【土木計画学研究・講演集 No.18(2) 1995年12月】

Management Analysis of Public Bus Transport System*

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1. Introduction

In many cities there is a noticeable decline in the absolute level of demand for bus. A key factor affecting this phenomenon is the fall of the level of services. This is mainly because of increasing road traffic congestion and thus increase of the operational cost of bus companies. Therefore bus companies can not avoid the decrease of the level of services.

The objective of this study is to develop the management model of bus companies in suburban area and analyze the management strategy for the future, in order to improve the efficiency of the public bus transport system.

2. Model Development

(1) Assumptions

The following assumptions have been made for model development.

a) Socio-economic characteristics of people are homogeneous.

b) There are no hourly, daily and seasonal variation of demand.

c) Management level is constant among companies.

d) Load factor is constant.

e) There is no competitiveness among companies.

(2) Structure of the whole model

Overall structure of the model is as shown in the figure 1. This model consisits of two sub models, demand sub model and cost sub model. By inputting the operator's variables such as network density and frequency and the external variables such as population density, operation area, average wage and average fare into the demand sub model and cost sub model, revenue, total cost and social surplus for a particular level of service can be calculated. Finally the different management strategies of bus companies can be determined by considering profit increase, cost reduction and social surplus increase.

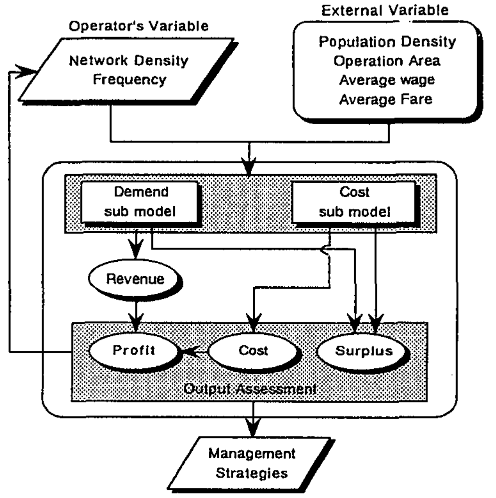

Figure 1 Structure of the whole model

3. Survey and Model Estimation

(1) Survey

Problems discussed in the introduction can be observed specially in the Tokyo suburban area. Therefore Tokyo suburban area was selected for our analysis.

There are nearly 30 bus companies operating in Tokyo suburban area. However only seven bus companies could be selected such that the zones of the bus companies having same population density and distance from the town center. Here the town center is both Tokyo and Yokohama. Moreover the selected bus companies have different organization level both private and governmental, different financial status both profit and loss and different size of company. These seven bus companies consiss of one public company and six private companies.

48 operational branch offices belong to these seven companies. Therefore we carried out the regression analysis by using the data of these operational branch offices.

*Keyword: Public Transport Planning

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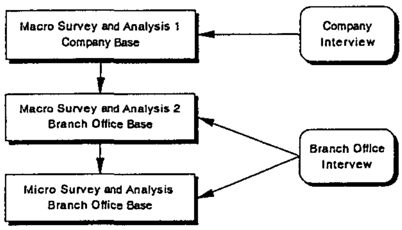

Figure 2 Structure of the surveys

Structure of the surveys is as shown in the figure 2.

The surveys were arranged in the following manner. At first, macro survey and analysis 1 was done in order to study the basic determinants of the demand and cost structure and company attitude. This survey and analysis was reinforced by the company interview. The developed demand and cost models in the macro survey and analysis 1, was further examined in the macro survey and analysis 2. In order to develop the micro cost model, micro survey and analysis was carried out. Branch office interview had been done to verify these survey and analysis.

In this paper only macro survey and analysis 2 is to be focused.

(2) Model Estimation

Multiple regression analyses were carried out to estimate the parameter of the demand and cost sub models.

a) Demand sub model

The output of this model is the revenue for a particular level of service, and is formulated and estimated as follows.

$$R = 365 \cdot TD \cdot A \cdot FA$$

R : Revenue(yen/year)

TD : Trip Density(persons/km^2/day)

A : Operation Area(km^2)

FA : Average Fare(yen)

$$TD = 1.63 \cdot PD \cdot [1\text{-}\exp(-1.28E\text{-}4 \cdot ND^{1.06} \cdot FR^{1.67})]$$

PD : Population Density(persons/km^2)

ND : Network Density(km/km^2)

FR : Average Frequency (times in one direction/day)

Revenue of bus companies can be caluculated by multiplying number of total trip and average fare. Here total trip is the product of trip density by operation area. Average fare is the external variable which can be explained in terms of fare rate of companies and average trip distance of passengers in the zone.

The function of trip density shows that network density and frequency have major impact on demand of the bus. Moreover frequency has more influence than network density, which explains the accessibility.

Population density of the zone is the important element to determine the demand. Trip density at one zone is proportional to population density of the zone. On the other hand, it is natural that trip density at one zone will become saturated at particular level of service in real situation. Therefore the shape of the function of trip density is the exponential type.

In general, it is natural that demand of the bus depends on the fare rate. Since the fare rate does not have much variation among companies, this is not treated as operator's variable in this model.

Figure 3 shows the regression result of the function of trip density.

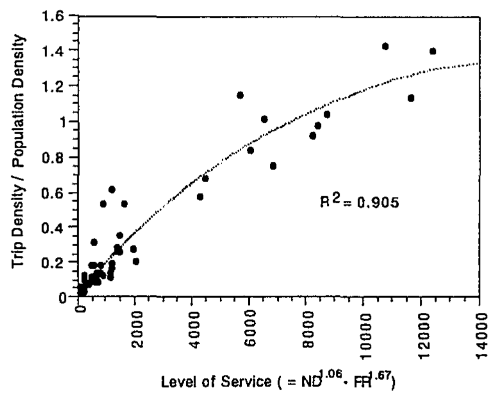

Figure 3 Regression result of the function of trip density

b) Cost sub model

The output of the model is the total cost of bus companies for a particular level of service. This model has two step structure. At the first step, fleet size can be determined for a particular level of service, and next step, total cost can be calculated from the fleet size. This model is formulated and estimated as follows.

$$FL = 7.93E\text{-}3 \cdot (ND \cdot A \cdot FR) \cdot PD^{0.10}$$

FL : Fleet Size

ND : Network Density(km/km^2)

A : Operation Area(km^2)

FR : Average Frequency(times in one direction/day)

PD : Population Density(persons/km^2)

$$TC = 124 \cdot W \cdot FL^{0.73}$$

TC : Total Cost(yen/year)
W : Average Wage(yen/month/person)

Fleet size is the function of the vehicle kilometer, which is product of network density, operation area and average frequency, and operation speed of the bus. However operation speed can be explained in terms of population density in this model.

It is said that personnel cost accounts for large part of total cost in bus companies. Therefore we can think that total cost is approximately proportional to number of workers and wage level of bus companies. On the other hand, most part of the workers are drivers in bus companies. Number of drivers can be explained in terms of fleet size. As a result total cost function includes the variables such as wage level and fleet size.

Figure 4 shows the variation between estimated total cost and actual total cost. Actual total cost of operational branch offices of public bus company are almost higher than estimated one, but not in private bus companies. Judging from this result, organization style of companies has impact on the total cost. Moreover from the function of total cost, scale of economy was found in bus companies.

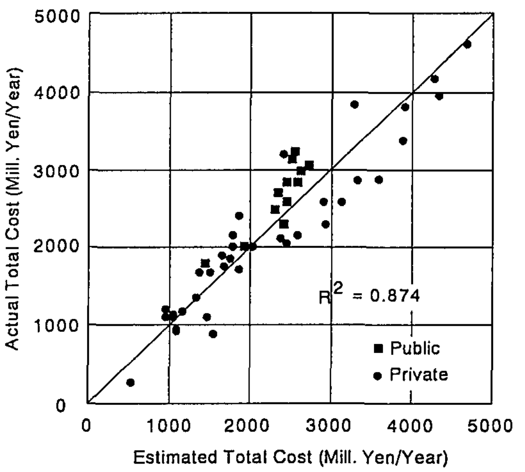

Figure 4 Regression result of cost model

(c) Calculation of Surplus

Demand function was improved in order to estimate the social surplus. Here the main variables of demand function such as network density and frequency, were transformed to average access time and average waiting time respectively. Calculation of average access time and average waiting time are as follows.

$$\text{Average Waiting Time (hour)} = \frac{12}{2 \cdot FR}$$

FR : Average Frequency
(times in one direction/day)

Assumption : Average operation hours in a day is 12 hours.

$$\text{Average Access Time (hour)} = \frac{1}{12} \cdot \sqrt{\frac{1}{2 \cdot ND}}$$

ND : Network Density(km/km^2)

Assumption : There are two bus stops in 1 kilometer.
Walking speed is 3 km/hour.

Access cost of bus was calculated by multiplying total time(= Waiting Time + Access time) and time value. Here, time value was assumed as 2,000 yen/hour. The equation between trips and access cost is estimated as follows.

$$T = 115 \cdot A \cdot AC^{-0.34}$$

T : Trips (persons/year)
A : Operation Area (km^2)
AC : Access Cost (Yen)

On the other hand, social surplus can be defined as follows.

Social Surplus
= Consumer's Surplus + Supplyer's Surplus
= (Service Surplus - Fare Expense)
+ (Fare Income - Service Cost)
= Service Surplus - Service Cost

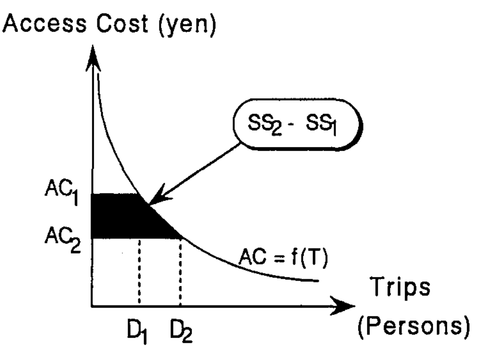

Figure 5 Change of service surplus of user's

We are interested in the change of social surplus after improving the level of service. Therefore we calculate the change of surplus as follows.

$\Delta S = \Delta SS - \Delta SC$

$= (SS_2 - SS_1) - (SC_2 - SC_1)$

S : Social Surplus

SS : Service Surplus

SC : Service Cost

1 : Actual

2 : After the Improvement

Figure 5 shows the change of service surplus of user's.

4. Application

One branch was selected in order to examine the future direction of the bus branches. The figure 6 shows the direction of the 20 % profit increase, the direction of the 20 % cost reduction and surplus increase direction. Here, surplus vector was drawn as the length is just equal to that of profit.

From the following figures, we can conclude that the direction of cost and profit are almost opposite. It is well known fact that bus industries usually try to do the cost reduction technique rather than doing other techniques such as surplus increase or profit increase. This is mainly because that since the bus industries are regulated, there is very less competition and thus leads to the less enterprise mind. Therefore bus industries usually do the protective stategy, thus make the cost reduction technique. On the other hand, the direction of the social surplus increase and profit increase are more or less same for this particular branch. If the bus company is operated for the profit increase, then the social surplus also would almost be increased. Therefore, we can conclude that no more regulation is to be imposed on this particular branch.

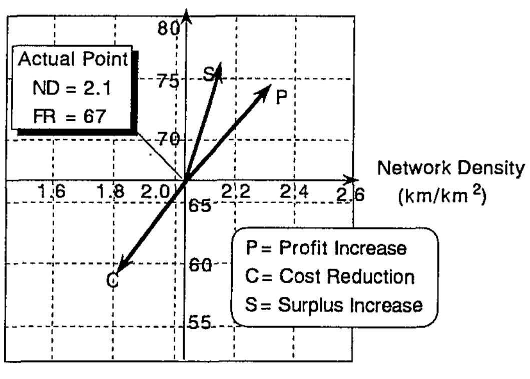

Figure 6 Strategy Vectors of one Profitable Branch Office

5. Conclusion

This study tries to develop the cost and demand function for bus transport industry for the Tokyo suburban area.

This study concludes that the trip density would become saturated at particular level of service. And, It is also found that the frequency has more impact than the accessibility. Moreover, it concludes that the trip density is proportional to the popualtion density of the zones.

Operation speed of the buses also has a major impact on the total cost function. Operation speed can be explained in terms of the population density. From the cost function, we can conclude that the bus transport industry in Tokyo sub urban area runs with the scale of economy.

Moreover, this study suggests the future management strategy in order to increase both profit of the bus company and social surplus.

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