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STUDIES OF DEMAND AND PLANNING PROCESS FOR REGIONAL PUBLIC TRANSPORT

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Abstract:
Ensuring mobility is one of the most important issues of regional public transport planning. Passengers of buses in Japan tend to be decreasing with developing motorization, and some bus routes are abolished and the number of buses running tends to be decreased.

We think municipalities in Japan need to have a responsibility to ensure mobility for citizen, but they are lacking in skill and experience for public transport planning. Thus, we need to construct planning process guidance for public transport.

In this paper, we focused on buses and considered three things.

Firstly, we considered about the way of transport needs survey. We carried out questionnaire in Tama City, Tokyo, and considered the bias and coverage of trips in our survey by comparing with Person-trip survey.

Secondly, we constructed trip frequency models and modal split models. We can conclude that people without their own car tend to rise their trip frequency as the number of buses in the daytimes, and main factors of affecting choice of transport mode were distances to destinations, car ownership, and the level of mobility difficulties.

Finally, we simulated the break-even point of the number of buses when population density along a bus route was X people/km^2.

Key words: Regional public transport; Transport needs survey; Profitability; Mobility
Topic Area: B1 Public Transport and Inter modality

1. Introduction

Ensuring citizen's mobility is one of the most important issues of regional public transport planning. Passengers of community public transport (especially buses) in Japan tend to be decreasing with developing motorization. So, some bus routes are abolished and the number of buses running tends to be decreased. In addition, current level of bus service tend to lose touch with citizen's needs, and bus service providers in Japan face the dilemma of further decrease of passengers.

Under these conditions, in Japan, deregulation of buses had implemented in February 2002, and some bus routes and services in rural or suburban areas may go out of existence. So, municipalities in Japan need to have a responsibility to ensure mobility for citizen like what local government of Europe and United States implement. Some municipalities in Japan run bus or minibus partly in low population density areas or where bus service providers gave up running buses. However, they have not yet led to ensure mobility fundamentally. In addition, municipalities are lacking in skill and experience for public transport planning. So, we need to construct planning process guidance for public transport (especially buses) as soon as possible.

In this paper, we considered four things.

(1) The way of transport needs survey which is the basis of public transport planning.
(2) Factors effecting demand for community public transport (especially buses).
(3) Factors of decreasing activities.
(4) Relationship between population density along a bus route and profitability.

2. Survey for transport needs

2.1 Object region

We conducted questionnaires about transport needs in Tama City, Tokyo, Japan. Tama City is a suburban city with a population of about 140,000 and its population density is 6,600 people/km^2. Figure 1 shows the location of this city.

There are four railroad stations in this city; Tama-Center, Nagayama, Seiseki-Sakuragaoka, and Karakida Staion. Stations except Karakida have a bus terminal, and commercial establishments. Many bus routes in this city start from stations and its service level are relatively high. For example, over 200 buses in a week day which run to stations arrive at some bus stops. Figure1 also shows locations of all bus stops, and the number of buses (run to stations) arriving.

2.2 Various surveys for transport needs

We made ourselves clear about features and problems of person-trip survey and activity diary survey (activity-based methods) before conducting our questionnaires.

Person-trip survey in Japan has been used for getting information on needs of urban transport, and this data also been used for community transport planning. However, we cannot analyze needs of bus services in depth, because person-trip in Japan is counted on relatively large zone basis, and their size are too large to get information on needs of bus services. Person-trip survey in Japan also has no question about the difficulty of walking or using buses.

Activity diary survey is a method figuring out activities and trips integrally. This survey can cover for short distance trip and low-frequency trips. However, this method also has some problems. For example, data precision is sometimes lost, because some people feel difficult to answer, and do not fill in some blanks (Nishii *et al* (2002)) .

From these considerations, we need to conduct more detailed (than person-trip) and simplified (than activity diary) survey. So, we conducted questionnaire in following way. (1)Our transport needs survey contained some questions about level of difficult-to-walk and difficult-to-ride buses.

(2)We asked destination, frequency, modes, trip chain, and so on of the highest frequency trips of six trip purposes respectively; work trip, school trip, hospital trip, shopping (foods) trip, shopping (others) trip, and other purposes trip.

(3) This survey is counted on about 50m×50m zone basis which used in census, and we can analyze the data combined with other survey (e.g. census in Japan, establishment census). Table 1 shows outlines of our transport needs survey.

Table 1 Outlines of transport needs survey in Tama City

Dates	Dec.8 – Dec.25, 2002
Distributing method	Posting
Collection method	Mail
The number of households we distributed	5,410
The number of questionnaire sheets we distributed	11,364
The number of questionnaire sheets we could collect	1,272
The number of response (rate)	1,272 (11.2%)
The number of households we could collect (rate)	893 (17.3%)
The number of zones	1,215

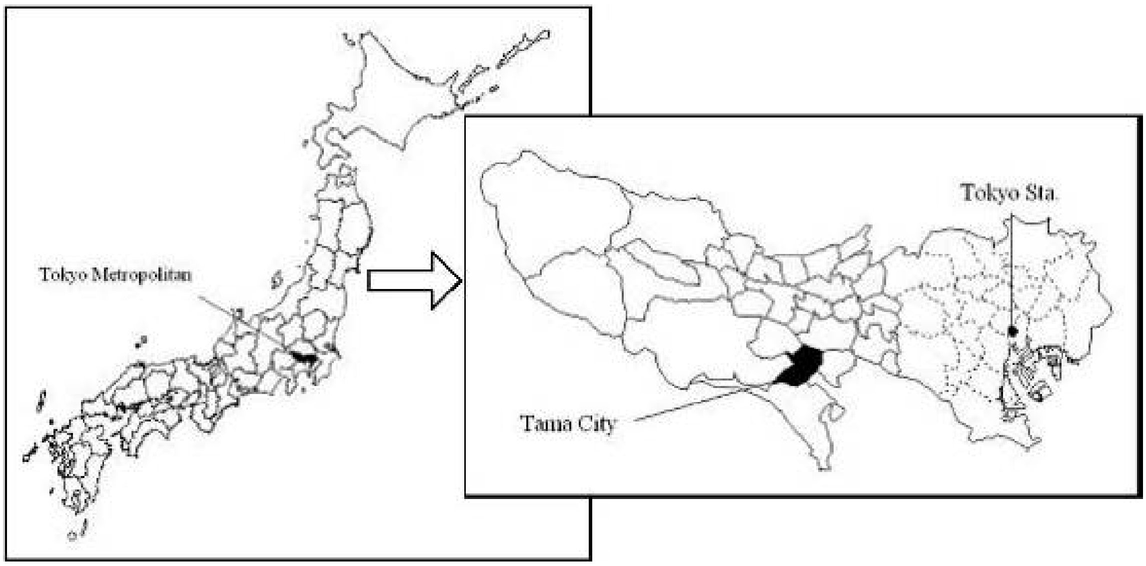

Figure 1 The location of Tama City

3. Demand predicting method

3.1 Demand predicting process

We considered demand predicting method for bus. This method focuses on any one route, and predicts number of passengers on this route[1]. Figure 2 shows basic concepts of this method. From now on, we considered number of bus passengers originated from homes. Firstly, we set "Influential area" around a bus stop, and calculated areal population. We assumed that many residents in an Influential area use a bus stop which is at the center of this area. Secondly, we counted on the number of trips per day per person originated from central point of zones. We assumed that all residents lived at central point of zones. Thirdly, we calculated bus trip rate of each area. Finally, we could predict passengers of each bus stop by using eq. (1).

$$P = T \times B \times A \qquad (1)$$

where

T = number of trips per day per person

B = bus trip rate

A = areal population

[1] This method is similar to previous studies, for example, Yamada, Takeuchi at el (1986).

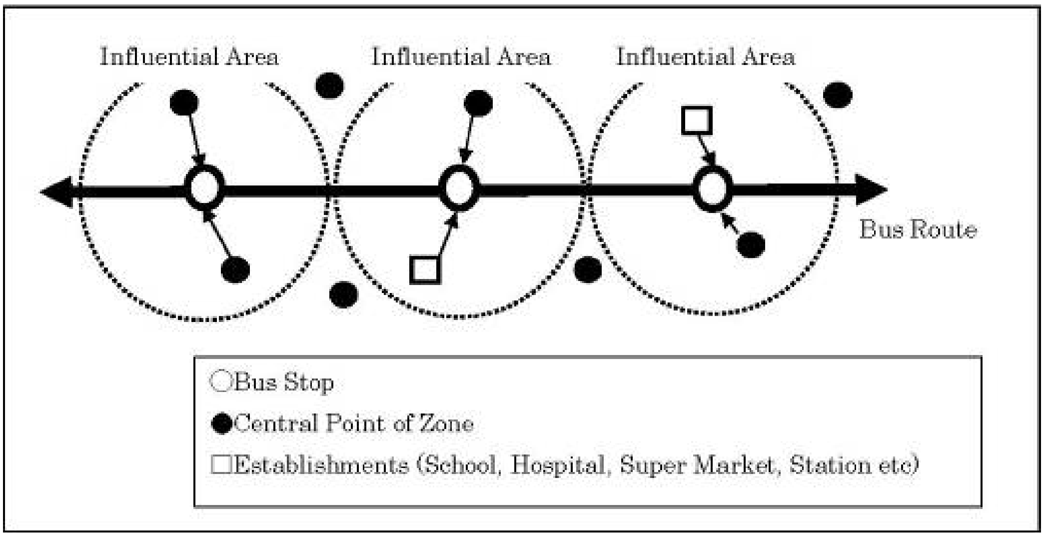

Figure 2 Basic concepts of demand predicting method for buses

3.2 Setting "influential area"

We assumed that many bus passengers choose a bus stop arriving the maximum number of buses within X meters from their homes (central point of zone)[2], and if hitting ratio of this assumption are the highest, we defined its X meters around bus stops as "Influential area". Our survey asked what bus stop around answerers' home they always use, and we defined 300 meters around bus stops as "Influential area".

However, some passengers chose a bus stop which is over 300 meters from their homes. And some passengers living within 1,000 meters from stations except Karakida walk to the nearest station and ride. Table 2 shows choosing rate of bus stops.

Table 2 Choosing rate of bus stops

	Within 300m from home		Over 300m from home	
	Bus stop arriving the maximum number of buses	Others	Nearest bus terminal	Others
Over 1,000m from nearest station	62.3%	24.1%	0.0%	13.6%
Within 1,000m from nearest station	52.5%	17.1%	15.8%	13.6%

3.3 Correction of questionnaire data

We conducted the transport needs survey in Tama City. However, number of trips per person per day of this survey may have some bias, because this survey was by questionnaire. So, we need to correct questionnaire data by person-trip data. Person-trip data we used was person-trip survey in Tokyo Metropolitan region conducted in 1998.

[2] If the bus stop arriving the maximum number of buses is not one within X meters from their homes, we assumed that many passengers use the nearest of them.

We tested our survey data and person-trip data by using chi-square test. Trip purposes we tested were work and shopping (foods) which were originated from homes (only weekdays).

Table3 shows number of trips per day per person which calculated by using questionnaire data and person-trip data. In our survey, we asked trip frequency of each purpose, but we did not grasp number of trips in direct. So, we need to transpose into number of trips by using trip probability of Table 4.

Table 3 The number of trips of each purpose

1) work

Sex	Age	Person-trip (trip/person/day)	Our survey (trip/person/day)	P-value
Male	15~24	0.24	0.26	0.90
	25~34	0.74	0.84	0.10
	35~44	0.84	0.87	0.46
	45~54	0.83	0.84	0.63
	55~64	0.72	0.70	0.84
	65~74	0.31	0.22	0.12
	over 75	0.05	0.05	0.67
Female	15~24	0.28	0.29	0.75
	25~34	0.44	0.49	0.25
	35~44	0.36	0.47	0.02 *
	45~54	0.47	0.48	0.28
	55~64	0.30	0.28	0.66
	65~74	0.08	0.03	0.36
	over 75	0.01	0.00	-

* p<0.05 ** p<0.01

2) shoppimmg (foods)

Sex	Age	Person-trip (trip/person/day)	Our survey (trip/person/day)	P-value
Male	15~24	0.03	0.06	0.61
	25~34	0.03	0.08	0.01 *
	35~44	0.02	0.03	0.67
	45~54	0.03	0.01	0.87
	55~64	0.08	0.07	0.75
	65~74	0.21	0.18	0.66
	over 75	0.08	0.21	0.05
Female	15~24	0.07	0.07	0.76
	25~34	0.23	0.12	0.03 *
	35~44	0.32	0.14	0.00 **
	45~54	0.28	0.20	0.13
	55~64	0.29	0.23	0.22
	65~74	0.29	0.29	0.89
	over 75	0.11	0.23	0.15

* p<0.05 ** p<0.01

Table 4 Trip probability of each purpose

a) work, school

Freqency	Trip probalitity	Caluculation method
1) over 5times/week	1.00	5times/5days
2) 3~4times/week	0.70	3.5times/5days
3) 1~2times/week	0.30	1.5times/5days
4) under 1times/week	0.00	0time/5days

* 5days = weekdays

b) hospital

Freqency	Trip probalitity	Caluculation method
1) over 5times/week	0.92	5times/6days
2) 3~4times/week	0.58	3.5times/6days
3) 1~2times/week	0.25	1.5times/6days
4) 2~3times/month	0.10	2.5tumes/26days
5) 1times/month	0.04	1time/26days
6) under 1times/month	0.00	0time/26days

*assumption : hospitals and clinics tend to close once a week

c) shopping, other purpose

Freqency	Trip probalitity	Caluculation method
1) over 5times/week	0.86	6times/7days
2) 3~4times/week	0.50	3.5times/7days
3) 1~2times/week	0.21	1.5times/7days
4) 2~3times/month	0.08	2.5tumes/30days
5) 1times/month	0.03	1time/30days
6) under 1times/month	0.00	0time/30days

Number of work trips of our survey was almost the same as that of person-trip. However shopping trips of female aged 25-44 of our survey was less than that of person-trip, because we analyzed shopping trips to buy foods, and they tend to buy various goods (e.g. clothes).

Hospital trips could not test by using chi-square test, because we could not understand number of hospital trips per person per day by person-trip data we allowed to use. So, we calculated ratio of hospital trips in our survey to private business trips[3] of person-trip survey. Table 5 shows the hospital trip ratio. Number of hospital trips and this ratio tended to rise as people become older.

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[3] Private business trips: All purpose trips which is except work, school, shopping, eating etc.

Table 5 Hospital trip ratio and number of hospital trips

Sex	Age	Hospital trips of our survey (trip/person/day)	Private business trips of person-trip (trip/person/day)	Hospital trip ratio
Male	15~24	0.005	0.093	5.2%
	25~34	0.007	0.068	10.9%
	35~44	0.009	0.061	15.3%
	45~54	0.009	0.031	29.8%
	55~64	0.020	0.073	26.9%
	65~74	0.050	0.170	29.3%
	over 75	0.129	0.197	65.5%
Female	15~24	0.002	0.091	2.3%
	25~34	0.013	0.134	9.6%
	35~44	0.010	0.217	4.6%
	45~54	0.023	0.154	15.1%
	55~64	0.043	0.201	21.2%
	65~74	0.051	0.219	23.1%
	over 75	0.076	0.139	54.7%

From these considerations, we calculated ratio of number of trips in our survey (4 purposes; school, work, hospital, and shopping (foods)) to that of person-trip (all trip purposes originated from homes). We also defined an expansion ratio by using that ratio mentioned above, because our questionnaire did not cover all trip purposes, and some bias in our survey needed to correct (see Table 6).

Table 6 Cover ratio of our survey and Expiation rate

Sex	Age	Cover ratio	Expansion ratio
Male	15~24	85.3%	1.08
	25~34	87.1%	0.99
	35~44	88.5%	1.00
	45~54	91.8%	0.98
	55~64	87.6%	1.02
	65~74	69.1%	1.27
	over 75	61.0%	0.92
Female	15~24	87.6%	1.08
	25~34	51.0%	1.70
	35~44	47.1%	1.85
	45~54	68.7%	1.46
	55~64	69.3%	1.34
	65~74	53.4%	1.47
	over 75	68.4%	0.71

3.4 Trip frequency model

We constructed four trip frequency models by use of multiple linear regression analysis; (1) people aged under 65 with their own car, (2) people aged under 65 without their own car, (3) people aged over 65 with their own car, (4) people aged over 65 without their own car. These models could predict the number of trips per person per day.

Firstly, we calculated number of trip per person per day by using questionnaire data (4 purposes; school, work, hospital, and shopping (foods)) and the expansion ratio (see Table 6).

Secondly, we defined some explaining variables. We need to mention about 3 variables; a level of difficult-to-use-buses, a level of difficult-to-walk, and a distance of easy-to-walk.

The level of difficult-to-use-buses was defined as Table 7. Answerers of our transport needs survey evaluated their physical burden of these 3 cases respectively; sitting in buses, standing in buses, and using buses except barrier-free vehicles. They rated on a scale of 1 to 4; from "usable" to "non-usable".

The level of difficult-to-walking was defined as Table 8. Answerers evaluated their physical burden of these 4 cases respectively; walking up the stairs, walking down the stairs, walking up the hill, and walking down the hill. They rated on a scale of 1 to 3; from "able" to "disable by oneself".

The level of easy-to-walk-distance defined as Table 9. Answerers evaluated easy-to-walk-distance of these 2 cases respectively; with shopping bag and without it.

Table 10 shows models we constructed. People without their own car tend to rise their trip frequency as the number of buses in the daytimes (10am~4pm on weekdays). Moreover, people aged over 65 of them tend to be more active as distance from their home to nearest bus stop become shorter.

Table 7 The level of difficult-to-use-buses

Level	Definition
1	Answerers who are not in level 2 or level 3.
2	Answerers who evaluated "3. Difficult to use" at least one case of the three.
3	Answerers who evaluated "4. Non-usable" at least one case of three .

Table 8 The level of difficult-to-walk

Type	Level	Definition
Type A	1	Answerers who are not in level 2 or level 3.
	2	Answerers who evaluated "2. Difficult" at least one case of the four.
	3	Answerers who evaluated "3. Disable by oneself" at least one case of the four.
Type B	4~12	Add up scores of the four cases. Score; "1.Able"=1, "2.Difficult"=2, "3.Disable by oneself"=3

Table 9 The distance of easy-to-walk Level Distance

Level	Distance
1	Cannot walk
2	About 100 meters
3	About 300 meters
4	About 500 meters
5	Over 500 meters

3.5 Modal split model

We constructed modal split models by use of logistic regression analysis. Our survey questioned about transport modes which answerers always use of each trip purpose. Modal split models were consisted of some binary choice models (see figure 3), and targeted these three purposes; work, hospital, and shopping (foods). If answerers used more than two modes from their homes to destinations, we constructed these models by using representative transport modes, which were defined according to the ranks showed Table 11. In addition, we also constructed a modal split model of feeder work trips to railroad stations. Table 12 shows modal split models we constructed.

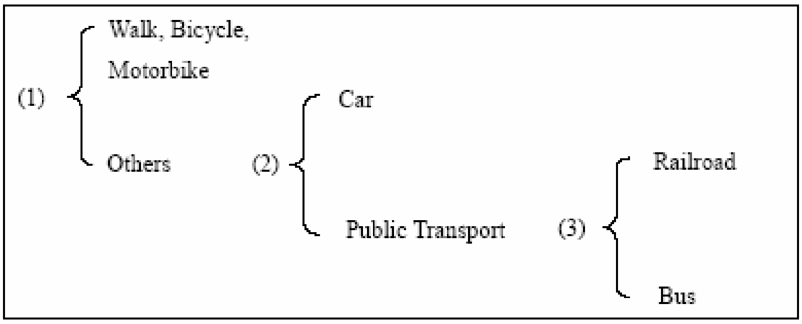

Figure 3 Structure of modal split models Eq.(2) is Logistic regression model that we used.

$$\log_e \frac{p(x)}{1-p(x)} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \qquad (2)$$

where
p = probability; e.g. bus / all modes ratio
β= coefficient
x = variable

We can conclude that main factors of affecting choice of transport mode were distances to destinations, car ownership, and the level of mobility difficulties. However, these models were contained any kinds of bus service levels. In addition, people with their own car tend to go to destinations by car.

Table 10 Trip frequency models

1) People aged under 65 with their own car

	Coefficient	t-stat	
ln (distance to nearest station) (meters)	-0.114	-1.43	
Age	-0.003	-1.21	
Sex (Male=1, Female=0)	-0.387	-5.21	**
Employed person (salaried worker) including part-time employment (yes=1, no=0)	0.818	11.49	**
Intercept	1.639	* $p<0.05$	
R	0.705	** $p<0.01$	
R^2	0.497		
R^2 (adjusted for the degrees of freedom)	0.484		

2) People aged under 65 without their own car

	Coefficient	t-stat	
Employed person (salaried worker) including part-time employment (yes=1, no=0)	0.460	5.40	**
Sex (Male=1, Female=0)	-0.302	-3.42	**
Number of buses in the daytime arriving the bus stop they always use around home	0.002	2.66	**
Housewife (yes=1, no=0)	-0.263	-2.80	**
Level of easy-to-walk-distance without shopping bags	0.278	2.06	*
Driving licence (with=1, without=0)	0.121	1.70	
Intercept	-0.577	* $p<0.05$	
R	0.666	** $p<0.01$	
R^2	0.444		
R^2 (adjusted for the degrees of freedom)	0.420		

3) People aged over 65 with their own car

	Coefficient	t-stat	
Age	-0.022	-1.32	
Employed person (salaried worker) including part-time employment (yes=1, no=0)	0.559	3.87	**
Level of easy-to-walk-distance without shopping bags	0.216	0.99	
Family-operated business (yes=1, no=0)	0.285	1.37	
Intercept	0.998	* $p<0.05$	
R	0.626	** $p<0.01$	
R^2	0.391		
R^2 (adjusted for the degrees of freedom)	0.324		

4) People aged over 65 without their own car

	Coefficient	t-stat	
ln (distance to nearest station) (meters)	-0.186	-1.62	
Age	-0.020	-2.52	*
Employed person (salaried worker) including part-time employment (yes=1, no=0)	0.560	2.97	**
Number of buses in the daytime arriving the bus stop they always use around home	0.002	1.72	
Distance to nearest bus stop (meters)	-0.001	-2.36	*
Level of difficult-to-use-buses	-0.181	-1.31	
Intercept	3.536	* $p<0.05$	
R	0.553	** $p<0.01$	
R^2	0.306		
R^2 (adjusted for the degrees of freedom)	0.252		

Table 11 Ranks of representative transport modes

Rank	Mode	Rank	Mode
1	Railroad	5	Car (Driving by others)
2	Bus	6	Motorbike
3	Taxi	7	Bicycle
4	Car	8	Walk

Table 12 Modal Sprit models

(1) Work (Representative)

a) walk, bicycle and mortorbike / all modes ratio (with car)

	Coefficient	P-value
ln (distance to the destination)	-1.028	0.00
Intercept	6.379	
Nagelkerke R^2	0.275	
Hitting ratio	89.4%	

b) walk, bicycle and mortorbike / all modes ratio (without car)

	Coefficient	P-value
ln (distance to the destination)	-2.011	0.00
Intercept	14.993	
Nagelkerke R^2	0.680	
Hitting ratio	87.4%	

c) public transport / car and public transport ratio

	Coefficient	P-value
Family-operated business (yes=1, no=0)	-2.086	0.00
ln (distance to the destination)	1.252	0.00
Distance to the nearest station	-0.001	0.00
Level of difficult-to-use-buses	-1.268	0.00
Level of easy-to-walk-distance without shopping bags	7.345	0.61
Intercept	-44.322	
Nagelkerke R^2	0.522	
Hitting ratio	77.6%	

d) bus / public transport ratio

	Coefficient	P-value
ln (distance to the destination)	-2.489	0.00
Intercept	19.685	
Nagelkerke R^2	0.604	
Hitting ratio	94.2%	

(2) Hospital (Representative)

a) walk, bicycle and mortorbike / all modes ratio (with car)

	Coefficient	P-value
ln (distance to the destination)	-2.678	0.00
Intercept	17.877	
Nagelkerke R^2	0.638	
Hitting ratio	0.863	

b) walk, bicycle and mortorbike / all modes ratio (without car)

	Coefficient	P-value
ln (distance to the destination)	-2.991	0.00
Level of easy-to-walk-distance with shopping bags	1.835	0.00
Intercept	13.343	
Nagelkerke R^2	0.764	
Hitting ratio	0.882	

c) public transport / car and public transport ratio

	Coefficient	P-value
Own car (with=1,without=0)	-4.707	0.00
Intercept	3.434	
Nagelkerke R^2	0.67	
Hitting ratio	87.5%	

d) bus / public transport ratio

	Coefficient	P-value
ln (distance to the destination)	-0.005	0.99
Intercept	63.044	
Nagelkerke R^2	1.00	
Hitting ratio	100.0%	

(3) Shopping (Representative)

a) walk, bicycle and mortorbike / all modes ratio (with car)

	Coefficient	P-value
ln (distance to the destination)	-3.985	0.00
Intercept	25.709	
Nagelkerke R^2	0.632	
Hitting ratio	84.1%	

b) walk, bicycle and mortorbike / all modes ratio (without car)

	Coefficient	P-value
ln (distance to the destination)	-0.002	0.00
Intercept	3.313	
Nagelkerke R^2	0.347	
Hitting ratio	79.6%	

c) bus / car and bus ratio

	Coefficient	P-value
Own car (with=1,without=0)	-6.111	0.00
Intercept	3.020	
Nagelkerke R^2	0.796	
Hitting ratio	95.6%	

(4) Work (Feeder)

a) bus / all modes ratio

	Coefficient	P-value
ln (distance to stations that people use)	2.371	0.00
Age	0.027	0.05
Sex (Male=1, Female=0)	-0.984	0.01
Intercept	-17.702	
Nagelkerke R^2	0.331	
Hitting ratio	72.3%	

4. Break-even point of buses in urban areas

4.1 Validity of models

We constructed two kinds of models; trip frequency models and modal split models. We predicted passengers of each bus stop by using these models, and considered the validity of these models by comparison with actual passengers[4].

Figure 4 shows comparison of predicted passengers with actual passengers. We can categorize these data into three groups. Predicted passengers of Group 1 are about the half of actual passengers, because establishments (school, hospital, office, store, etc) are around these bus stops, and bus passengers are also originated from these establishments. Number of predicted passengers of Group 2 is almost the same with actual passengers, but there are few passengers using bus stops of Group 3 actually.

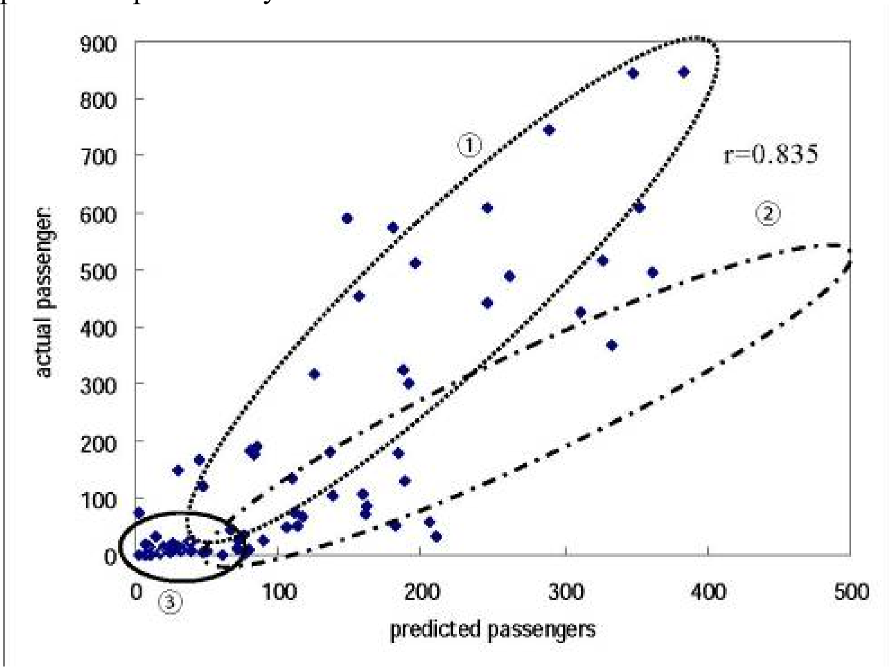

Figure 4 Comparison of predicted passengers with actual passengers

4.2 Simulation

(1) Outline

We developed a program which calculated a break-even point of the number of buses when population density along a bus route was X people/km^2.

This program was produced by use of Visual Basic.net. We imputed population and the ratio of people who have their own cars by age and sex into this program, and we can understand the break-even point of number of buses.

Bus stops we compared are the part of the whole, and did not included number of passengers at bus terminals.

(2) Assumption

Our program assumed four things mentioned below.

1) Table13 shows number of trips per person per day that we used in our program. These data was obtained from our survey.

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[4] Bus stops we compared are the part of the whole, and did not included number of passengers at bus terminals.

Table 13 Number of trips per person per day used in our program

1) Number of trips per person

Group	trip/day
People aged over 65 with their own cars	0.60
People aged over 65 without their own cars	0.47
People aged under 65 with their own cars	0.92
People aged under 65 without their own cars	1.03
Average	0.91

2) Number of trips per person per day by age and sex and purpose

Sex	Age	Work	Hospital	Shopping (foods)
Male	15~24	0.24	0.00	0.06
	25~34	0.74	0.01	0.08
	35~44	0.84	0.01	0.03
	45~54	0.83	0.01	0.01
	55~64	0.72	0.02	0.07
	65~74	0.31	0.05	0.18
	over 75	0.05	0.13	0.21
Female	15~24	0.28	0.00	0.07
	25~34	0.44	0.01	0.12
	35~44	0.47	0.01	0.14
	45~54	0.47	0.02	0.20
	55~64	0.30	0.04	0.23
	65~74	0.08	0.05	0.29
	over 75	0.01	0.08	0.23

2) According to trip frequency models, people without their own cars tend to rise their trip frequency as the number of buses in the daytimes. In addition, we assumed that incremental trip by increasing number of buses was equal to incremental shopping trip.

3) Distance to the nearest station from homes are defined by eqs.(3) and (4).

- Bus routes from station to suburban

$$s = \frac{1}{2}b \qquad (3)$$

- Bus routes from station to suburban

$$s = \frac{1}{4}b \qquad (4)$$

where

b= length of bus route (meters)

4) Distance to a store where people buy foods is defined as follows.

Firstly, we constructed a model which predict the ratio of people chose a store where near the nearest station from their homes, because distance to a store is related to distance to the nearest station. Eq.(5) are this model.

$$p_s = \frac{\exp(-1.719 \times \ln(s) + 12.219)}{1 + \exp(-1.719 \times \ln(s) + 12.219)} \qquad (5)$$

where

p_s = the ratio of people chose a store where near the nearest station from their homes

Secondly, we calculated distance to a store where people buy foods by eq.(6).

$$u = p_s s + (1 - p_s) \times 995.7 \qquad (6)$$

where

u = distance to a store where people buy food (meters)

995.7 = average meters to stores which are not around the nearest stations

(3) Calculating process

Our program calculates a break-even point of number of buses by these processes.

1) Firstly, we approximate the number of buses in the daytimes by eq.(7). In Tama City, 26.7 % of the number of busses on weekdays ran in the daytimes.

$$Y_i = 0.267 \times X_{i-1} \tag{7}$$

where

i = number of people living in "Influential area"

Yi = number of buses in the daytime

Xi-1 = a break-even point of number of buses when population is i-1

2) We calculate incremental trip by increasing number of buses by eq.(8).

$$\Delta T_i = \frac{T_i - TT}{TT} \tag{8}$$

where

ΔTi = incremental trip by increasing number of buses

Ti = weighted average number of trips per person per day which is calculated by using trip frequency models.

TT = weighted average number of trips per person per day which is calculated by using Table13.

3) Modal split models we constructed targeted 3 trip purposes; work, hospital, and shopping (foods). We need to calculate the number of trips which our questionnaire can grasp by eq.(9) in order to apply modal sprit models we constructed.

$$Q_i = QQ(1 + \Delta T_i) \tag{9}$$

where

Qi = number of trips which our questionnaire can grasp

QQ = weighted average number of trips per person per day which is calculated by using Table13-2).

4) Bus trip ratio is predicted by eq.(10).

$$P_i = \frac{QA \times P_A + QB \times P_B + QC \times (1 + \Delta T_i) \times P_C}{Q_i} \times 0.85 \tag{10}$$

where

Pi = bus trip ratio

QA = weighted average number of work trips calculated by using Table13-2).

PA = bus trip ratio of work trips calculated by using modal split models.

QB = weighted average number of hospital trips calculated by using Table13-2).

PB = bus trip ratio of hospital trips calculated by using modal split models.

QC = weighted average number of shopping (foods) trips calculated by using Table13-2).

PC = bus trip ratio of shopping (foods) calculated by using modal split models.

0.85 = parameter which is in order to consider other trip purposes

5) We can predict passengers originated from homes of each bus stop by eq.(11).

$$A_i = (P_i + P_D \times R_i) \times T_i \times I \tag{11}$$

where

Ai = passengers originated from homes of each bus stop

PD = bus trip ratio of feeder trip[5]
Ri = train trip ratio (based on representative transportation mode)
I = population of "Influential area" of a bus route; the sum of passengers of a bus stop

6) Bus passengers originated from establishments (hospital, school, store etc) are predicted by using regression analysis, and we conducted eq.(12).

$$B_i = (1.60 - 1)A_i \qquad (12)$$

where
Bi = passengers originated from establishments of each bus stop
1.60 = parameter which is in order to consider other trip purposes

7) Bus passengers originated from stations (that is, bus terminals) are assumed by eq.(13).

$$C_i = A_i + B_i \qquad (13)$$

where
Ci = passengers originated from stations

8) And we can predict passengers of a bus route as eq.(14).

$$Z_i = (A_i + B_i + C_i) \times T_i \qquad (14)$$

where
Zi = passengers of a bus route
Ti = weighted average number of trips per person per day which is calculated by using trip frequency models.

9) Total revenue of a bus route can predict as eq.(15).

$$R_i = Z_i f \qquad (15)$$

where
Ri = total revenue of a bus route
f = average of bus fare that we assume eq.(16).

$$f = \begin{cases} 170 & s<1{,}000 \\ 170 + 20.00 \times \left(\frac{s}{1000} - 1\right) & 1{,}000<s<10{,}000 \\ 350 + 20.00 \times \left(\frac{s}{1000} - 10\right) \times 0.9 & 10{,}000<s \end{cases} \qquad (16)$$

10) Finally, we define total cost of a bus route as 574.25yen per kilometer[6].

(4) Setting of simulation

We simulated the break-even point of the number of buses under the setting as follows;

1) Population and the ratio of people who have own cars; see Table 14

[5] A modal split model of feeder trips we constructed were only work trip purpose. Thus, calculated bus trip ratio was collected by using Person-trip data in order to apply this model to all trip purposes. In our program, calculated ratio was multiplied by 0.54.
[6] 574.25yen/km; Average cost of a bus service in Tokyo suburban areas ("Bus Service in Japan 2003")

Table 14 Population and the ratio of people who have own cars

1) Population of the Tama City (2003.7)

Age	Male	Female	Total
15~24	10,698	9,351	20,049
25~34	12,644	11,395	24,039
35~44	9,573	8,654	18,227
45~54	9,615	10,798	20,413
55~64	10,693	11,035	21,728
65~74	6,290	6,300	12,590
over 75	2,489	4,362	6,851

2) The ratio of people who have own cars

Age	Male	Female
15~24	0.30	0.07
25~34	0.66	0.66
35~44	0.87	0.66
45~54	0.64	0.64
55~64	0.74	0.45
65~74	0.60	0.20
over 75	0.24	0.03

2) Route length and number of bus stops;

We assumed that the length of a bus route is 9 kilometers, and the number of bus stops is 16, that is, bus stops are at 600-meter intervals (See Figure 5).

In addition, we defined 300 meters around bus stops as "Influential area".

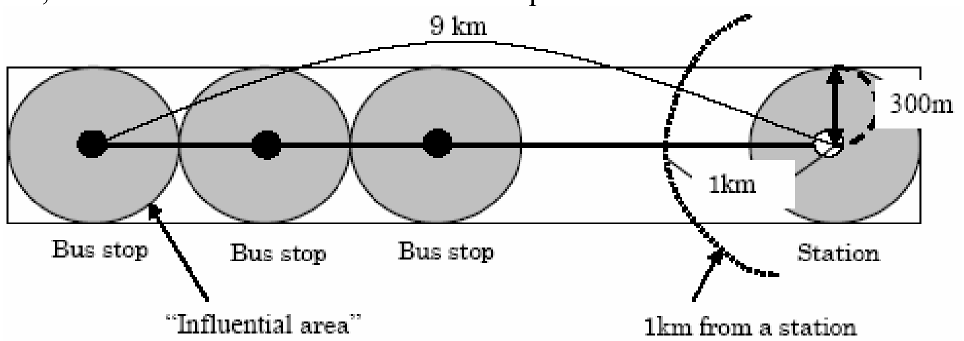

Figure 5 Route length and number of bus stops

3) Overlapping area;

If an influential area overlaps that of other routes, people living in overlapping area tend to choose a bus stop arriving more number of buses.

Figure 6 shows this situation. For example, most people living in overlapping area 1 choose Bus stop A, but a few people in overlapping area 2 choose Bus stop B. We defined the former area as "Strong overlapping area", and the latter as "Weak overlapping area" in this simulation.

We calculated the ratio of people using bus stops on a route which we want to evaluate. Table 15 shows these ratios by using the data of our transport needs survey. Ratios in areas within 1,000m from railroad stations tended to be lower than those in other areas, because some people living near the station walked to bus terminal, and rode.

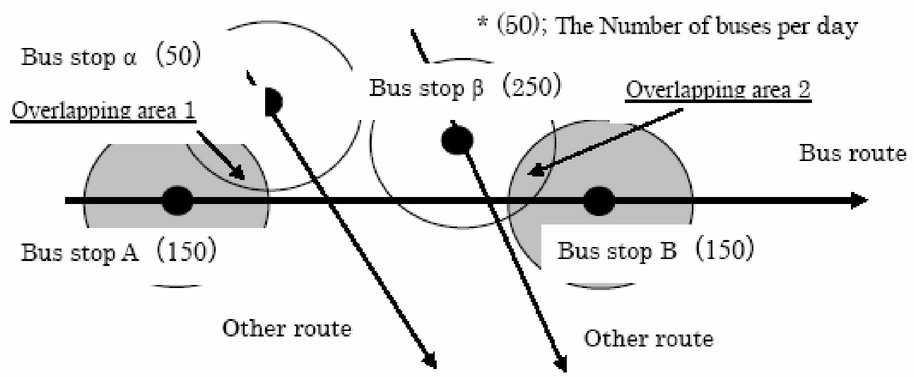

Figure 6 "Strong overlapping area" and "Weak overlapping area"

Table 15 The ratio of people using bus stops on our evaluated route[7]

Distance from stations	Overlapping area	The ratio
Over 1,000m	No	88.3%
	"Strong Overlapping Area"	75.9%
	"Weak Overlapping Area"	12.4%
Within 1,000m	No	74.1%
	"Strong Overlapping Area"	62.7%
	"Weak Overlapping Area"	11.4%

4) Contention rate;

We predicted passengers of each bus stop, but we evaluate profitability of each bus route. Thus, if some routes stop at the same bus stop, we need to assign passengers to each bus route.

In this study, we assign passengers by the number of buses of each route. We used eq. (17) to assign passengers, and this equation was weighted with distances from stations, because the ratio of bus trips was different by the distance from stations.

$$D_j = \frac{\sum_{i=1}^{I} s_i \times \frac{X_{ji}}{X_i}}{I} \qquad (17)$$

where

Dj : Contention rate of a route j $(1 \leqq j \leqq J)$

si : Distance to the nearest station from a bus stop i

Xji : The number of buses of a bus stop i $(1 \leqq i \leqq I)$ on a route j

Xi : The number of buses of a bus stop i

(5) Simulation

1) Assumption of the evaluated routes

We assumed three types of routes showed Table 16, and simulated profitability of bus routes. The first type of routes we evaluated was "Non overlapping and non contention route", which was able to run buses with the maximum frequency. The second was "Line-haul Route", which was running a large number of buses. The third was "Feeder Route", which was running a little number of buses.

Table 16 The ratio of people using bus stops on our evaluated route

Type	Ratio of "Strong Overlapping Area" *	Ratio of "Weak Overlapping Area" **	Contention rate
Non overlapping and Non contention Route	0%	0%	0%
Line-haul Route	30%	0%	70%
Feeder Route	0%	50%	30%

[7] Actually, there are some residents in an "Influential area" did not choose bus stops on a route which we evaluate profitability. However, there are also some people living in Influential areas of other bus routes use the bus route we evaluated. Thus, we collected the ratio showed Table 15 by our questionnaire data as follows;

1) Areas of over 1,000m from the nearest station; each ratio showed Table 15 was multiplied by 1.13.
2) Areas of within 1,000m from the nearest station; each ratio showed Table 15 was multiplied by 1.38.

In addition, we assumed that the mean distance from bus stops to homes was 150 meters.

2) Results

Figure 7 shows a break-even point of the number of buses when population density along a bus route was X people/km^2 that was calculated under assumptions mentioned above.

For example, if population density of Influential area is 7,000 (people/km^2), we can predict the break-even point of Line-haul Route is about 70 (shuttles/day). In other words, 70 buses can go to the (nearest) station every weekday.

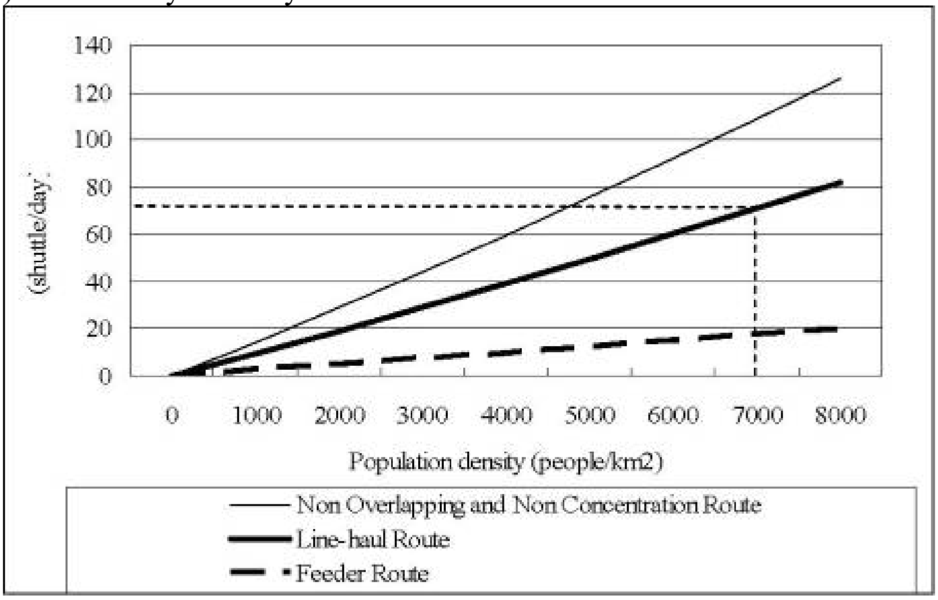

Figure 7 Result of simulation

In addition, we can predict the average number of private trips per person when the number of buses is on the break-even point by using our programs (See Figure 8). These trips are included shopping, eating, and so on. We can evaluate bus services from the aspect of ensuring mobility by our programs. For example, if we provide a new bus route which runs 100 shuttles per day, the average number of private trips per person aged over 65 without free access to a car (in other words, people without their own cars) raised to about 0.16 (trips/day) that is predicted from Figure 8. If we do not provide a new bus route, that is, no bus are provided, the average number of their private trips are about 0.13 (trips/day). From these considerations, we can understand that an increase in the number of local bus services can lead to a slight increase in the number of trips by residents.

In a future, we need to consider the minimum basis of trip frequency that local government in Japan should ensure in order to evaluate bus services from the aspect of ensuring mobility.

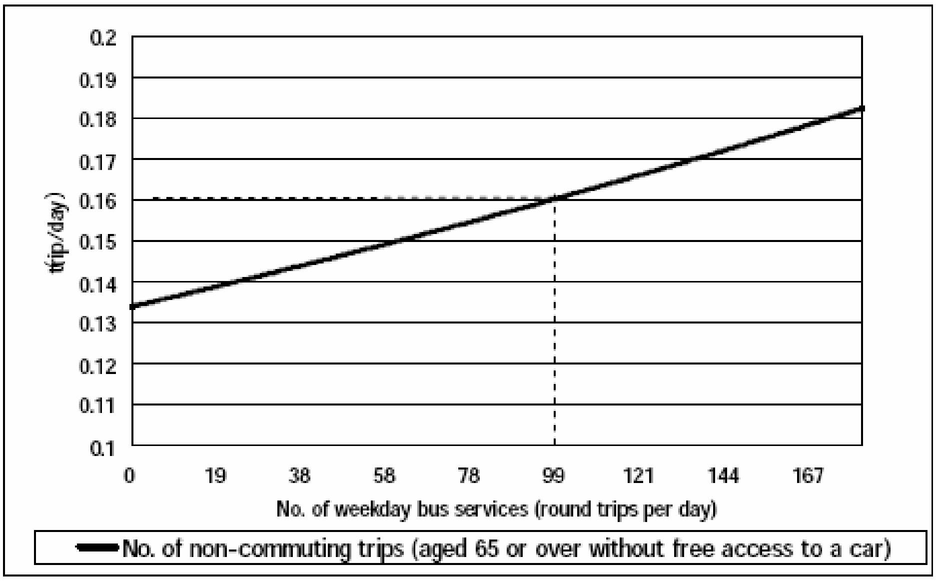

Figure 8 The number of private trips per person (aged over 65 without their own cars)

5. Conclusions

5.1 Summary

In this paper, we described three things as follows;

Firstly, we considered about the way of transport needs survey. We carried out questionnaire in Tama City, Tokyo. Our survey asked trips of six purposes respectively; work trip, school trip, hospital trip, shopping (foods) trip, shopping (others) trip, and other purposes trip. Thus, it did not cover all trip purposes. Especially, trips of female aged 25-44 calculated from our survey were less than that of person-trip.

Secondly, we constructed trip frequency models and modal split models. From trip frequency models, we can conclude that people without their own car tend to rise their trip frequency as the number of buses in the daytimes (10am~4pm on weekdays), and people aged over 65 of them tend to be more active as distance from their home to nearest bus stop become shorter. From modal split models, we can conclude that main factors of affecting choice of transport mode were distances to destinations, car ownership, and the level of mobility difficulties.

Thirdly, we simulated the break-even point of the number of buses when population density along a bus route was X people/km^2. For example, if population density of Influential area is 7,000 (people/km^2), we can predict the break-even point of Line-haul Route is about 70 (shuttles/day) (See Figure 7).

And, finally, we understand that an increase in the number of local bus services can lead to a slight increase in the number of trips by residents.

5.2 Further issues

In this paper, we have some issues mentioned below.

Firstly, we should consider the applicability of programs we constructed. There are various types of region in Japan; from urban areas to depopulated areas. Tama City that we surveyed is one of the urban areas, and relatively high level of bus service is supplied. Thus, we cannot conclude our programs can apply all areas in Japan.

Secondly, we need to consider the minimum basis of trip frequency that local government in Japan should ensure, because we can also evaluate bus services from the aspect of ensuring mobility by using our programs.

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