density). This thus allows the consideration of the competition of these with the bus service. The flow of input and outputs is shown in Fig. 4.

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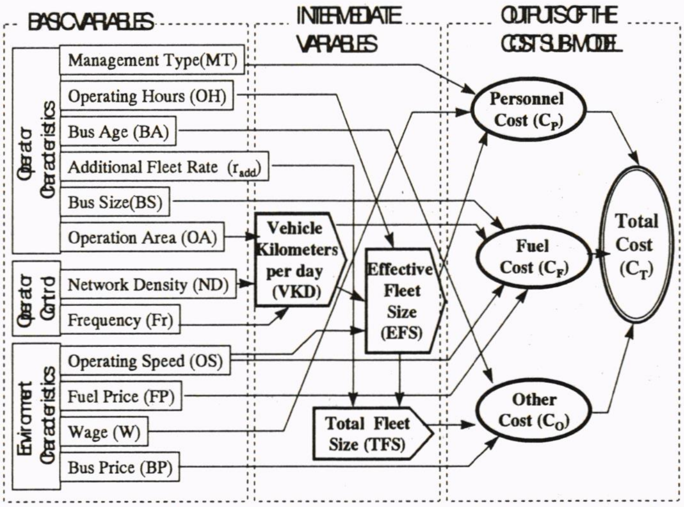


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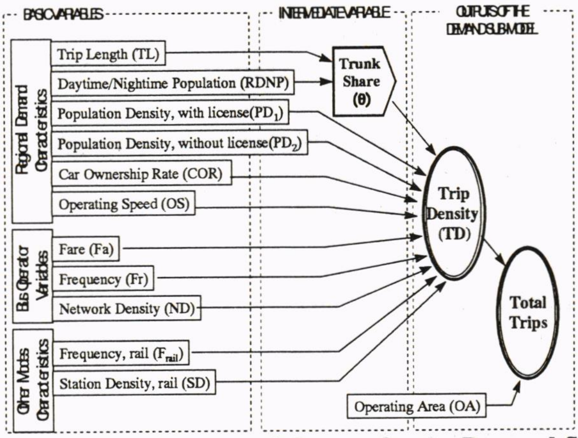



**Figure 4. Flow Chart of Input and Output for the Demand Sub-model**

Note: Endogenous variables are considered to be only Network Density and Frequency; other variables are considered to be Exogenous due to the strict regulations regarding bus services in Japan.

Figure 5 shows the concept of the transport market that is modeled by this sub-model. It is shown that bus only has the role of being a trunk or direct commuter mode or as a feeder to person trips. It is assumed that other than a trunk function, the only other significant contribution that bus service makes is as a feeder to the rail service.

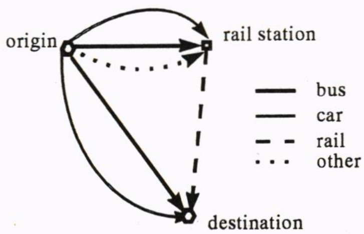



**Figure 5. Concept of the Transportation Market**

For the expression of the demand itself, is in the form of a type of a demand density function, in units of trips (by bus) per square kilometer. The trip density function TD is expressed as :

$$TD = (1 + RDNP) \cdot \left[ \beta_1 \cdot PD_1 \left\{ \theta \cdot \frac{1}{1+\exp(-A_1)} + (1-\theta) \cdot \frac{1}{1+\exp(-B_1)} \right\} \right.$$
$$\left. + \beta_2 \cdot PD_2 \left\{ \theta \cdot \frac{1}{1+\exp(-A_2)} + (1-\theta) \cdot \frac{1}{1+\exp(-B_2)} \right\} \right] \qquad (7)$$

where :

TD= Trip density (trips per square kilometer)
RDNP = Ration of daytime to nighttime population
$PD_1$ = denotes the population density for the part of population having a drivers' license.(persons per square kilometer)
$PD_2$ = denotes the population density for the part of population without a drivers' license. (persons per square kilometer). This means that ($PD_1$ +$PD_2$) =Total Pop. Density..
$\theta$ = proportion of the trips on bus for direct or trunk trips from origin to destination
($1-\theta$ ) = remainder of trips on bus

$$A_i = \left\{\gamma_1 \cdot ND^{\gamma_2} \cdot Fr^{\gamma_3} \cdot Fa^{\gamma_4} \cdot OS^{\gamma_5} - \gamma_6 \cdot LOS_{rail}^{\gamma_7} - \delta_i \cdot (\gamma_8 \cdot COR^{\gamma_9} \cdot OS^{\gamma_{10}})\right\} \quad @ \quad (8)$$

$$B_i = \left\{\gamma_{11} \cdot Fr_{rail}(\gamma_1 \cdot ND^{\gamma_2} \cdot Fr^{\gamma_3} \cdot Fa^{\gamma_4} \cdot OS^{\gamma_5} - \gamma_{13} \cdot SD^{\gamma_{13}}) - \delta_i \cdot (\gamma_8 \cdot COR^{\gamma_9} \cdot OS^{\gamma_{10}})\right\} \quad (9)$$

where:

ND = Network Density of bus service (kilometers per square kilometer)
Fr = Frequency of bus (times/direction/day)
Fa = Average fare rate of bus (\/kilometer)
OS = operating speed of bus
$LOS_{rail}$ = Level of service of rail
COR = Car Ownership Rate (cars/family)
$Fr_{rail}$ = Frequency, rail
SD = Station density, rail
$\delta_i = 1, i = 1$ case of with license
$\delta_i = 0, i = 2$ case of without license

The variable δ shows the inclusion or exclusion of the effect of car usage on the demand for bus. On the other hand the unknown parameters of equations $A_1$, $B_1$, $A_2$, and $B_2$ are meant to be estimated within the frame of equation 6. The separate expression here is meant to facilitate the understanding of the equation, as well as to underscore the meaning of these sub-equations. "A" refers to the factors affecting the trunk share of passengers, while "B" reflects the conditions of the feeder portion of the bus service. The subscript *i* refers to whether or not a license is possessed by that portion of the users of the bus service.

On the other hand, values of trunk ratio, θ used for the estimation of equation 6 came from census data. However, since there would be differences in the locales in terms of the travel behavior of the population, θ was also separately modeled as follows:

$$\theta = \frac{1}{1 + \exp(\varepsilon_1 + \varepsilon_2 \cdot TL + \varepsilon_3 \cdot RDNP)} \quad (9)$$

where :

TL = average trip of population (kilometers)
$\varepsilon_1, \varepsilon_2, \varepsilon_3$ : unknown parameters

This would allow the possibility of supplying such values in the absence of such information.

The form, $\frac{1}{1+\exp(\ldots)}$ is adopted here because its has the property of its values being able to range from 0 to 1, a useful property when modeling the shares of different portions of the market being modeled. In addition, its shape is able to reflect "saturation" in demand level in response to service levels, saturation meaning that under certain circumstances, increases of service level will not be followed by increases in the patronage.

Adopting this shape for equation 6 is an attempt to describe captive ridership wherein riders can only choose from a limited range of options. For example, families without car may choose from among walking, going by bicycle, or using public modes. This example makes the assumption (albeit somewhat extreme) that people without a license do not use cars. This is done for the sake of convenience.

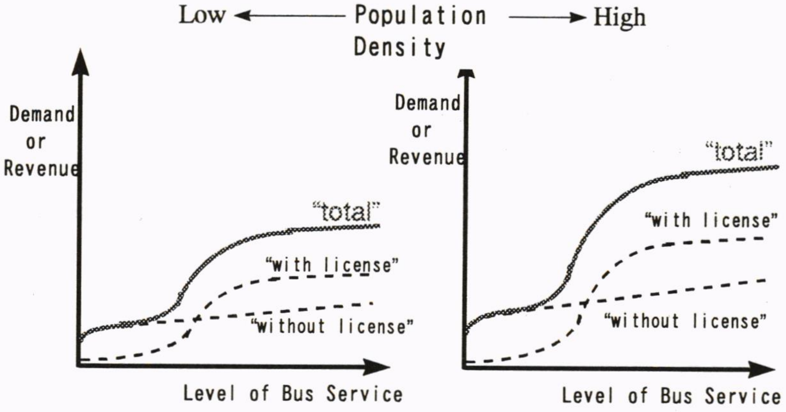



**Figure 6. Captive and Non-captive Demand**

Figure 6 illustrates the concept of a "layering" of the demand with a shifting of a type of logistic curve showing the "captivity" of the demand. In this case, the "with license" group is not captive to the bus service, while those without are. It shows that as service level increases, it can be expected that the demand for the service will increase, sharply at first and then tapering off in the fashion of decreasing returns. This curve would show that the captive demand is not zero at even low levels of service because the users basically have a limited choice range and are "forced" to use the bus. Assuming that the shape of the captive and non-captive curves are similar in shape, then can represent the captive curve as left-shifted, compared to the non-captive curve, such that the demand level at levels of service near to zero is a positive value.

## 2.5 Calculating Operator's Profit and User Surplus

The resulting model is to be used to analyze the effect of changes in levels of service as defined by the network density and frequency of the bus operations with respect to their effect on operator profitability and user surplus. "Total Surplus" is taken as the sum of the operator's profit and user surplus.

Operator profitability can be calculated as the difference between the cost(estimated using the cost sub-model) and revenue(estimated using the demand sub-model). However, due to the difficulty of measuring gross values of user surplus, we turn to approximating the *changes* in the user surplus. This is accomplished by adopting an expression of generalized cost which is considers costs associated with access, waiting and on-board time costs, as well as the fare. Thus, the expression of a generalized cost (Gc) is as follows :

$$Gc = (T_{access} + T_{wait} + T_{on-board}) \cdot VOT + Fa \tag{10}$$

where : $T_{access}$ : Time associated with accessing the service,

$T_{wait}$ : Time associated with waiting for service to arrive,

$T_{on\text{-}board}$ : Time spent on board the bus,

VOT : Value of time (yen/minute), assumed to be 2000yen/hour

Fa : Average Fare (yen/trip)

Access time, $T_{access}$ is approximated to be

$$T_{access} = \left\{ \frac{2}{3} \cdot \left( \frac{Iv}{\pi ND} \right)^{0.5} \right\} \div WS \tag{11}$$

where Iv : Interval between bus stops (km)

ND : Network Density (km/sq.km.)

WS : Walking Speed (assumed to be 4 km/h)

This derived under the assumption of a circular catchment area with demand density evenly distributed in the area.

Waiting time, $T_{wait}$ is approximated by :

$$T_{wait} = \frac{OH}{2Fr} \tag{12}$$

where OH : operating hours

Fr : Frequency

This assumes that average waiting time for all passengers is half of the frequency of service.

O-n-board time, $T_{on\text{-}board}$ is approximated as :

$$T_{on-board} = \frac{TL_{average}}{OS} \tag{13}$$

where $TL_{average}$ is the average on-board trip length (in kilometers) of passengers, and OS is the average operating speed of the bus service.

Using these approximations, generalized cost is calculated. Coupled with the output of the demand sub-model, it is possible to make an estimate of the change in user surplus that would result from changing the level of service. Figure illustrates the concept.

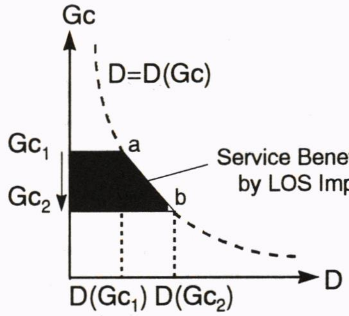



**Figure 7. Concept Figure for User Surplus Calculation**

Since the calculation of gross values of user surplus is very difficult, it was opted that differences in user surplus resulting from changes in the level of service should be calculated instead. This will allow us to assess any given situation from the view point of whether or not improvements are still possible. From figure 7, the area under the curve corresponding to the change in the user surplus is approximated as a trapezoid.

$$UserSurplus = \frac{1}{2}\{Gc_1 - Gc_2\} \cdot \{D(Gc_1) + D(Gc_1)\} \tag{14}$$

This user surplus is a macroscopic and aggregated approximation. It is consistent with benefits at the level of trip generation, without necessitating the consideration of link or OD demand estimations. At the same time, theoretical consistency between the demand model and the user surplus model is ensured by the use of the same demand model within the user surplus calculation.

These results are then applied to the investigation of the appropriate directions management should take with respect to their level of service variables, in order to achieve a desirable market situation. This is done by mapping different values of profit corresponding to different scenarios of frequency and network density will allow us to see in which direction a given operator (with other given characteristics) should modify his level of service in order to improve its profits. A similar mapping can be done for changes in total surplus to see what direction would be favorable.

The surplus estimate provided by this formulation is expected to be an underestimation because it does not account for a the benefit to the environment inherent in shifting car users to the bus.

## 3. ESTIMATION OF THE MODEL

### 3.1 Survey and Data Collection

The data used for the model estimation came from an original survey and interview conducted. Seventeen (17) companies operating in different urban regions were interviewed. The companies operate a combined total of 83 branches, having a variety of conditions, with respect to the variables described in the previous sections. The survey included suburban bus companies operating around the Tokyo metropolitan area. In addition, operators in smaller urban regions smaller conurbation of the Tokyo Metropolitan Area were also represented. Figure 5 shows the locations of these regions.

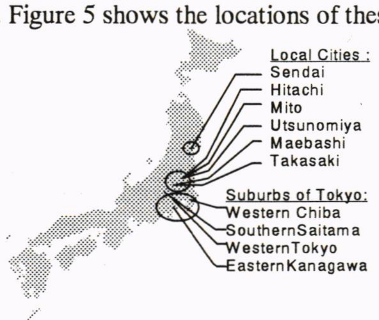



**Figure 8. Map of surveys locales**

These regions were chosen with the following points in mind : structure of the existing transport systems, size of the urban area and land use characteristics, reflecting employment opportunities. It was assumed that the chosen regions reasonably represented a variety of conditions existing in different Japanese cities. Operators were then selected to have a variety of fleet size, level of service, as well as variations of the population density, land use, etc., within in their urban region. Respondents provided information on ridership, revenues and total cost, in addition to basic information about their fleet and operations, on two or more of their branches. Other sources of information are documents of the transport ministry, census data, and commercial and official statistical publications.

### 3.2 Estimation Results

The parameters values were estimated to be as follows.

**Table 1. Results for the Cost Sub Model**

| Equation | Parameter | Value |
|---|---|---|
| Effective Fleet Size, $EFS = \alpha_0 \cdot \frac{VKD}{OH \cdot OS} \cdot (1 + r_{add})$ | $\alpha_o$ | 1.96 |
| **Number of Samples** | | **83** |
| **Sub-Model's Correlation Coef., r** | | **0.924** |
| Personnel Cost, $C_P = \alpha_1 W \cdot EFS^{\alpha_2} \cdot MT^{\alpha_3}$ | $\alpha_1$ | 23.8 |
| | $\alpha_2$ | 1.05 |
| | $\alpha_3$ | 0.168 |
| Fuel Cost, $C_F = \alpha_4 \cdot FP \cdot VKD \cdot BS^{\alpha_5} \cdot OS^{\alpha_6}$ | $\alpha_4$ | 0.0446 |
| | $\alpha_5$ | 1.12 |
| | $\alpha_6$ | 0.194 |
| Other Cost, $C_O = \alpha_7 \cdot TFS \cdot (BP \cdot BA^{\alpha_8} + \alpha_9)$ | $\alpha_7$ | 127 |
| | $\alpha_8$ | -9.57 |
| | $\alpha_9$ | 3264 |
| **Number of Samples** | | **83** |
| **Total Model's Correlation Coefficient, r** | | **0.962** |

As can be seen from the results, we can see that scale economies, relating to fleet size are slightly negative, since $\alpha_2$ is greater than 1. Another interesting result is the indication that public corporations tend to spend about 47% more on personnel than private operators.

**Table 2. Estimation Results for the Demand Sub-Model**

| Equation | Parameter | Value |
|---|---|---|
| Trunk ratio, $\theta = \frac{1}{1 + \exp(\varepsilon_1 + \varepsilon_2 \cdot TL + \varepsilon_3 \cdot RDNP)}$ | $\varepsilon_1$ | -0.082 |
| | $\varepsilon_2$ | -0.18 |
| | $\varepsilon_3$ | 1.30 |
| **Number of Samples** | | **83** |
| **Sub-model's Correlation Coefficient, r** | | **0.87** |
| Trip Density, $TD = (1 + RDNP) \cdot \left[ \beta_1 \cdot PD_1 \left\{ \theta \cdot \frac{1}{1+\exp(-A_1)} + (1-\theta) \cdot \frac{1}{1+\exp(-B_1)} \right\} + \beta_2 \cdot PD_2 \left\{ \theta \cdot \frac{1}{1+\exp(-A_2)} + (1-\theta) \cdot \frac{1}{1+\exp(-B_2)} \right\} \right]$ | $\beta_1$ | 184 |
| where | $\beta_2$ | 93 |
| $A_i = \left\{ \begin{matrix} \gamma_1 \cdot ND^{\gamma_2} \cdot Fr^{\gamma_3} \cdot Fa^{\gamma_4} \cdot OS^{\gamma_5} - \gamma_6 \cdot LOS_{rail}^{\gamma_7} \\ - \delta_i \cdot (\gamma_8 \cdot COR^{\gamma_9} \cdot OS^{\gamma_{10}}) \end{matrix} \right\}$ | $\gamma_1$ | 0.00598 |
| | $\gamma_2$ | 0.988 |
| $B_i = \left\{ \begin{matrix} \gamma_{11} \cdot Fr_{rail} (\gamma_1 \cdot ND^{\gamma_2} \cdot Fr^{\gamma_3} \cdot Fa^{\gamma_4} \cdot OS^{\gamma_5} - \gamma_{13} \cdot SD^{\gamma_{13}}) \\ - \delta_i \cdot (\gamma_8 \cdot COR^{\gamma_9} \cdot OS^{\gamma_{10}}) \end{matrix} \right\}$ | $\gamma_3$ | 1.14 |
| | $\gamma_4$ | -0.0893 |
| with $\delta_i = 1, i = 1$ | $\gamma_5$ | 0.327 |
| $\delta_i = 0, i = 2$ | $\gamma_6$ | 3.25 |
| | $\gamma_7$ | 0.163 |
| | $\gamma_8$ | 0.284 |
| | $\gamma_9$ | 1.16 |
| | $\gamma_{10}$ | 0.650 |
| | $\gamma_{11}$ | 0.00298 |
| | $\gamma_{12}$ | 4.90 |
| | $\gamma_{13}$ | 0.0633 |
| **Number of Samples** | | 83 |
| **Total Model's Correlation Coefficient, r** | | 0.956 |

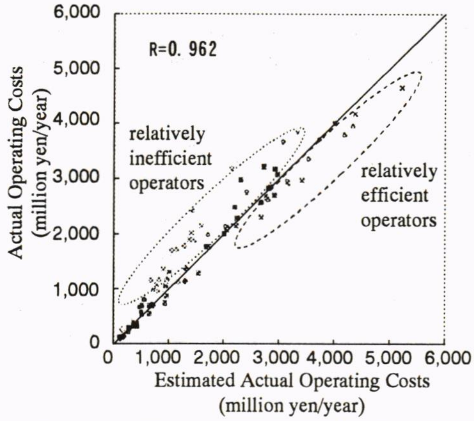



**Figure 9. Fitness of Cost Sub-Model**

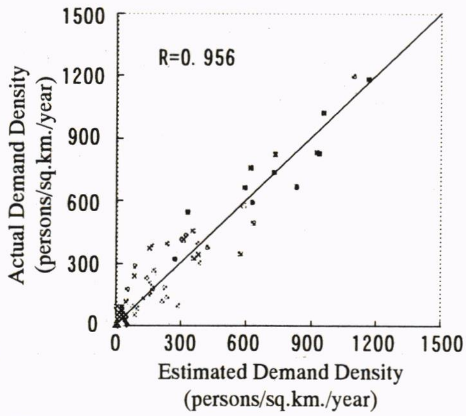



**Figure 10. Fitness of Demand Sub-Model**

It can be seen that a reasonably high level of precision in the modeling was achieved. In figure 9, we can observe the differences in the cost efficiency. R is used as a reasonable measure of fitness considering that the model was estimated through an implementation of least-squares methodology.

Based on the interview, which accompanied the survey, it was observed that operators which we can see as "relatively cost efficient" tended to take an "aggressive" approach to securing their market and making a profit. In other words, their approach to service was oriented both in lowering costs and raising level of service. On the other hand "inefficient" operators tended to take a more "retreating" approach, seeking to cut costs by reducing the level of service.

## 4. APPLICATION OF THE MODEL TO ANALYSIS

The following applications are an attempt to clarify the impact of the choice of the level of service on the operator profit, as well as the total surplus. Keeping all other variables constant, the effect of different scenarios for network density and frequency can be mapped to produce a set of isocurves describing profit and total surplus. By comparing the management "maps" of different operators, it is possible to make some assessments. The results of these applications are discussed in the following sections.

### 4.1 Assessment of the Operators Management Strategy Regarding Level of Service

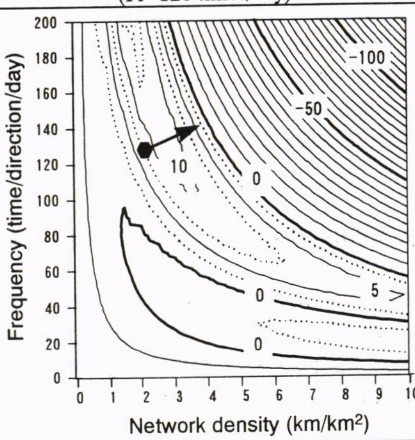
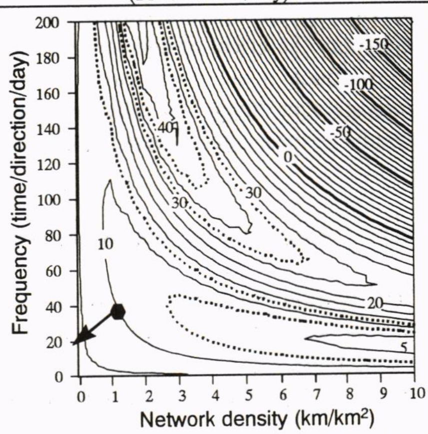
This section compares two private operators under similar environmental conditions, but having dissimilar levels of service. The net effect to them is that they have different levels of profitability and their management maps will lead them to make different decisions about the direction they should take in deciding a suitable level of service.

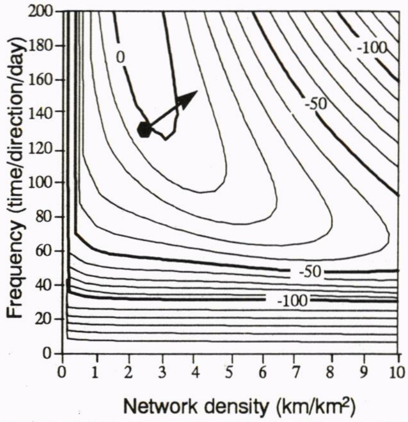
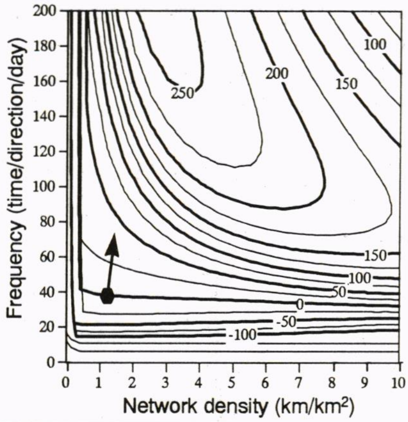
The figures shown in Table 3 indicate the iso-value curves for profit and total surplus (all iso-curves are in units of millions of yen per year). The vertical axis corresponds to the frequency of service(trips/direction/day) while the horizontal curve indicates the route density(km./sq.km.). The zero profit line corresponds to a break-even situation where all costs, including the salaries of workers are covered. The point and arrows indicate the present level of service and desirable direction to be taken from that point. This indicates the direction of the steepest increase for profit or total surplus from the point corresponding to the existing level of service.

From the viewpoint of the role of government, the indication is that a different approach is appropriate in each case. For company A, there is apparently no need for government to restrain or support, since the operator, if he follows the profit motive, it will coincide with an increase in total surplus. In contrast to this, operator B if allowed to follow its "short-sighted" view of how to improve its profit, it may adopt a reducing management direction, which is counter to the protection of total surplus. Reasons for "short-sightedness" might be one or two of the following : limited ability to finance expansions, regulations making it difficult to change routes or frequencies.

Thus a prescription for these two cases may be as follows : For operator A, no action need be taken except to monitor any changes in the operating market. Or alternatively, deregulation of the selection of routes or frequency. For operator B, some support could be provided in the form of advising the company of the potential profitability of higher levels of service, help in making a market survey to determine potential areas for expansion. If potential is determined, an offer of low-interest loans for the acquisition of new vehicles and other initial costs that are incurred will make it possible to raise the level of service. This type of action would be in the public interest, and due to the possibility to improve profitability, it is inherently sustainable, so long as the appropriate level of service is reached.

**Table 3. Comparison of Operators Under Similar Environment Conditions, but with Different Levels of Service**

| Operator / Aspect | A<br>(PD = 5808persons/km$^2$)<br>(OS=26.6km/h)<br>(ND=2.02 km/km$^2$)<br>(Fr=126 times/day) | B<br>(PD = 4708persons/km$^2$)<br>(OS=22.4km/h)<br>(ND=1.24 km/km$^2$)<br>(Fr=38 times/day) |
|---|---|---|
| Profit (100 million Yen) |  |  |

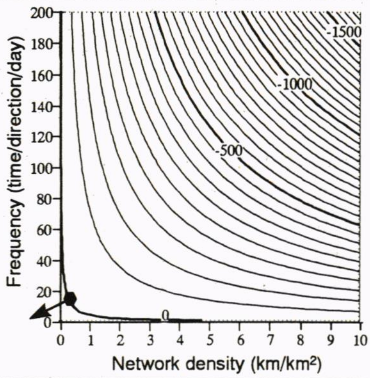
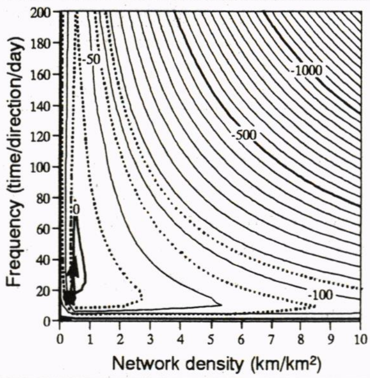
| Operator / Aspect | A<br>(PD = 5808persons/km$^2$)<br>(OS=26.6km/h)<br>(ND=2.02 km/km$^2$)<br>(Fr=126 times/day) | B<br>(PD = 4708persons/km$^2$)<br>(OS=22.4km/h)<br>(ND=1.24 km/km$^2$)<br>(Fr=38 times/day) |
|---|---|---|
| Total Surplus Increase<br>(100 million Yen) |  |  |

## 4.2 Case of Need for Public Support

This section illustrates the case where an operator is faced with a "harsh" environment (population density of 165 persons/square meter) wherein increase of profit can not be attained without lowering the level of service offered. However, it is also necessary to protect the public interest, and maintain a certain level of service. In fact, in the example presented here, the achievement of the maximum level of total surplus is possible with a small increase of service level, especially frequency.

This thus presents a supporting argument for the need to provide subsidies in some cases, at least for the maintenance of existing service, especially in cases where operators can not secure a reasonable profit.

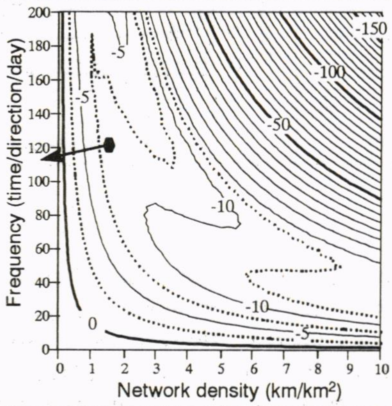
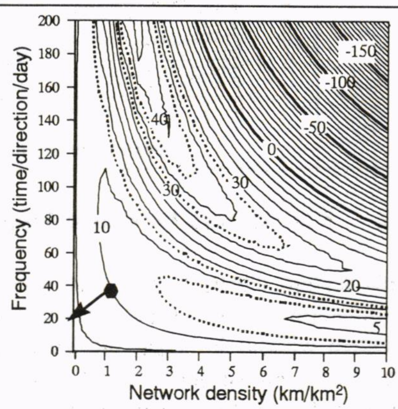
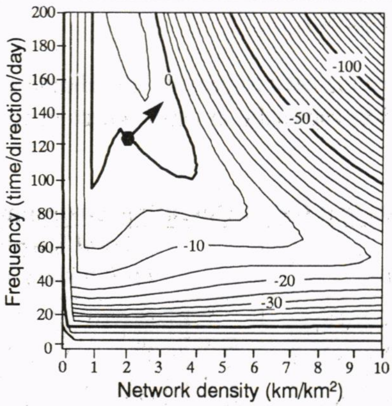
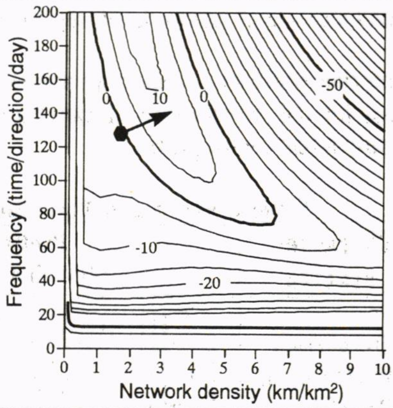
**Table 4. Profit and Total Surplus in a Harsh Operating Environment**

| Characte-ristics | Profit<br>(100 million Yen) | Total Surplus<br>(100 million Yen) |
|---|---|---|
| (PD=165/km$^2$)<br>(OS=42.5km/h)<br>(ND=0.22 km/km$^2$)<br>(Fr=15 times/day) |  |  |

## 4.3 Effect of Privatization

This application deals with the identifying whether the a change in the type of management might have any significant impact on the performance of an operator. It was assumed a priori that this would most likely have an impact on the cost structure of the operators. To make a comparison, the data of one of the samples of public company operator was used, however, changing the specification of the management type (MT), dummy variable. As it will become obvious upon examination of the cost, profit and user surplus curves, the model predicts a significant impact on the selected public operator.

**Table 5. Modeled Before and After Cases of Privatization**

| Case<br>Aspect | Before | After |
|---|---|---|
| Profit (100 million Yen) |  |  |
| Total Surplus Increase (100 million Yen) |  |  |

Close examination of the profit curves reveals that the desirable direction for any changes in the operating variables of network density (km/km$^2$, horizontal axis) and frequency (trips/direction/day, vertical axis) are diametrically opposed. The before case shows that a "retiring" action is appropriate, implied by the higher values of profit at lower levels of network density and frequency. However, the opposite case exists for the "privatized" operator.

On the other hand, total surplus values are shown to be open to improvement in similar manners, increasing network density and frequency by a certain degree.

## 5. CONCLUSIONS

The main findings of this study can be outlined as follows :

1) Successful development of cost and demand models which can comprehensively describe the operating situation of operators with a reasonable level of precision (R>0.95).
2) Application of this model reveals the appropriate direction for management of service level (in terms of network density and frequency) with respect to the profit maximizing objective, for operators facing different conditions. Balancing with this is the possibility to reveal the appropriate direction for the choice of service levels with respect to the achievement of increase of total surplus. The model has shown that cases exist wherein these two objectives may or may not be achieved by going in the same direction.
3) Subsequent to 2), this model can be used as an assessment tool, to guide appropriate government policy regarding bus transport service. Government policy can be tailored to meet the needs of different situations.

The authors recommend that further study should be made focusing on the following aspects:

1) Further study should be done to determine suitable "magnitude" for appropriate service improvement actions. Whereas this study clarified the kinds of "directions" that an operator might hypothetically take, it was not yet able to conclude regarding the magnitude of these changes in frequency or network density.
2) Effect of the level of regulation. At present, operators are required to get a license to operate a route. In contrast authorization is required for setting frequencies. If regulation is loosened to the level that only reporting such changes is necessary, what effects can be expected?
3) Effect of allowing bus operators to compete more freely in each others' regions of operation.
4) Effect of different fare systems and structures on the demand and viability of the bus service.
5) Since the model only considers a homogenous level of demand with respect to time of day, it might be fruitful to incorporate a consideration of the variations, such as "peak" demand, or "off-peak" demand.

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