OD-BASED MEASURES FOR BUS ROUTE RESTRUCTURING IN THE OBIHIRO AREA*

by Ma. Rojarlyn GAID**, Shinji YOKOYAMA***, Kunihiro KISHI****, Takashi NAKATSUJI**** and Keiichi SATO*****

1. INTRODUCTION

The use of public transport is continuously decreasing in Obihiro City because of population imbalance, changes in travel behavior, and motorization (as seen in the increase in the number of driver's license-holders). Peak hour traffic volume has gone even lower than half its value in the last thirty years. The role of public institutions has also grown bigger as they now need to address altogether issues on development, the aging population, environmental conservation, and energy consumption. More specifically, the challenge of the local government in Obihiro is to determine the best transportation mode that will sustain people's mobility needs given the limited sources of revenue. In the Obihiro area (*Obihiro City, Otofuke Town, Makubetsu Town and Memuro Town*), car usage is more than 80%. In contrast, for the past ten years, bus ridership in urban areas only shares a meager 2%. To promote a more efficient and transit-oriented community, a new method of assigning bus services is needed.

This study intends to restructure the network of bus routes specifically in the Obihiro area. Using the data obtained from the Person Trip Survey conducted in 2005, existing routes are evaluated vis-à-vis PT zones. Using OD matrices, movement patterns are determined and new routes are assigned.

2. METHODOLOGY

(1) Route Evaluation

Movement Patterns. In 1990, Obihiro city had a daily average of 371,641 trips. In 2005, it decreased slightly to 367,152 trips per day. As for car trips, there has been a significant increase in the frequency of trips headed towards the suburban zones and also intra-zonal trips within the city proper. The section between the Tokachi River and the Satsunai River also has the propensity to increase. In Obihiro, there is a considerable number of intra-zonal trips in the West-Obihiro, West, and South districts. Moreover, the West district is highly characterized by frequent inter-zonal trips. Trips headed to the inner city also have the tendency to decrease. Commercial development in the suburban areas may have brought about changes in the population distribution, which in turn, cause the changes in trip densities.

Mode Distribution. Car dependence is highly observable in the Obihiro area. According to the 2005 PT Survey, car trips alone make up 78% of the total trips. In contrast, bus ridership takes up only 2%. About 60% of car-users are over 65 years of age, notwithstanding the fact that it is precisely this age group for whom buses are highly serviceable. In 1995, buses served over 10,000,000 trips in a year; but in 2000, this figure shrunk to about 5,100,000.

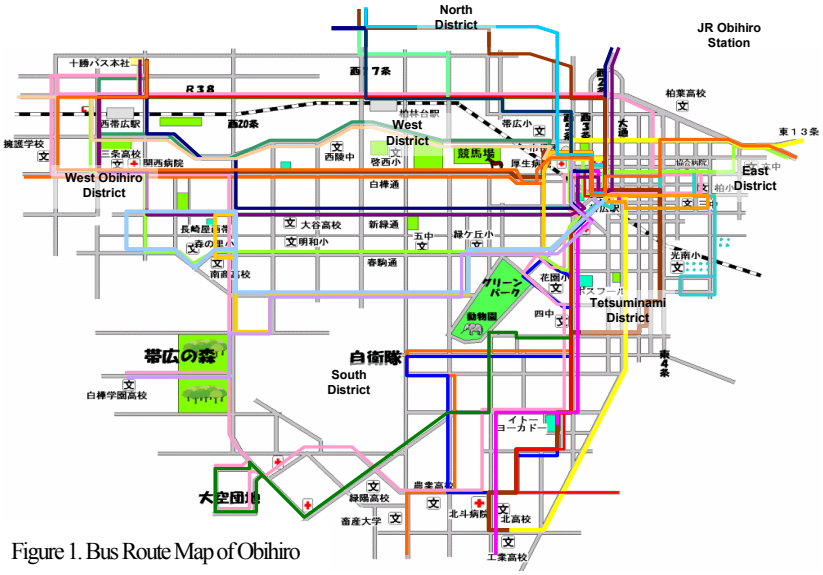

Figure 1. Bus Route Map of Obihiro

Existing Route Network. Routes traversing the Obihiro station play a key role in Obihiro (Fig. 1). The Tokachi Bus main office in West-Obihiro and the bus terminal at the Obihiro station square play key roles as origin and destination points, respectively. There are many routes moving

*Keywords: Public Transportation Planning, Bus Route Reconstruction, Person Trip Survey, OD Matrix, Compact City
** Student Member of JSCE, Graduate School of Engineering, Hokkaido University (North 13 West 8, Sapporo, 060-8628, Japan, TEL 011-706-6217, FAX 011-706-6216)
***Hokkaido Railway Company
****Member of JSCE, Dr. Eng., Graduate School of Engineering, Hokkaido University (North 13 West 8, Sapporo, 060-8628, Japan, TEL 011-706-6209, FAX 011-706-6216)
***** Member of JSCE, Dr. Eng., Hokkaido University, School of Public Policy (North 13 West 8, Sapporo, 060-8628, Japan, TEL 011-706-6215, FAX 011-706-6216)
*****Fellow of JSCE, Dr. Eng., Hokkai School of Commerce (6-6-10, Toyohira, Toyohira-ku, Sapporo, 062-8607, Japan, TEL 011-841-1161, FAX 011-824-0801)

east and west. As such, many routes overlap along the Shirakaba street. Much to the inconvenience of commuters, there are also transfers needed even between adjacent areas in the city. In Obihiro, access to the Obihiro station is given more premium than the routes connecting the South and West districts. This alone proves that the bus route network does not address the mobility needs of the people. The existing bus routes, designed during 1955-65, can no longer support changes in the city structure.

Mobility Needs. A correlation is not found between the number of bus services and the number of OD trips at every zone. There is a huge gap between mobility needs and bus serviceability. There are zones with large demand for travel but no available bus services. Likewise, there are zones without much OD trips but are served by bus routes. No correlation is found either between the number of bus services and the number of OD trips done by bus. In other words, the good number of bus services, in total, does little to increase the number of users. Improving the network, especially by making more direct routes, can stimulate activity in the inner city area.

(2) Route Classification

Route Classification Based on OD Patterns. An OD matrix is made based on the 2005 PT data. Mobility needs then are compared with the bus routes from the OD list which displays the number of bus services at every section. With these comparisons, four patterns are devised to classify existing routes. Route evaluation, in essence, is based on each route's conformity to a certain pattern characterized by the total number of trips and the number of services per route.

Table 1. OD Patterns for Route Evaluation

PATTERN	Trip Rate	Bus Service Rate	Remarks on OD
1	High	High	with satisfactory bus service
2	High	Low	lacks bus services
3	Low	High	has excessive bus services
4	Low	Low	needs to eliminate bus route

Table 2. Summarized Route Classification

ROUTE	TRIP SHARE RATE	PERCENTAGE OF ODs with 0 TRIP RATES	OD PATTERN	CHANGE ROUTE/ SERVICE RATE
Touzai Junkan Sen	1.8%	62.0%	4	O
Nanboku Junkan Sen	2.2%	78.0%	4	O
Minami Shou Sen	1.5%	58.0%	3	O
Higashi 8 Jou Sen	0.9%	85.0%	4	O
Makubetsu Sen	1.3%	69.0%	4	O
Obihiro .RikubetsuSen	1.4%	66.0%	4	O
Minami Akinaa Kashiya Sen	1.6%	64.0%	4	O
Kanjou Sen	2.0%	66.0%	4	O
Memuro Sen	1.2%	57.0%	2	O
Memuro Minami Sen	1.4%	69.0%	4	O
Shinmachi Sen	1.3%	47.0%	2	O
Otofuke Sen	1.7%	54.0%	3	
Fun .Kizumi Sen	1.5%	88.0%	3	O
Kami Shihoro Sen (1)	1.8%	61.0%	3	
Nukabira Sen	1.8%	61.0%	3	
Hirou Sen	2.3%	66.0%	4	
Oozora Danchi Sen	2.1%	67.0%	3	
Jieitai Inada Sen	2.3%	61.0%	3	
Dai Sen	2.3%	61.0%	3	
Ryou Tokoro Sen	1.2%	76.0%	3	O
Ichi naka Sen	1.2%	76.0%	3	O
Kita Oya touri Sen	1.2%	76.0%	3	O
Untenmenkyoshikenba Sen	0.9%	78.0%	3	O
New town 23 Jou Sen	1.9%	49.0%	2	O
Obihiro no Mori/ Shirakaba Gakuen Sen	1.9%	53.0%	2	O
Minami Shougyou Koukou Sen	1.6%	64.0%	2	O
Naka Suzuran Sen	1.1%	82.0%	3	O
Hoken Fukushi Sentaa Sen	1.0%	84.0%	3	O
Yuuhi oka Danchi Sen	2.2%	70.0%	3	
Oto fuke Koukou Sen	2.4%	66.0%	3	
Shikaribetsuko Sen	2.6%	65.0%	3	
Shika tsui Sen	2.6%	60.0%	3	
Shin Obi sen	2.6%	60.0%	3	
Kami Shihoro Sen (2)	2.6%	60.0%	3	

Identifying the OD Pattern for Each Route. To identify the routes observing the aforesaid patterns, the zones traversed by each route are extracted. Isolating each route, an OD matrix is devised accordingly. The share of bus trips in the mode distribution and the rate of ODs with zero trips are calculated from this matrix, from which the number of bus services available can readily be compared with the OD trip rates. Table 2 summarizes the result of this classification for all routes within Obihiro. As seen below, not one route matches Pattern 1. Most routes match pattern 3, especially those originating from and terminating at Obihiro station. Most routes that match pattern 4 are those which are eastward. In this study, the following measures are proposed based on the aforementioned patterns.

Pattern 1: Retain route. : Maintain bus service standards.
Pattern 2: Establish new route. : Increase bus service rates.
Pattern 3: Reduce service rates : Employ DRT services.
Pattern 4: Abolish route, or employ DRT services.

(3) Route Reorganization. In re-routing, three factors are taken into consideration: mobility needs, route evaluation results, and directives for city planning.

Basis for Transportation Masterplan. Obihiro appears to have a diffusing structure. Efficiency-wise, this seems problematic, and depopulation further aggravates the situation. Population distribution is essential in developing an urban traffic master plan for the Obihiro area. In this vein, the committee on transportation planning is promoting a compact city-oriented design by assigning multiple sub-centers around the city.

Within one kilometer around each sub-center are existing commercial establishments, medical facilities, and government offices. Figure 2 indicates the sub-centers with dense trip

distribution. As for bus transit efficiency, all districts are accounted for and a radial main route is designed to connect all sub-centers to Central Obihiro. In its entirety, the restructured route network plan is based on the concept of designing compact cities.

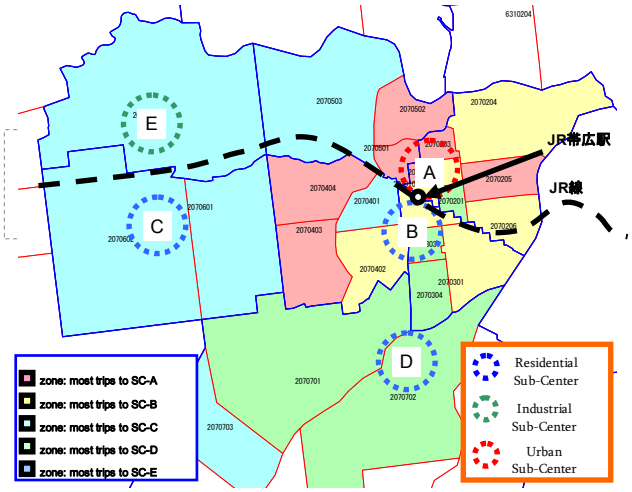

Figure 2. Sub-Centers in Obihiro

Establishing New Routes. In this study, two new routes are proposed (as in figure 3), based on OD patterns and the current route map, linking schools and government offices to the district's sub-center.

***First New Route*:** The North district has more trips to the West district and West-Obihiro district than the central district. However, there are no bus transits directly connecting the North and West districts. Takushoku buses are routed mainly towards the North district; but to the inconvenience of passengers heading to the west district, these buses have to pass through Obihiro station (central district) first. Therefore, it is suggested that a route directly connecting the North district with the West and West-Obihiro districts be constructed. The East district is selected as the origin instead of the Obihiro station because most recorded bus trips (school trips) run from the northeast side.

***Second New Route*:** There are relatively many trips between the South district and the West district, most of which include schools and welfare institutions as destinations. However, there are no routes that link these districts other than the Kanjousen (line). As for this line, there are only four trips a day. Therefore, it is proposed that a second route be established to connect the sub-center at West-Obihiro district to that in the south district by passing through the West district.

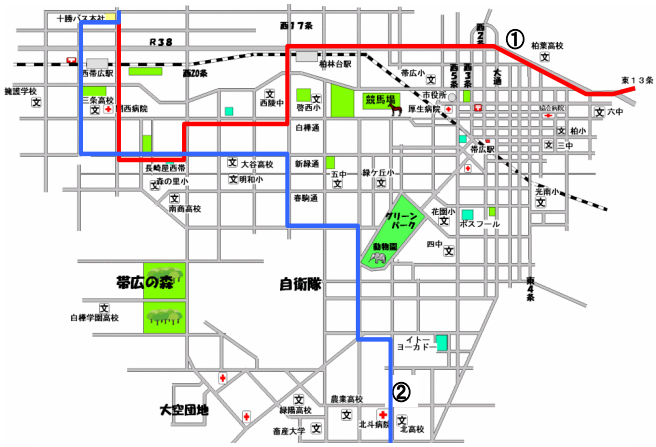

Figure 3. Two Proposed Additional Bus Routes

DRT-Serviced District. Routes observing patterns 3 and 4 are highly inefficient. From the viewpoint of efficiency, it is proposed that the following areas receive DRT (demand-responsive transportation) services: Oozora Danchi, Green Park, the Jieitai base at the East district and the former base in the South district. The East district has low trip rates and is traversed only by a few routes: inter-city buses, a circulation bus, and intra-zonal buses. Convenience is verifiably low and DRT is deemed suitable because of the district's low population.

3. ANALYSIS

(1) Evaluation Index for the Restructured Route Network

The effect of the total service distance, the number of trips, and the travel time required are examined as they cause the value of the evaluation index to change when the new route network is introduced. It is important to maintain the same level of service while reducing the total service distance, so that bus utility will increase to the advantage of the same bus service provider. In table 3, it is shown how ODs with indirect routes and the total number of trips (back and forth) change because of the restructured route network. As a result, direct routes can now replace the routes following Pattern 2.

Table 3. OD & Trip Generation before and after Re-Routing ·

OD Trips with Indirect Routes

BUS SERVICE CHARACTERIZATION	POST		PRE	
	OD	Trip	OD	Trip
OD Pattern 1	0	0	0	0
OD Pattern 2	0	0	25	21071
OD Pattern 3	0	0	0	0
OD Pattern 4	241	27158	165	17131
SUM	241	27158	190	38202

OD Breakdown after Re-Routing

Service by DRT	35	5166
Indirect Routes	103	15575

As for routes conforming to Pattern 4, choosing the routes, which originate from a low trip attraction zone to other destination zones, can be encouraged; and therefore, the level of service can be improved. In addition, table 4 shows how in some ODs, travel time for buses is reduced because of the reorganized routes.

Table 4. Change in Bus Travel Time (Shortened Travel Time)

			01207 帯広 (Obihiro)												
			02		04			05			06		07		08
			03	04	02	03	04	01	02	03	01	02	01	02	01
01207 帯広	02	03		-1	0	-4	0	0	0	0	-5	-7	0	0	0
		04	-1		0	-7	-2	0	-11	-5	-4	-2	0	0	0
	04	02	0	0		-3	-19	0	0	0	-5	-24	-10	-11	-10
		03	-4	-7	-3		-27	0	-10	-29	-38	-5	-16	-4	-26
		04	0	-2	-19	-27		0	-8	-26	-33	-2	-30	-23	-20
	05	01	0	0	0	0	0		0	0	0	-55	0	0	0
		02	0	-11	0	-10	-8	0		0	-9	-11	0	0	0
		03	0	-5	0	-29	-26	0	0		-28	-65	0	0	0
	06	01	-5	-4	-5	-38	-33	0	-9	-28		0	-18	-6	-29
		02	-7	-2	-24	-5	-2	-55	-11	-65	0		-2	-24	-77
	07	01	0	0	-10	-16	-30	0	0	0	-18	-2		-5	-23
		02	0	0	-11	-4	-23	0	0	0	-6	-24	-5		-9
	08	01	0	0	-10	-26	-20	0	0	0	-29	-77	-23	-9	

CONSTANTS:
C = ¥243 per km (Standard Operating Cost)
T = 32 [Standard No. of Services (2/hour, 6:00-21:00)]

VARIABLES:
x_1 : First New Line
x_2 : Second New Line
x_3 : Minamishou Line
x_4 : Shinmachi Line

PROGRAM: max $(x_1 + x_2 + x_3 + x_4)$ subject to

$12.1x_1 + 14.4x_2 + 10.1x_3 + 10x_4 \leq 1933$ (Operation Distance)
$2940x_1 + 3499x_2 + 2454x_3 + 2430x_4 \leq 469719$ (Operating Cost)
$32 \leq x_1 \leq 64$ (Number of Services)
$32 \leq x_2 \leq 64$
$X_3 \leq 15$
$X_4 \leq 32$

Figure 4. Linear Programming Application

(2) Determining the Number of Bus Services

With consideration for the routes under pattern 4 and the shortening of total service distances, the number of services the new routes are to have and the increase in service frequency for routes under Pattern 2 are henceforth examined. Linear programming is employed to determine by how much the number of bus services can be increased without changing the total service distance. This is an optimization technique whereby an objective function is minimized given certain limiting conditions (see figure 4). Variables to be maximized represent: (1) the first new route; (2) the second new route; (3) the Minamishou line; and (4) the Shinmachi line. The increase in the number of two-way trips in the Minamishou line and Shinmachi line are calculated. Restraining conditions include (1) the total operation distance, (2) the number of services, and (3) the operational cost. The results of the calculation are shown below in table 5. In table 6, the total operation distance and change in the number of services are shown. Total operation distance achieves very minimal change while the numbers of services increase drastically. It can be said that the level of service is improved without adding to the burdens of bus companies.

Table 5. Resulting Number of Bus Services

	NUMBER OF SERVICES		TOTAL SERVICE DISTANCE
	BEFORE RE-ROUTING	AFTER RE-ROUTING	
First New Line	-	57	774.4
Second New Line	-	60	720
Minamishou Line	29	45	342.2
Shinmachi Line	28	40	600

Table 6. Total Operation Distance and Change in the Number of Services

	TOTAL OPERATING DISTANCE	REQUIRED TRAVEL TIME	NUMBER OF SERVICES
BEFORE ROUTE RESTRUCTURING	17148	21284	750
AFTER ROUTE RESTRUCTURING	17133	19758	767

4. CONCLUSION AND RECOMMENDATION

In this study, an OD matrix derived from the PT Survey data and the existing bus routes are used to qualify four route patterns, each pattern requiring specific measures to improve the route network in the Obihiro area. Separating intra-zonal routes and DRT-based routes are done to ensure that: (1) mobility needs around sub-centers are addressed; and (2) public transport services are effective.

In recent years, route assignment for buses in depopulated cities has become increasingly difficult. In a predominantly car-dependent city, such as Obihiro, local government subsidies to public transport enterprises can do more harm than good. But removing public transport as an option can also be to the impediment of the inhabitants of Obihiro. It is recommended that a new form of transportation service, such as demand-responsive buses, will be a more viable option rather than the provision of conventional route buses. Moreover, demand prediction will be discussed as this study progresses.

REFERENCES

[1] Howard P. Benn. Bus Route Evaluation Standards, TCRP, synthesis of transit practice 10, Transport Research Board, National Academy Press, Washington DC, 1995

[2] 2006 Obihiro Area General Urban Traffic System Investigation (Masterplan Development Investigation), Hokkaido, March 2006 (in Japanese)

[3] Tokachi Bus Website: http://www.tokachibus.jp/index.php

[4] Takushoku Bus Website: http://www.takubus.com/