Cost Analysis of Community Bus System Operations in Japan

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In Japan, many community bus systems were already in operation when the bus service industry was deregulated in 2002. Most of these services depend on subsidies from the local municipalities and many of them have now been forced to discontinue due to budget cuts of the subsidizing local governments.

As a case study of a successful operation of a community bus system, the cost analysis of Sumiyoshidai Kurukuru Bus system in Kobe, Japan, which is operated without public subsidy, has been performed. In the cost analysis, formulas for estimating various costs, which are applicable to other bus services, are proposed. From the cost analysis and the sensitivity analysis of Kurukuru Bus, the reasons for its success have been found to be its relatively short service length of eight kilometers and lower level of driver wages.

Keywords: community bus, cost analysis, bus management, bus deregulation

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1. INTRODUCTION

As the problem of global warming becomes increasingly more important, renewed attention has been placed on public transportation systems even in many developed countries. The recent development of public transportation systems in Korea reported by Kang (2005) and Kim (2005) is a good example of applying a modern approach to the design of an integrated public transportation system. In addition to large-scale comprehensive transportation systems, local-scale public transportation systems are also important. One nagging problem in starting a system is the balance between the costs of operation and the quality of the provided service. The proper estimation of the operational costs is of utmost importance. White and Turner (1987), Banister and Mackett (1990), and Banister (1997) describe the minibus service systems in Great Britain. Kirl (1990) describes similar small community bus systems in the United States. We also focus on a small community bus system and analyze the costs and the viability of non-government operated user based systems. In this respect, Nakamura (2006) shows possibilities of community bus systems in Japan, and Tomita and Doi (2007) implemented an experimental analysis of a community bus linking museums.

In Japan, many community bus systems were already in operation after the bus service industry was deregulated in 2002. Most of these services depend on subsidies from the local municipalities and many of them have now been forced to discontinue due to budget cuts of the subsidizing local governments. Kurukuru Bus System is one of a few bus systems in Japan that have been successful without funds from the local government. When this service was being planned, Morikuri (2007) pointed out that it was important that the resident users, the operator and the local government had to work together in making the plan and solving possible conflicts. However Morikuri (2007) did not examine detailed quantitative analyses of the demand and supply of the bus service and the factors to balance the cost and revenue associated with the operation of the Kurukuru Bus System.

In addition, the detailed empirical cost analysis for particular bus-routes has not been viewed. According to the "Handbook of Bus Transportation Service Planning" published by the Infrastructure Planning Committee of Japan Society of Civil Engineers (2006), the detailed bus operation cost data is not available.

In this paper, we propose formulas for estimating the operational costs of particular bus routes, which are applicable to any bus services. However, these formulas are suited for making cost estimates of community bus systems like Kurukuru Bus, for which accurate cost estimates are crucial for successful management. Then as a case study, the formulas are applied to analyze the structure of the costs of operating the Kurukuru Bus System by utilizing data provided by Minato Kankou Bus Company. Finally, the sensitivity analysis is performed to obtain an idea about how such bus systems should be designed in terms of the costs of operation. The method and the results of the present case study will be useful for planning financially viable local bus systems in many other cities.

2. FORMULA TO ESTIMATE THE COST OF BUS OPERATIONS

2.1 The Cost of Items Needed for Bus Operations

In formulating the equation for estimating the operational costs of a bus system, the items related to the costs are enumerated and the items we use in the present study are selected.

Table 1 is a list of the cost items associated with the operation of a bus system. The items vary depending on the locality and the type of operation, but the fraction of the transportation cost is generally in the range of 85% to 95% of the total cost. The personnel, fuel, vehicle maintenance costs and depreciation are approximately 90% of the total operation costs.

〈Table 1〉 The cost of Items needed for bus operations and estimated items

Categories	Items
Operation costs	Driver's wage* Fuel costs* Vehicle lease fees* Vehicle maintenance costs* Insurance fees Rental fees of various facilities Facility taxes Accident compensation costs Road fees Other costs
Management costs in the back-office	Wage of staff in the back-office, Other costs.

Note: "*" means an item of cost estimated in this paper

The general management costs in the list are excluded from the estimated items since they are not needed in the present case of adding a new route. Rental fees of various facilities, vehicle lease fees, facility taxes, accident compensation insurance and road fees are not included since they are only about ten percent of the bus operation costs and the exact amounts vary depending on the size of the system and the way of operation. The items that the present calculations consider are driver personnel, fuel, rental fees of the vehicles and the vehicle repair costs. In the examination of the actual costs, the items that are not included in the present computation should be augmented in one way or another.

2.2 Formulation of Equations to Estimate Costs

The driver personnel wages, fuel, vehicle rental and repair costs are estimated based on the number of buses to be used and the required number of drivers. The cost estimate is done on a per day basis.

2.2.1 Numbers of buses and drivers

In estimating the amount of buses required, the number needed during the critical time of peak hours is used. It is possible to move buses from one line to another if the peak hours are different, but we assume that buses are not shared by different lines. The number of buses (n) needed during peak hours is obtained by dividing the total distance-buses in kilometer-buses (the numerator of Equation (1)) required in one hour of peak time by the average speed of the bus (v) expressed as the minimum integer greater than this quotient.

$$n \geq \frac{L \cdot f}{v} > n-1 \qquad (1)$$

where

n : Number of buses

f : Frequency of service during peak our (per hour)

L : Route length of round-trip (km)

v: Average bus speed during peak hour (km per hour)

The number of bus drivers is obtained by dividing the total number of bus-operation-hours by the number of hours one driver works in one week. The integer number (m) of the drivers is given by:

$$m \geq \frac{7 \cdot A \cdot L / \bar{v}}{bd} > m-1 \qquad (2)$$

where

m : Number of bus drivers

A : Number of round-trip services in a day

$\bar{v}$: Average bus speed (km per hour)

b : Bus driving hours of one driver in a day (hour)

d : Number of driver's working days in a week (days)

2.2.2 Personnel cost of drivers

The personnel costs per day of drivers can be obtained by multiplying the number of drivers by the cost per day calculated from the annual driver's wage and is given by:

$$C_p = \frac{m \cdot w}{365} \qquad (3)$$

where

C_p : Daily drivers' wages (in yen per day)

m : Number of drivers

W : Annual wage of one driver (yen)

2.2.3 Fuel cost

The cost of fuel (C_o) needed to run the buses is calculated by dividing the total distance the buses travel per day by the length a bus can travel on a liter of diesel fuel.

$$C_o = \frac{A \cdot \hat{L} \cdot p_o}{e} \qquad (4)$$

where

C_o : Fuel cost (yen per day)

p_o : Price of diesel fuel (yen per liter)

e : Bus running distance per a liter of diesel fuel (km per liter)

2.2.4 Vehicle cost

The cost of vehicles (C_r) is the payment per day of the loan to acquire a bus over the life of the bus, and is

$$C_r = \frac{r_v}{365} \times n \qquad (5)$$

where

C_r : Bus lease fee in a day (yen per day))

r_v : Bus lease fee in a year (yen per year))

2.2.5 Vehicle repair cost

The vehicle repair cost (C_k) is the total repair costs per year C_{year} converted to a daily cost multiplied by the number of buses

$$C_k = \frac{C_{year}}{365} \times n \tag{6}$$

where

C_k : Repair cost of one bus in a day (yen per day)

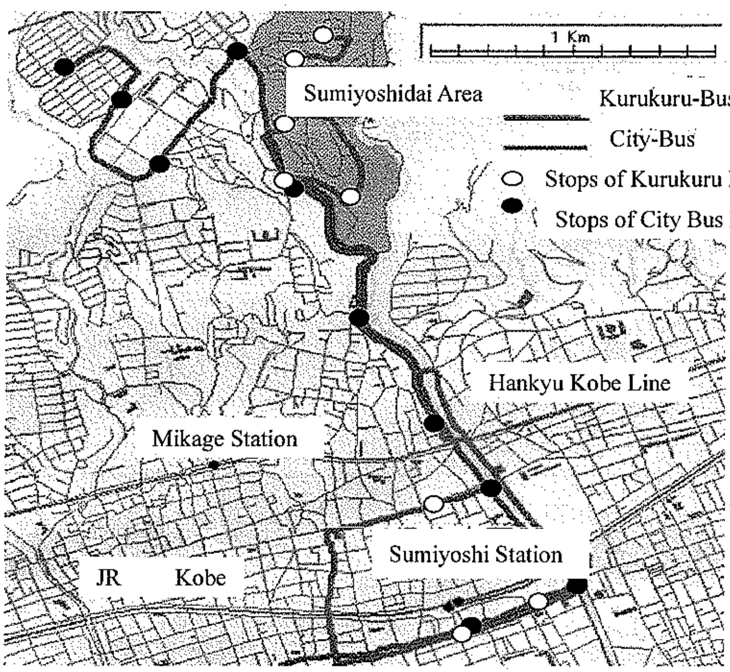
C_{year} : Annual repair cost of one bus in a year (yen per year)

As a result, the total of equations (3) through (6) is the cost of operating one line per day.

3. COST STRUCTURE OF KURUKURU BUS

3.1 Outline of Kurukuru Bus

Kurukuru Bus links Sumiyoshi Station of Japan Railway (JR) and the Sumiyoshidai area which is located about four kilometers north of Sumiyoshi Station, as shown in Figure 1. The average elevation of this area is about 250m higher than that of Sumiyoshi Station and there is a variation of 100 meters in elevation within the area. The population of this area is 3,900 according to the 2005 population census.



⟨Figure 1⟩ Sumiyoshidai area and route map of Kurukuru-bus & Kobe-city-bus

The Kurukuru Bus runs from Sumiyoshi Station to the Sumiyoshidai terminal bus stop in about twenty minutes one way as shown in Figure 1. There are nine stops between these terminals and six of them are located within the Sumiyoshidai area. There is a city transit bus that has been in service for many years before the Kurukuru Bus started in 2005 that overlaps a part of the route of the City Bus, but the City Bus does not run in the Sumiyodhidai area. The Kurukuru Bus system was created to meet the demand of the area's residents who desired a bus service in this hilly area.

The number of daily users is around 900 and has been stable over the four years of its operation. The frequency of the bus service is four services per hour in a sixteen hour time span from 6AM to 10PM every day. The regular fare is 200 yen per ride and 180 yen per ride if a ticket book is purchased, which many riders do. The summary of the data used to compute the operating costs is given in Table 2.

⟨Table 2⟩ Attributes of Kurukuru bus

Attributes	*Values*
Frequency of bus services in peak hour : f (unit: number of round-trips per hour)	4
Bus route length of round-trip : L	8.3 (km)
Average bus speed in peak hour : v	12 (km/h)
Average bus speed in a day : $\overline{v}$	12 (km/h)
Frequency of bus services in a day : A (unit: number of round-trips per day)	55.5
Bus driving hours of one driver in a day : b	7 (h/person)
Number of driver's working days in a week : d	5 (days/person)
Annual wage of one driver : W	4,200,000 (yen)
Price of diesel fuel : p_0	100 (yen/liter)
Bus running distance per a litter of diesel fuel : e	4 (km/liter)
Bus lease fee of one bus in a year : r_v	1,500,000 (yen/year)
Annual repair cost of one bus in a year : C_{year}	700,000 (yen/year)

3.2 Results of Cost Estimate

The result of estimating the number of buses is 3 and the number of drivers is 8. The number of buses coincides with the actual ones in service and the number of drivers is also close to the actual amount of drivers, though exact comparisons are difficult. The amount of each cost item is as shown in Table 3.

⟨Table 3⟩ Results of cost estimate

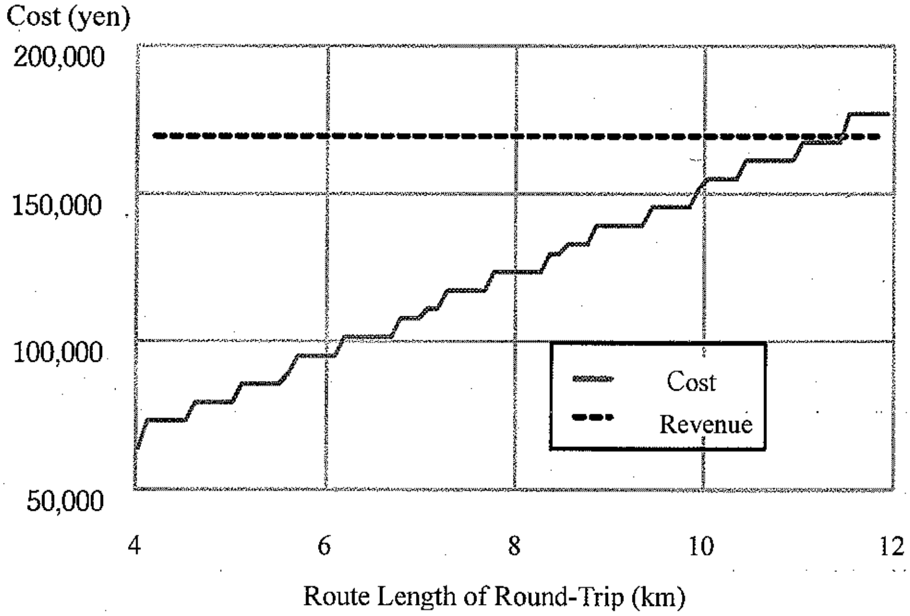
Items		*Estimated costs (yen per day)*	*Ratio (%)*
Drivers' wage	(C_p)	92,055	76
Fuel cost	(C_o)	11,516	9
Bus lease cost	(C_r)	12,329	10
Repair cost of bus	(C_k)	5,753	5
Total operation cost	(C)	121,653	100

The total cost of operation per day is 120,000 yen, 76 percent which are personnel costs. These results do not include the fees for using facilities, insurance fees, a general management fee, and the driver's wage is estimated from an average of private bus companies.

3.3 Sensitivity of the Operating Cost

3.3.1 Route length and the total cost

The total length of the Kurukuru Bus route is eight kilometers. The changes in costs due to changes in the length, for example, to routing changes or detours to a neighboring area, have been computed. The results are shown in Figure 2. The revenue shown in the figure is the current fare of 900 people per day.



Note: The route length of Kurukuru Bus is 8.3km.

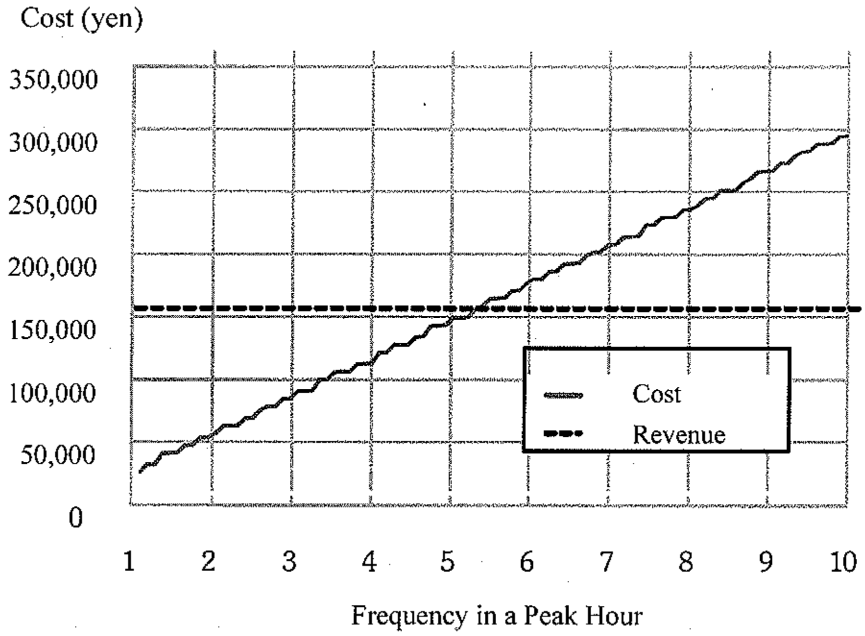
⟨Figure 2⟩ Relationship between route length of round-trip and bus operation cost

Figure 2 indicates that the cost increases stepwise with the increase in the service length. This is due to the fact that the number of buses and the number of drivers increase discretely. As the number of buses increases by one, the cost increases by 6,100 yen/day (or 22 million yen/year) and as the number of drivers increases by one, the cost increases by 11,500 yen/day (or 4.2 million yen/year). When both occur at the same time, the cost increases by 17,600 yen/day which is as much as 6.4 million yen/year. The influence of these discrete increases in the costs cannot be overlooked. In the design stage of bus routes, the lengths of operating services should be kept on the lower side of the step increase when the comparable increase in the fare revenue cannot be expected.

According to Figure 2, the costs overrun the fare revenue when the service length increases over twelve kilometers, and extending the service length beyond this limit will not be a good choice on the basis of a cost/revenue balance. This figure also shows that it is more desirable to reduce the service length. If the length is reduced, some riders may switch to other transportation like bicycles and motorcycles or even walking in which case the revenue itself will be reduced. Normally more people use bicycles or walk if the bus-route length becomes shorter than about four kilometers. On the other hand if the bus-route length is longer than twelve kilometers, the cost exceeds the revenue as shown in Figure2. Therefore, the service route of eight kilometers is adequate for the balance of cost and revenue. This is another reason that Kurukuru Bus has been successful.

3.3.2 Service frequency and the total cost

Figure 3 shows how the costs change if the service frequency is changed from the current four services an hour. Similar to the changes due to the changes of the route length, the costs increase in a stepwise manner. This figure indicates that if the number of riders is assumed to stay the same as now, which means that the number is already a maximum of one, the balance of costs and revenue occurs when the number of services is 5.

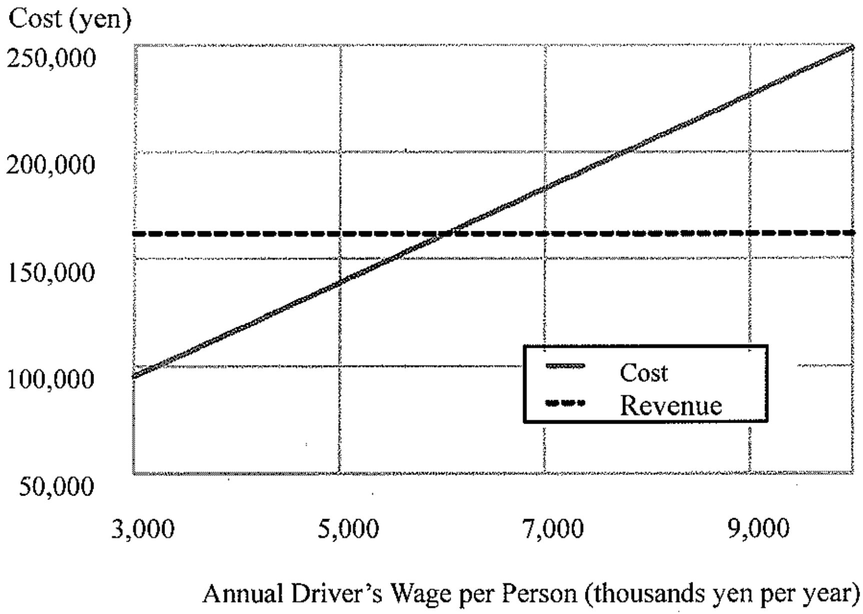


Note: The frequency of Kurukuru bus is 4.

⟨Figure 3⟩ Relationship between bus service frequency and operation cost

3.3.3 Driver's wages and the total cost

The differences due to the changes in the driver's wages are shown in Figure 4. In this case, unlike the cost changes with the number of buses and the increase in the service lengths, the cost increases continuously with the increase in wages. It is seen that as the annual wage increases one million yen, the costs increases by 250,000 yen per day. The balance between the costs and the revenue occurs when the annual wage is six million yen. If the same bus system was operated by the City of Kobe which pays their drivers about 9 million yen per year (Kobe News Paper, 2008), the system's financial balance would be in the red. On the other hand, if it is assumed that the wage which Kurukuru Bus pays the driver is equal to the average one of private bus companies, that is 4.2 million yen per year, the net benefit is about 40 thousand yen per day.



⟨Figure 4⟩ Relationship between annual driver's wage and bus operation cost

4. CONCLUSIONS

As a case study of a successful operation of a community bus system, the cost analysis of a successful bus system, Kurukuru Bus of Kobe, Japan, which is operated without public subsidy, has been conducted. In the cost analysis, formulas for estimating various costs are proposed. These formulas are applicable to other bus services in other areas including countries outside of Japan. The sensitivity analysis, in particular, is found useful in planning a new system or in revising existing systems. From the cost analysis and the sensitivity analysis of Kurukuru Bus, the reasons for its success have been found to be its relatively short service length of eight kilometers and lower level of the driver wages.

In the present analysis, the needs of the users were not studied, but the reasons that it could maintain the high level of ridership is due possibly to 1) the relatively high population of 4000 people in the serviced area, 2) high service frequency of four per hour and 3) close communication with the residents as to finding the user's needs and meeting them. However, these need to be studied further.

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REFERENCES

Banister, D.J. and Mackett, R.L., 1990, "The Minibus: Theory and Experience, and Their Implications", *Transport Reviews* 10(3).

Banister, D., 1997, "Bus Deregulation in the UK: the First Decade", in McConvilla, J. ed., Transport Regulation Matters, Pinter: 31-51.

Infrastructure Planning Committee of Japan Society of Civil Engineers, 2006: Handbook of Bus Transportation Service Planning, Maruzen (in Japanese).

Kang, M.S., 2005, "Toward Better Public Transport: Experience and Achievement of Seoul", Seoul Development Institute.

Kim, G., 2005, "Renovation of Seoul Transit System: Supported by ITS", Seoul Development Institute.

Kirl, M.R., 1990, "Small Community Bus Service", in Due, J.F. et al, Transportation Service to Small Rural Communities: Effects of Deregulation, Iowa States University Press: 73-111.

Morikuri, S., 2007, "Sustainable Old New-Town Realized by Kurukuru Bus", *Transport Engineering (in Japanese).*

Nakamura, F., 2006, "How to Plan and Implement Community Bus", *Gendai-Bunka-Kenkyusho (in Japanese).*

Tomita, Y. and Doi T., 2007, "Possibility and Problems of a Community Based Museum Bus to Support Local Culture in the Hanshinkan Area", *Journal of 7^{th} East Asia Society of Transport Studies* 7.

White, P.R. and Turner, R.P., 1987, "Development of Intensive Urban Minibus Services in Britain", *Logistics and Transportation Review* 23 (4).

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