Memoirs of the Faculty of Engineering, Okayama University, Vol.23, No. 2, March 1989

An Applicability of Aggregate and Disaggregate Estimations to Mode Choice by Inter-regional Occupational Person Trips

Sho Myojin*, Masahito Yamada*, Naoto Fujii**

(Received January 30, 1989)

SYNOPSIS

Diversion model and disaggregate behavioral model of logit type are adopted as aggregate and disaggregate estimates, respectively. Diversion model is assumed as a binary choice process including diversion ratio function at each step in the process. Diversion ratio is assumed as a function of generalized-travel-time ratio. The function is identified with each of the two steps of diversion; diverson from rail and bus to car at first and from the rest undiverted to bus at second. The data used are those on inter-regional occupational person trips. Each function are found enough and/or critically significant in the statistical sense.

At the beggінning, sixteen characteristics variables are enrolled in disaggregate model, which are identified by use of the above data. Six variables are reached finally and are all reasonable.

A brief comparison of goodness of fit to the data are made between two models.

1. Introduction

Two kinds of analysis are made in this paper of mode choice by inter-regional occupational trip makers. One is made by applying diversion ratio model, that has long been used in the field of traffic flow on road network but little in mode choice and the other by disaggregate behavioral model of logit type, that has been studied in recent ten years or so in Japan

* Department of Civil Engineering

** Graduate Student

through being applied to mode choice mostly in urban area or to some other fields. Disaggregate behavioral model of logit type is written as disaggregate model hereafter in the paper.

The paper is concerned with

1) an applicability of diversion and disaggregate models to mode choice by inter-regional occupational person trips and

2) the difference in goodness of fit of the mode choice estimated by each model to that surveyed

The first subject is related to the fact that the application of diversion ratio model to mode choice is, so to say, a diversion of the original model and the application of disaggregate model is, as it were, a spatial expansion of the area that has been put under mode choice study by the model. In fact, most of the applications of disaggregate logit model in the field of transportation in Japan has been made to urban transportation. [1] So far as the authors know, Morichi et al.[2] and Myojin et al.[3] are a few exceptional cases in Japan.

2. Person Trip Survey

The person trip data used in this study were given by Tsuyama Aircommuter Consultative Meeting and Okayama Institute of Economics,[4] who surveyed together occupational person trips, except for those for commodity distributing, originating from and arriving in Tsuyama area to and from other regions outside. Tsuyama area is in the north-eastern part of Okayama prefecture lying at about 150 kilometers to the west of Osaka city (Fig.1, 2). The survey was conducted by mail questionnairing on 9.4 percent sampled from the whole number 9,833 of establishments in the area and the number of replies available for this study was 23.6 percent of the sampled.

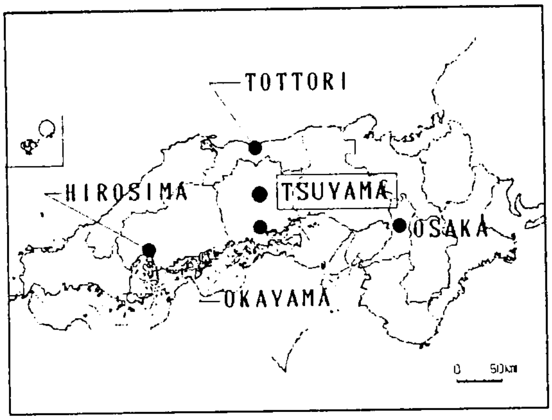

FIG.1 TSUYAMA AREA

From among those which were surveyed, the data on the followings were selected to use in this study ; trip characteristics and trip maker's characteristics . Trip characteristics include;

origin,

destination,

departure time,

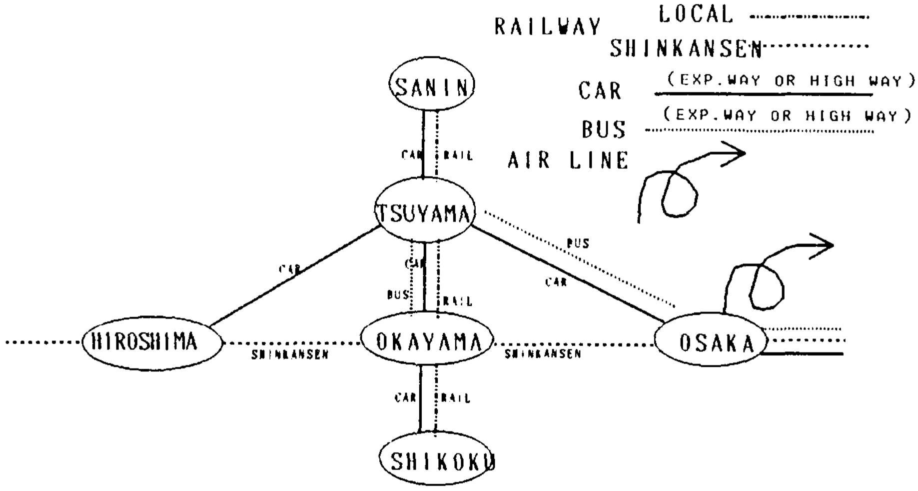

FIG.2 TRANSPOTATION NETWORK

mode,
either with or without heavy baggages,
the number of fellow trip makers and
the number of visits in destination area.

Trip maker's characteristics include;
the position in his establishment,
drivers license and
car ownership.

The mode choices surveyed by the questionnairing are shown in Table 1, in which the first column shows the regions outside of Tsuyama area. Each element in the left half on the table shows the number of choices of mode taken by those who made occupational trips originating from Tsuyama area and arriving at the regions outside and the element in the rest half is

TAB.1 NUMBER OF CHOICES to/from TSUYAMA

	from TSUYAMA					to TSUYAMA					REMARKS
dest.or orig./MODE	RAIL	BUS	CAR	AIR	TOTAL	RAIL	BUS	CAR	AIR	TOTAL	MAIN CITY
HOKKAIDO TOUHOKU			1	1	1						SAPPORO
KANTOU	4	6	5	5	15	8	5	5	4	18	TOKYO
CHUBU HOKURIKU	3	1	4		8	3	1	2		6	NAGOYA
OSAKA	3	12	22		37	6	16	69		91	OSAKA
HYOUGO	1	1	23		25		4	30		34	KOBE
OKAYAMA	12		69		81	3		115		118	OKAYAMA
HIROSHIMA	13		7		20	11		31		42	HIROSHIMA
SANIN	1		29		30			18		18	TOTTORI
SHIKOKU	2		5		7	1		4		5	TAKAMATSU
KYUSYU	3		1	1	4			3		3	FUKUOKA
TOTAL	42	20	166	7	228	32	26	277	4	335	

corresponding to those trips originating from the regions outside and arriving in Tsuyama area. Mix mode, if any, is represented by representative one that is of the highest rates among the mode mix.

3. Diversion Model

A binary mode choice process is supposed to have realized what is shown in Table 1. The diversion ratio model is applied to binary choice at each stage in the process. One of the important matters is to decide the sequence of modes to be chosen. The sequence is assumed as shown in Fig.3, where three modes and two stages of binary choice are assumed. The air is omitted from modes under study by reason that there are very few regions related to its choice as seen in Table 1. In Fig.3 it is supposed that there exists so called a primary mode before the first stage, from which diversion takes place to car. The primary mode is assumed to be a compound of rail and, if any, bus. It is also a set of public transportations that are available in Tsuyama area. Second stage diversion occurs from the rest of the primary mode to bus, if any.

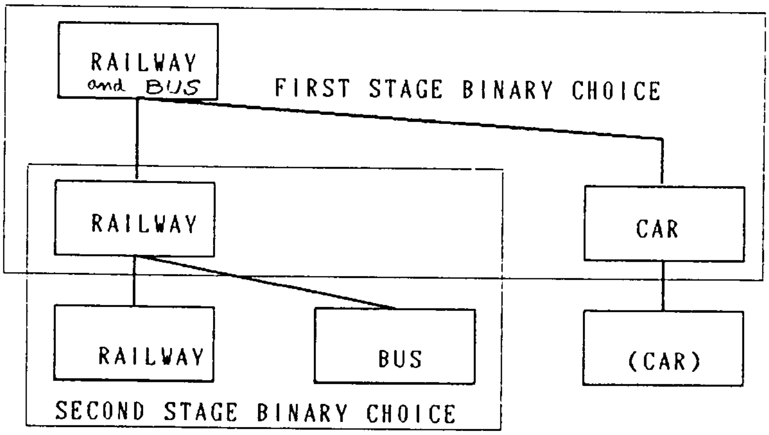

FIG.3 BINARY CHOICE MODEL

The following is assumed at each stage where

$$P = \frac{1}{1 + \alpha X^{\beta}} \qquad (1)$$

P: diversion ratio

X: travel time ratio and

α , β: parameters.

This type has been used for studying diversion of traffic, for example, from streets to urban expressways in Tokyo Metropolitan Area and Osaka-Kobe Area [5], [6].

Another definition of X is, given by such an incremental cost form that is used by, for instance, Japan Highway Public Corporation, whose X is defined as the toll rates divided by travel time saved through diverting from the surface road to expressway [5]. In case of following after the incremental cost form in our study, X is defined as the incremental travel cost to be paid for a unit of travel time saved. The incremental cost form, however, was found to cause an undesirable problem that negative or unstable values of X came out though in a few cases. Negative value of X means, for example, that travel time is shorter by a mode of lower cost than by that of the higher. Instability of X was found in such a case where a very little save in travel time is gained by diversion.

Travel time ratio, though it does not have such clear and explicative meaning as the incremental cost form, can avoid the undesirable problem mentioned above. That is the reason why we adopted travel time ratio instead of the incremental form. In calculating the value of travel time ratio, generalization of travel time is made by use of fares, fuel consumption in driving and toll rates. The fuel consumption and toll rates are discounted by the number of fellow passengers.

(1) diversion to car

Identification of the diversion ratio model was done for each of the three kind of trips : trips originating from Tsuyama area to other regions, vice versa and those including both. Diversion curves are shown in Fig.4 by use of the estimated parameters in Table 2.

Tab.2 Estimated Parameters

	α	β	Corr. Coeff.icient*
from RAIL to CAR (First Stage Binary Choice)			
to and from TSUYAMA	0.84	4.07	0.738
from TSUYAMA	0.91	3.22	0.623
to TSUYAMA	0.71	5.63	0.626
from RAIL to BUS (Second Stage Binary Choice)			
from TSUYAMA	1.66	9.26	0.874

* between log(1/P-1) and logX

Generalization of travel time was made by using travel cost (fares, rates or some other cost) and time value, which was presumably estimated by use of the average yearly earned income and man-hours per a worker. Those are what were surveyed in November, 1986, when the person trip survey was done. Generalized travel cost for the primary mode, in the sense mentioned before, was given by averaging over rail and bus.

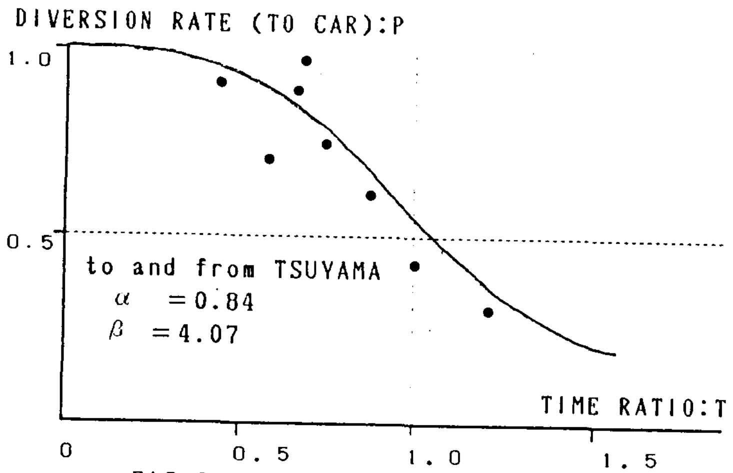

FIG.4a DIVERSION CURVE(TO CAR)

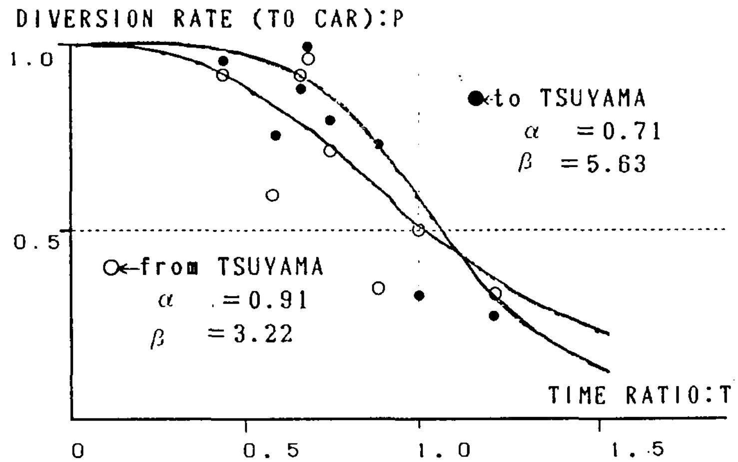

FIG.4b DIVERSION CURVE(TO CAR)

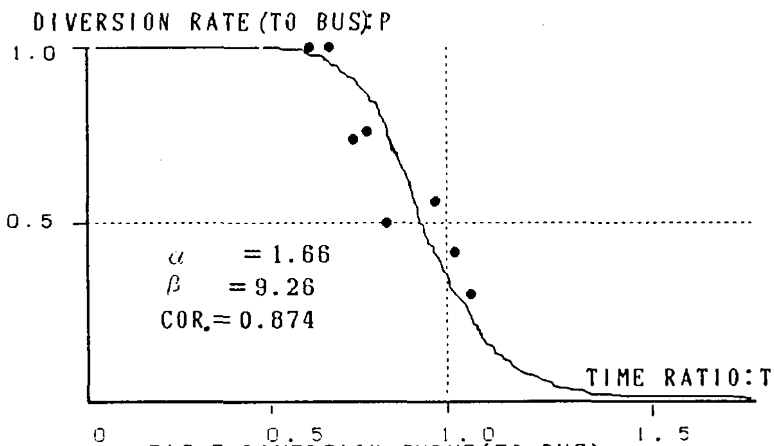

FIG.5 DIVERSION CURVE(TO BUS)

(2) diversion to bus

Parameters were estimated for those trips alone from Tsuyama area to other regions, but not for those vise versa because of incompleteness in data. It may be a fact that the questionnaires were filled out by trip makers themselves or their fellow workers as for those trips from Tsuyama area to other regions but, as for those vise versa, the questionnaires are apt to be filled out by some proxies who are selected from among workers at the establishments where trip makers visit. That is one of the reasons why sufficient data were easy to obtain on trips from Tsuyama area to other regions but not easy on trips vise versa.

The data used for estimating parameters are not those aggregated by every pair of Tsuyama area and other regions, because the number of the pairs available is, as seen on the left half in Table 1, only four that is not enough to use for estimation of parameters. Revised sets of the data on travel time ratio and diversion ratio were obtained by putting individual travel time ratio together into any one of intervals of 0.05, to which diversion ratios were given by aggregating individual choice of mode. Finally, the number of the sets of the data available was eight as plotted in Fig.5.

The diversion curve is also shown in Fig. 5 together with the values of parameters, which are not to be compared with those estimated for diversion to car because of the difference in data processing as mentioned above.

The followings are found so far in this section ;

(1) Among the three regression curves fitted to diversion to car, the one for the mix of trips that include those originating from and arriving in Tsuyama area is best fitted to the plotted points. By the way, the correlation coefficient between Logarithms of both sides of the diversion ratio function(1) for which observed values are substituted is 0.738 for the mix, while it is 0.623 for the trips from Tsuyama area and 0.626 for the ones to Tsuyama area. The first is significant at significance level of 5%, while the last twos are significant not at 5% but 10%. That is, correlation in the sense mentioned above is rather critical in significance.

(2) Diversion ratio for the mix is nearly equal to 50% at travel time ratio 1.0. This is one of characteristics that the parameters are expected to have since diversion ratio should be 50% when two modes have a same travel time.

(3) There may be a little difference in mode choice behavior between trip-makers from Tsuyama area to other regions and the ones vice versa. The difference is found especially below travel time ratio 1.0, where the former diverts to car by a little less ratio than the latter. The difference, of course, should be analyzed by some aspects other than travel

time ratio.

(4) The values of α 's lie between 0.7 and 0.9, which lead to diversion ratios of about 50% at travel time ratio 1.0. The values of β 's lie between 3.2 and 5.6, which are analogous to what are often used in studying traffic diversion on road network.

(5) As to diversion to bus, the correlation is highly significant. Diversion ratio is nearly 40% at travel time ratio 1.0, which implies that some conditions other than travel time ratio are also necessary to join in further studying.

4. Disaggregate model (logit type)

As is well known, the model is expressed by

$$P_{in} = \frac{\exp(V_{in})}{\sum_{j \in A_n} \exp(V_{jn})} \qquad (2)$$

where,

Pin: probability of n-th person with i-th choice,

Vin: deterministic part of utility for n-th person to gain by i-th choice,

An: choice set to n-th person.

It is well known that this is drawn from following assumptions [7]; the individual picks up the one of maximum utility from among choices and the whole utility for him to gain by a choice is given by the sum of the deterministic part of utility and the random one that is assumed to follow Gumbel distribution. Choice probability Pin is obtained by identifying the function for deterministic part of utility that is assumed as a certain function of characteristics variables proper to choices. Choice probability is, of course, finally tested by hit ratio that is a measure of applicability of the model to the problem under study.

As usual, utility function is assumed as

$$V_{in} = \sum_k \theta_k X_{ink} \qquad (3)$$

where,

Xink: k-th characteristics variable for n-th person with i-th choice,

θ_k : parameters

The model was identified with those trips alone from Tsuyama area to other regions because of the same reason as stated before. At the beginning, sixteen characteristics variables were enrolled as shown on the left half of Table 3. Six variables were finally found to be of statistical significance, as shown on the right half of Table 3. Those are as follows;

TAB.3 ESTIMATION BY DISAGGREGATE LOGIT MODEL(WITH 16 AND 6 VARIABLES)

VARIABLES	θ	T-VALUE	θ	T-VALUE
TRIP DISTANCE(Km)	$+0.105*10^{-2}$	0.379		
AUTO-FUEL EXPENCE(YEN)	$+0.118*10^{-2}$	2.236	$+0.222*10^{-1}$	6.052
EXP.WAY TOLL(YEN)	$-0.156*10^{-2}$	-4.957	$-0.185*10^{-2}$	-6.795
FARE(YEN)	$-0.447*10^{-3}$	-3.947	$-0.514*10^{-3}$	-6.776
TRAVEL TIME(MIN)	$-0.258*10^{-1}$	-4.601	$-0.337*10^{-1}$	-7.375
ACCESS TO THE NEAREST EXP.WAY BUSSTOP(Km)	$-0.550*10^{-1}$	-0.745		
ACCESS TO THE NEAREST RAILWAY STATION(Km)	$-0.186*10$	-1.922	$-0.868*10^{-1}$	-1.982
ACCESS TO THE NEAREST EXP.WAY I.C.(Km)	$+0.943*10^{-2}$	+0.153		
FREQUENCY(PER DAY)	+0.789	+0.005		
NO. OF FELLOW TRAVELER W/ MANAGER(PERSONS)	-0.531	-3.069		
NO. OF FELLOW TRAVELER W/O MANAGER(PERSONS)	-0.418	-1.908		
W/ EXECUTIVE DUMMY	-0.935	-1.594		
W/ MANAGER DUMMY	$-0.139*10^{+1}$	-2.665		
W/ HEAVY BAGGAGE DUMMY	$+0.359*10^{+1}$	+2.880	$+0.429*10^{+1}$	+3.493
DRIVING LISENCE DUMMY	$+0.142*10^{+1}$	+1.802		
CAR OWNERSHIP DUMMY	$+0.117*10^{+1}$	+1.443		
L(0) (L(c))		-237.0	(-235.9)	
L(θ)	-120.2		-139.7	
χ_0^2 (χ_c^2)	233.7	(231.5)	194.7	(192.5)
ρ^2-VALUE	0.4930	(0.4727)	0.4107	(0.4020)
HIT RATIO				
CAR(EXP.WAY DRIVING)	94.29%		94.29%	
RAIL	14.29%		9.52%	
BUS(VIA EXP.WAY)	57.14%		40.48%	
OVER ALL	80.33%		76.99%	

W/:traveling with DUMMY:with=1,without=0

alternative specific variables;

auto-fuel (yen per a head)

expressway rates (yen per a head)

access to the nearest station (km)

either with or without heavy baggages

partly generic variable;

fares

generic variable;

travel time

The signs of the parameters for those variables are all what are expected to be but one for auto-fuel that is positive in sign. Auto-fuel is in usual highly correlated with expressway rates, travel time etc. That is the reason why the parameter for auto fuel consumption is unexpectedly positive in sign. The positive sign of the parameter is no reason why auto-fuel is negligible, because t-value is so large as seen in Table 3.

Attention should also be paid to dummy variable, either with or without heavy baggages. It was enrolled as a variable specific to car choice since it does not influence on the alternative of rail or bus. Heavy baggages proved accelerating car choice.

Disaggregate model has a good applicability to the trips from Tsuyama area to other regions, because it has considerably high hit ratio 77% with likelihood ratio 0.40.

5. Comparison of diversion model with disaggregate model

Table 4 shows mode choice ratios by regions that are destinations of trips from Tsuyama area. Each entry is a percentage of mode choice by models and the survey.

TAB.4 CHOICE RATIO by MODELS AND SURVEY(from TSUYAMA)

MODEL	DIVERSION RATE MODEL			DISAGGREGATE LOGIT MODEL			SURVEY		
dest. / MODE	CAR	BUS	RAIL	CAR	BUS	RAIL	CAR	BUS	RAIL
KANTOU	16.6	49.8	33.6	11.8	23.5	64.7	33.3	40.0	26.7
CHUBU HOKURIKU	40.0	32.0	28.0	62.5	0.0	37.5	50.0	12.5	37.5
OSAKA	58.8	38.1	3.1	100.0	0.0	0.0	59.5	32.4	8.1
HYOUGO	75.4	12.5	12.1	92.0	8.0	0.0	92.0	4.0	4.0
OKAYAMA	91.7	--	8.3	100.0	--	0.0	85.2	--	14.8
HIROSHIMA	61.6	--	38.4	57.9	--	42.1	35.0	--	65.0
SANIN	76.8	--	23.2	100.0	--	0.0	96.7	--	3.3
SHIKOKU	72.0	--	28.0	33.3	--	66.7	71.4	--	28.6
AVERAGE	72.2	12.2	15.6	85.3	2.5	12.2	73.2	9.2	17.6

From viewpoint of goodness of fit of the estimated ratios to the surveyed, diversion model has better applicability than disaggregate model. Diversion model gives better estimation on five regions and the average while disaggregate model does on three regions. Attention, however, should be paid to the aspect that diversion model proved critical in statistical significance for the trips from Tsuyama to other regions. That is the reason why the above comparison is not necessarily statistically convincing.

6. Concluding remarks

The study was undertaken to test empirically applicabilities of diversion model and disaggregate behavioral model of logit type to the estimation of mode choice by those who made occupational trips longer than about fifty kilometers by any one of the three mode : rail, bus and car.

Diversion model was set down as so called a binary choice process with two stages, where diversion of mode choice took place by a ratio that was given by a certain function of a generalized travel time ratio. First stage diversion was supposed to occur from rail and bus to car, the second from rail to bus and no other diversion occurs. First stage diversion ratio was tested on three sets of trips; a set of those from Tsuyama area to other regions, the one vice versa and the one of the mixed. For the first two sets, first stage diversion ratio was found to be rather critical in statistical significance, while it is highly significant for the last one. Second stage diversion ratio, though tested merely on a set of trips from Tsuyama area to other regions, proved highly significant. On the whole the diversion model is acceptable as applicable to the estimation of mode choice by those inter-regional occupational person trips.

Disaggregate behavioral model of logit type, is acceptably identified by six variables that are all quite likely to gain general acceptance but one whose parameter is against our expectations in sign. It deserves attention that the dummy variable, whether or not a trip maker has any heavy baggage with him was found to be significant in influence upon car choice.

So far as the trips from Tsuyama to other regions are concerned, diversion model gives better estimation of mode choice ratios than disaggregate behavioral model of logit type.

Acknowledgment

The authors are much indebted to the research fellows at Okayama Institute of Economics for their helpful advices and cooperation in preparing the person trip survey. They also wish to express their gratitude to the leaders of the Tsuyama Aircommuter Consultative Meeting who allowed them to use the data surveyed. They are very grateful to Mr. Keiichi Kishino, who changed from their department to Chuo Fukken Consultants Co., Ltd., for his suggestive comments.

REFERENCES

[1] Ruiter,E.R. and M.E.Ben-Akiba: Transportation Research Record, 673(1978), 121, 136.

R.Kitamura: Transportation Research, 15A(1981), 473, 486.

Y.Sugie: Traffic Engineering, 16, 6(1981), 3, 11, (in Japanese). etc.
[2] S.Morichi, T.Tamura and J.kondo: Kotsugaku-Kenkyu, (1984), 46, 51. (in Japanese)
[3] S.Myojin, K.Kishino and M.Yamada: Memoirs of the Fuculty of Engineering, Okayama Univ., 22(1988), 63, 70.
[4] Tsuyama Aircommuter Consultative Meeting: A Preliminary Survey on Feasibility of Aircommuter in Tsuyama Area, (1987). (in Japanese)
[5] JSTE: Traffic Engineering Handbook, (1984), 355, 356. (in Japanese)
[6] Hanshin Expressway Public Cooporation: Report of Empirical Study on Diversion Ratio Function, (1976). (in Japanese)
[7] K.Ohta: Disaggregate Behavioral Model, Theory and its Application, JSCE, (1984), 9, 23. (in Japanese)