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BUS INDUSTRY EVALUATION METHOD PER ROUTE

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Abstract: Transport density and the rate of revenue and costs are usually applied to assessment to expend public subsidy in operating bus service. However, these indexes overlook factors such as business effort as bus services supply under minimum costs. Then, the aim of this paper is to develop an evaluation method of business management condition per bus route in order to distinguish the subsidized bus route efficiently. This method reflects operating condition for inside and outside business environment of bus route. This method is applied to the evaluation of 45 bus routes in Kumamoto city. Consequently, each bus route is classified under 16 categories. Roughly speaking, 20 bus routes are inexpensive and profitable, 6 bus routes are inexpensive and unprofitable, 2 bus routes are expensive and profitable, 17 bus routes are expensive and unprofitable.

Key Words: deregulation of bus business, public subsidy, evaluation of business efforts, productivity

1. INTRODUCTION

Regulations to adjust supply and demand of bus service are repealed, and subsidization for local bus was modified because of a partial amendment of the Road Transport Law in 2002. Former subsidization was conditional on cross subsidy but is changed to a subsidy system per bus route. Several issues are raised by this modification. New low-fare bus services are expected in urban area. However, disorder is also foreseen because of excessive competition between bus companies. On the other hand, since bus companies can discontinue routes with deficit easily, unprofitable routes may be discontinued rapidly, and bus services for daily transport in local areas may be lost. Unprofitable bus routes need to be kept by public subsidy if they are indispensable for living there. However, subsidization without planning will cause financial trouble and may spoil business efforts. Therefore, characteristics of bus routes have to be evaluated to subsidize the bus industry appropriately.

When the public subsidy for bus industry is determined, transport density and the rate of revenue and costs are usually employed to assess bus transit operation. However, these indexes overlook factors such as business effort as bus services supply under minimum costs. Since these indexes are calculated from operation outputs which are fare revenues and number of passengers, it seems problematic that bus business is evaluated by only these indexes.

In this situation, the evaluation and the improvement of a bus business management were proposed to the following studies. Haraguchi and Takayama et al. (2001) constructed the evaluation system of planning the bus route network. This system searches the optimal bus route network by considering the number of bus schedule and bus drivers. Tamazawa and Tokunaga (2002) created simulation model in order to evaluate bus priority measures for increasing the level of bus service. Sugio and Isobe (2001) developed the supporting tool for public transportation system by applying GIS. This study uses Route-Potential and Marginal-Population-Depended for the index that a route is evaluated. Sugio and Isobe et al. (1999) clarified relationships between business environment and management policies. They proposed the desirable management policies suited by various bus-route types, and divided the bus routes into several bus-groups considering the key concept of business/public characters and potential/actual stage. Takeuchi and Yamada (1991) developed the route potential as a measurement for the public subsidy to bus business. They distinguished the bus route that may be subsidized, and manage the productivity under the subsidized system by using this measurement.

There are not many studies about treating the management and the public subsidy of bus business. For this reason, the aim of this paper is to develop an evaluation method of business management condition per bus route in order to distinguish the subsidized bus route efficiently. The improvement policy according to business management condition in each bus route is also proposed.

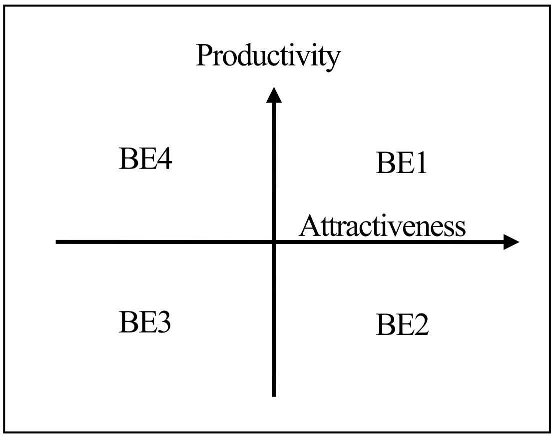
2. GROUPING CONCEPT OF BUS ROUTES

Sugio and Isobe et al. (1999) take bus business environment form two angles of business and public. The business and the public of each bus route are evaluated by actual operating condition and potential operating condition. The bus routes are divided several bus groups according to the evaluation. They also propose four management policies, which are “Increase passenger”, “Cut in costs”, “Rationalization of bus route formation”, and “Public subsidy”, in order to improve a management of bus business. The concept of business/public characters and potential/actual stages is introduced to interpret correspondence between the bus groups and the management policies.

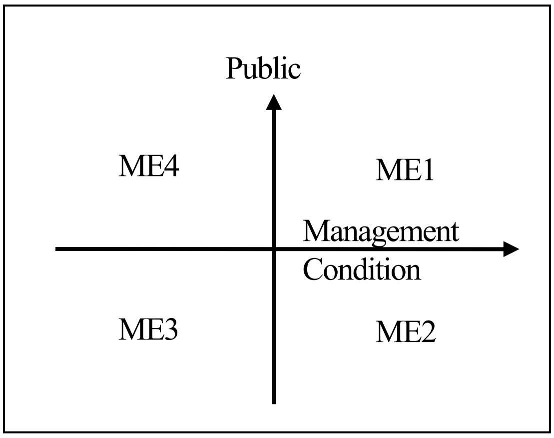
In this paper, we make reference to the above study, but more managerial viewpoint is introduced to the grouping concept of bus route in order to improve bus business management. Bus routes are classified by inside and outside management environment of each bus route. Inside management environment indicates whether managerial resources are used effectively. In addition to management condition which means balance of revenue and costs, productivity of bus route should be considered as one of the evaluation indexes. Then, productivity and management condition of bus route are used for the indexes of inside management environment. The rate of actual passenger number to potential demand, which we call attractiveness of passenger, may be used as index of business effort for getting passengers. Potential demand and public of bus route act for the indexes of outside management environment. The productivity, potential demand and management condition usually correlate to each other under efficient operation of bus route respectively. Therefore, if all of the bus routes operate efficiently, it may be meaningless to define such indexes. These indexes are defined on assumption that inefficient operation of bus route exists and the aim of defining such indexes is to identify the inefficient bus routes and quicken the improvement of them.

The attractiveness of passenger and productivity of bus route compose a plane of business effort. Management condition and public compose a plane of business environment. Bus routes are classified according to these two planes. Figure 1. a) shows plane of business effort. The horizontal axis is the rate of attractiveness of passenger, and the vertical axis is productivity. Figure 1.b) shows plane of business environment. The horizontal axis is management condition, and the vertical axis is public. Plane of business effort is composed of four quadrants which are BE1, BE2, BE3 and BE4. Plane of business environment is also composed of four quadrants which are ME1, ME2, ME3 and ME4. In this paper, each bas route is characterized according to a combination of the quadrants on two planes and is classified.

Basic concept of the improvement policy is that business management condition of each bus route should be improved toward BE1 on the plane of business effort and toward ME1 or ME2 on the plane of business environment. The bus route is a proper object of subsidy basically when a bus route belongs to BE1 and ME3 or ME4 on two planes. In this paper, we try to apply this grouping concept to bus routes of private company K in Kumamoto prefecture, and propose the improvement policy.



a) Plane of Business Effort



b) Plane of Business Environment

Figure 1. Conceptual Figure of Bus Route Grouping

3. PRODUCTIVITY ANALYSIS OF BUS BUSINESS

3.1 Translog Cost Function

The cost minimization framework is applied to analyzing productivity of the bus industry. A translog type cost function is selected for this purpose. The translog function is one of the families of flexible function, which may be interpreted either as an exact function or an approximation to arbitrary function by Taylor's series expansion up to second degrees. The translog function is flexible in that it places no a priori restriction on its own structure and the structure of production process (Viton P., 1981). The flexibility allows us to perform statistical tests of various restrictions against those imposed structure. A second order, n -factor, m -output, translog cost function is defined as follows.

$$\begin{aligned}\ln C = \alpha_0 + \sum_{i=1}^{n}\alpha_i \ln P_i + \sum_{i=1}^{m}\beta_i \ln Q_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij}\ln P_i \ln P_j \\ + \sum_{i=1}^{n}\sum_{j=1}^{m}\delta_{ij}\ln P_i \ln Q_j + \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m}\varepsilon_{ij}\ln Q_i \ln Q_j\end{aligned} \tag{1}$$

Where, C is total costs, P_i is price of input, Q_i is output, and $\alpha_0, \alpha_i, \beta_i, \gamma_{ij}, \delta_{ij}, \varepsilon_{ij}$ are parameters. In this paper, the number of passenger Q_J and the vehicle-miles Q_S are employed as output, and the labor price P_W, the unit cost of repair P_R, and the unit cost of fuel and oil P_F are employed as price of input. A symmetry and homogeneity constrains are imposed to translog cost function. Furthermore, since data are not enough for estimating the parameters, fifth and sixth terms in Equation (1) are neglected. Therefore, Equation (1) is transformed as follows.

$$\ln C - \ln P_F = \alpha_0 + \alpha_W(\ln P_W - \ln P_F) + \alpha_R(\ln P_R - \ln P_F) + \beta_J \ln Q_J + \beta_S \ln Q_S \\ - \gamma_{WR}(\ln P_W - \ln P_R)^2/2 - \gamma_{WF}(\ln P_W - \ln P_F)^2/2 - \gamma_{RF}(\ln P_R - \ln P_F)^2/2 \\ \sum_i \alpha_i = 1, \sum_i \gamma_{ij} = 0, \sum_j \gamma_{ij} = 0, \gamma_{ij} = \gamma_{ji}, (i, j = W, R, F) \tag{2}$$

According to Shephard's lemma, the derived demand functions of production are simply the partial differentials of the cost function with respect to corresponding factor price. Therefore, the share functions of the labor prices and the cost of repairs are obtained by differentiating Equation (2) with respect to the logarithm of the labor prices P_W and the unit cost of repairs P_R as follows.

$$U_W = \alpha_W + \gamma_{WR}(\ln P_R - \ln P_W) - \gamma_{WF}(\ln P_W - \ln P_W) \tag{3}$$

$$U_R = \alpha_R + \gamma_{WR}(\ln P_W - \ln P_R) - \gamma_{RF}(\ln P_R - \ln P_F) \tag{4}$$

It has been widely known that the optimal method of estimating all the parameters is to jointly estimate the translog cost function and the factor share equations as a system. For such a system estimation does not neglect additional information that can be derived from the cost and the share equations. All the parameters of the share equations simultaneously with the cost function are estimated.

The translog cost function of private bus company K in Kumamoto prefecture is estimated. The data to estimate parameters are used tables of the bus transit operating cost factor for twelve years from 1991 to 2002. The estimated parameters are shown in Table 1. Since the parameters β_J and β_S of outputs are positive, the cost increases when the number of passenger or the vehicle-miles increases. Considering the parameters α_W, α_R and α_F of factor prices, the coefficient of the labor prices W is only negative. This result is the opposite of an empirical assumption. Other parameters without γ_{RF} clear 5% level of significant. Since R^2 of each equation is also enough, the estimated equations are good fitness. Wald statistic about homogeneity is χ^2 distribution with 5 degrees of freedom. Since $Wald_{linear}$=5868.402 and P-value=0.000, homogeneity restriction is valid hypothesis.

Table 1. The Estimated Parameters of Costs Function

	Coefficient	t-value
α_0	6.378	7.730
α_W	-0.410	-2.199
α_R	0.328	3.990
β_J	0.407	4.471
β_S	0.548	5.534
γ_{WR}	-0.094	-7.549
γ_{WF}	-0.159	-4.692
γ_{RF}	0.024	1.379

	R^2	D-W
Eq. (2)	0.917	2.147
Eq. (3)	0.917	1.356
Eq. (4)	0.998	1.424

3.2 Evaluation of Productivity by Cost Function

Operating ratio and level of bus fare are usually employed as the evaluation indexes of bus business. These indexes are calculated through fare revenues and number of passengers without considering the level of business effort. These indexes are the total values as a bus company and can not evaluate productivity per bus route.

The estimated translog cost function can give the standardized cost of bus company K. The standard cost of a bus route can be estimated by inputting the data of bus route into the cost function. Productivity of a bus route is evaluated to compare the standard cost with the actual cost. Since only 1993'data of operating ratio per bus route are got, productivity of 45 bus routes of private bus company K in 1993 is evaluated.

The number of passengers and the vehicle-miles per bus route need adjusting because the estimated cost function yield cost of company unit. These data have to be expanded according to the rate of the vehicle-miles per bus route to the total vehicle-miles of bus company K. To sum up, each bus route is regarded as a company and the productivity of each bus route is evaluated.

The comparisons between the standard cost and the expanded real cost per bus route are shown in Figure 2. Consequently, 26 bus routes are less and 19 bus routes are more than the standard cost, that is, 26 bus routes are inexpensive condition and 19 bus routes are expensive condition.

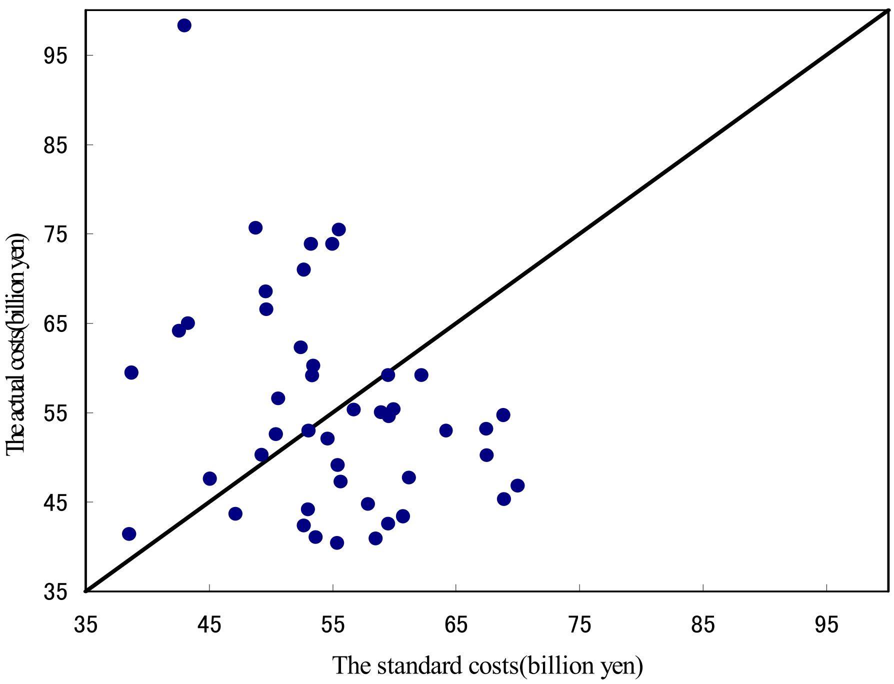


Figure 2. Comparison between The Standard Costs and the expanded Real Costs

4. THE GROUPING OF BUS ROUTES AND IMPROVEMENT POLICY

4.1 The Grouping indexes of Bus Routes

In addition to the productivity in Chapter 3, attractiveness of passengers, public and operating ratio need calculating in order to apply the grouping concept in Chapter 2.

(1) Attractiveness of Passengers
In this paper, an idea of route-potential (Takeuchi and Yamada, 1991) is simplified and is applied to calculating the attractiveness of passengers. Attractiveness of passengers means the ratio of actual passenger number to potential demand per kilometer and the actualization level of potential demand. Attractiveness of passengers is calculated as follows.

First, trip generation potential in a sphere of bus stop is calculated. A sphere of bus stop means a circle with the radius of 500 meter as bus stop is the center. The data of a sphere of bus stop include the population, number of employee by industries, student and sickbed, and number of other facilities' user in the circle. Multiply the trip generation potential and average frequency of trip generation and share ratio of bus transit together, and the product is potential of bus stop. The data of average frequency of trip generation and share ratio of bus transit are got from C zone data of person trip survey in Kumamoto city area. The former is 2.47 trips/person, and the later is 0.041.

Second, the potential of bus stop on any route are summed up, and the total divided by number of overlapping bus routes is the route potential. A weighted average of the route potential by service frequency divided by a weighted average of operating kilometer by service frequency is the route potential per kilometer in each bus route.

The attractiveness of passengers of the bus route is evaluated to compare the route potential per kilometer with actual passenger number per kilometer.

(2) Public
Here, to show significance of bus transit for daily life along the bus route is regarded as showing public. Number of people who can not consume public transit service without the bus route is called Limited Dependent Population.

Those who can not drive a car because of no driving license, too young or too old are considered to be dependent on public transit. Thus the people is divided into three age groups; young age group is form 0 to 14 years old, middle age group is from 15 to 64 years old, old age group is more than 65 years old. The population of each age group is surveyed along each bus route, and population ratio of each age group is calculated.

Multiplying these ratios and population in each circle, population of each age group in each circle is calculated. Then, giving added weight to the population of each age group, Total Limited Dependent Population is calculated according to Equation (5). This Total Limited Dependent Population represents public. If Total Limited Dependent Population of a bus route is lager than an average of Total Limited Dependent Population, public is judged high.

$$TLP = \alpha x_1 + \beta x_2 + \gamma x_3 \tag{5}$$

Where, x_1, x_2 and x_3 are population of young age group, population of middle age group and population of old, old age group respectively. α , β and γ are public intense coefficient of each age group. These coefficients are got from person trip survey in Kumamoto city area (Kumamoto Transport Plan Council, 1999), bus transit share ratio of middle age group is standardized as 1.0. The public intense coefficient of each age group is shown in Table 2.

Table 2. Weight Coefficients of Public

Young Age Population	α	0.31
Middle Age Population	β	1.00
Old Age Population	γ	2.38

(3) Management Condition

The operating ratio of each bus route represents management condition whether each bus route is in the black or red. Here, operating ratio indicates operating expenses as a percentage of operating revenue.

4.2 Grouping of Bus Route

45 bus routes of private bus company K are classified according to a combination of the quadrants on the two planes of business effort and business environment. The result is shown in Table 3.

The bus routes belonging to ME4 are 9. They need examining business management condition in more detail as targets for public subsidy because the public is high and the operating ratio is more than 100 %. However, all of them need improving the business effort because no route belongs to BE1 and ME4. The bus route belonging to BE2 and ME4 is 1. The attractiveness of passengers is high and the productivity is less than the average in it. Therefore, this bus route will be subsidized publicly under condition that the operating cost is cut and the productivity is increased. The bus routes belonging to BE4 and ME4 are 4. Since the productivity is high and the attractiveness of passenger is less than the average in them, they will get public subsidies provided that they make efforts to increase passengers. The bus routes belonging to BE3 and ME4 are 4. Since they lack business efforts, they need making effort to increase passengers and cut in cost without public subsidy.

The bus routes belonging to ME3 are 14. Judging from only operating ratio as usual, these routes are targets of public subsidy because of the red. However, they need making business efforts because the public is low in them and they belong to BE2, BE3 and BE4. If these are in the red and are improved toward BE1, the routes will be subsidized publicly with rationalizing the formation.

Table 3. Grouping of Bus Routs

		Business Environment				total
		ME1	ME2	ME3	ME4	
Business Effort	BE1	9	1	0	0	10
	BE2	0	2	7	1	10
	BE3	0	0	5	4	9
	BE4	6	4	2	4	16
Total		15	7	14	9	

In this way, a target of public subsidy can be narrowed efficiently by characterizing each bus route according to a combination of the quadrants on the two planes, and then the business effort will be stimulated, if necessary.

4.3 Proposal of Improvement

Principal component analysis is executed for primary variables determining bus operating condition because concrete improvements of each bus route are found. As accumulated proportion is more than 70% and eigenvalue is more than 1.0, the first three components are examined. Here, standardized variables are used in this analysis. Factor loadings of the first three components are shown in Table 4.

The first principal component gives heavy weight to vehicle-miles, travel time, the first bus time, the last bus time and frequency bus and thus represents "level of service". The second component represents "speediness", with average speed, number of bus stop and interval of bus stop weighted heavily. The third component represents "localness of bus route". Because vehicle-miles, travel time, average speed and number of bus stop are weighted positive, frequency of bus, number of route overlapping and the last bus time are weighted negative, the score of local bus route tends to get bigger.

Table 4. Factor Loading

	First component	Second component	Third component
Vehicle-miles	0.81	0.25	0.49
Travel time	0.88	-0.03	0.37
Average speed	-0.14	0.79	0.39
Number of bus stop	0.45	-0.68	0.41
Interval of bus stop	0.10	0.86	-0.18
The first bus time	-0.55	-0.06	0.25
The last bus time	0.69	-0.12	-0.31
Frequency of bus	0.85	0.09	-0.33
Total travel distance	0.94	0.15	0.00
Number of overlapping	0.49	-0.04	-0.41
Accumulated	42.76	62.09	73.73
Eigenvalue	4.28	1.93	1.16

Table 5. shows the average score of principal components by the group according to the business effort and the business environment. Judging from characteristics of each group leaded from the score and the business management condition in the previous section, the improvement goals and the policies are arranged in Table 6.

The productivity, the attractiveness of passenger and the management condition are well in the bus routes belonging to (BE1, ME1) and (BE1, ME2). Thus the business management condition is satisfactory. However, more operating revenues are expected by improving factors of "speediness" in the local bus route whose score of "localness of bus route" is low.

The attractiveness of passenger and the management condition are well but the productivity is not well in the bus routes belonging to (BE2, ME2). These need cutting in cost to improve the productivity.

The productivity and the management condition are not well in the bus routes belonging to (BE2, ME3) and (BE2, ME4). These need improving the management condition and the productivity. Since the scores of "level of service" and "speediness" tend to be high in the bus routes belonging to (BE2, ME3), these need cutting in cost to improve the productivity. The bus route belonging to (BE2, ME4) needs cutting in cost and increasing passengers by improving factors of "speediness" to improve the productivity.

Table 5. Average Principal Component Score of Each Bus Route Group

	Level of service				Speediness				Localness			
	ME1	ME2	ME3	ME4	ME1	ME2	ME3	ME4	ME1	ME2	ME3	ME4
BE1	0.59	0.37	—	—	-0.70	-0.01	—	—	-0.19	-1.16	—	—
BE2	—	0.69	0.26	0.35	—	1.13	1.46	-1.03	—	0.27	-0.41	1.04
BE3	—	—	-1.22	0.48	—	—	0.46	0.08	—	—	0.39	0.82
BE4	0.32	-0.66	-1.04	-0.56	-0.92	-0.24	0.17	-0.40	0.25	-0.66	-0.46	0.26

Table 6. Improvement target and policy of each group

	ME1		ME2		ME3		ME4	
	Goal	Policy	Goal	Policy	Goal	Policy	Goal	Policy
BE1	To improve management condition	To improve speediness in local route	To improve management condition	To improve speediness in local route	***	***	***	***
BE2	***	***	To increase productivity	To cut in cost	To improve management condition, To increase productivity	To cut in cost	To increase productivity	To cut in cost, To improve speediness
BE3	***	***	***	***	To increase passenger, To increase productivity	To cut in cost, To improve LOS	To increase passenger, To increase productivity	To cut in cost, To rationalize bus route formation
BE4	To increase passenger	To improve speediness in local route, To improve LOS in urban route	To increase passenger	To improve LOS	To improve management condition, To increase passenger	To improve LOS	To improve management condition, To increase passenger	To improve LOS, To improve speediness

All of the productivity, the attractiveness and the management condition are not well in the bus routes belonging to (BE3, ME3) and (BE3, ME4). Thus they are required to make quite a business effort. The sore of "level of service" is low in the routes belonging to (BE3, ME3). They need improving factors of "level of service" to improve the attractiveness of passengers and the productivity. The sores of "level of service" and "speediness" are not low in the route belonging to (BE3, ME4). They need basically rationalizing their formation to improve the attractiveness of passengers and the productivity.

The productivity and the management condition are well but the attractiveness of passenger is not well in the bus routes belonging to (BE4, ME1) and (BE4, ME2). Thus they need improving the attractiveness of passengers. The score of "speediness" is low in all 6 bus routes belonging to (BE4, ME1). 4 local bus routes in them are expected to increase passengers by improving factors of "speediness". On the other hand, 2 urban bus routes in them need improving the attractiveness of passenger by improving factors of "level of service" rather than "speediness". The bus routes belonging to (BE4, ME2) are mostly urban bus route, and need improving factors "level of service" to increase passengers.

The productivity is well but the management condition and the attractiveness of passengers are not well in the bus routes belonging to (BE4, ME3) and (BE4, ME4). Thus they need improving the management condition by increasing passengers. They need improving factors of "level of service" to increase passengers because the score of "level of service" is low in all of them.

5. CONCLUSION

The grouping method according to business management condition of bus route is proposed. Business management condition of each bus route can be indicated according to a combination of the plane of business effort and the plane of business environment.

This method is applied to the evaluation of 45 bus routes of private bus company K in Kumamoto city. Consequently, each bus route is classified under 16 categories. Roughly speaking, 20 bus routes are inexpensive and profitable, 6 bus routes are inexpensive and unprofitable, 2 bus routes are expensive and profitable, 17 bus routes are expensive and unprofitable.

Furthermore, the characters of bus route are summarized by principal component analysis, because business management elements of each bus route are characterized efficiently. The result of this principal component analysis and grouping of bus route according to business management condition are combined, and the improvement policies of management are proposed. Through this method, the subsidized bus route can be distinguished efficiently, and the improvement policy can be shown for the bus routes without public subsidy definitely. These results will be helpful in assessing business management condition when public subsidy is expended in operating bus service.

REFERENCES

Haraguchi, Y., Takayama, J., Shioji, K. and Kato, T. (2001) A study on the examination system of planning the bus route network. **Papers on City Planning, No.36, CPIJ**, 601-606.

Kumamoto Transport Plan Council (1999) Report of 3rd person trip survey in Kumamoto city area.

Regional Transport Office (2001) To ensure regional transport. **Local Bus Manual 2001**, Passenger Transport Division, Road Transport Bureau, Ministry of Land, Infrastructure and Transport Government of Japan.

Sugio, K., Isobe, T. and Takeuchi, D. (1999) Proposition of desirable management policies by various bus-route types considering characteristics of both business and public enterprise : Using gaps between potential and actual stages as key concept., **Infrastructure Planning Review, Vol.16**, 785-792.

Sugio, K., Isobe, T. and Takeuchi, D. (2001) Development of supporting system for bus network planning applying GIS : Bus route assessment based on potential demand. **Infrastructure Planning Review, Vol.18, No.4**, 617-626.

Takeuchi, D. and Yamada H. (1991) Theory of public subsidies for city bus and development of route-potential as a measurement for that decision making. **Journal of Infrastructure Planning and Management, No.425, IV-14, JSCE**, 183-192.

Tamazawa, M. and Tokunaga, Y. (2002) Comparison of social cost reduction of bus priority measures. **Infrastructure Planning Review, Vol.19, No.4**, 691-698.

Viton, P. (1981) A translog cost function for urban bus transit. **The Journal of Industrial Economics, Vol.29, No.3** , 287-304.