CONSTRUCTION OF MODAL CHOICE MODEL CONSIDERING USER'S CONSCIOUSNESS

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Abstract: This paper studies how to make a useful, meaningful and precise model of modal choice. As a modal choice model, a disaggregate logit model is generally applied in the practical use. On the other hand, Analytic Hierarchy Process (AHP), which is useful to evaluate user's consciousness, is used to make another type of model. But, each model has not only merits but also demerits. Therefore, as one of solution of these problems, the model is proposed by the use of both AHP and disaggregate logit models. As a result, improved AHP model and AHP-type of disaggregated logit model are also proposed. These proposed models are compared with traditional AHP and disaggregate logit models and each other in the various viewpoints. Characteristics of these models are understood, and it is discussed how to use these models.

Key Words: Analytic Hierarchy Process, Disaggregate logit model, Modal choice

1. INTRODUCTION

A disaggregate logit model is applied to analysis and forecast the travel demand in each modal choice. This model is analyzed using physical factors on personal behavior. However, modal choice is influenced not only physical factors but also personal consciousness factors. The evaluation of physical factors is also different among various groups of persons. And, as merit of this model, prediction of explanation variables is possible in future. But, fuzzy evaluation, which is essential in many persons, is not included in explanation variables of physical factors, and another model is required to construct a new if settled choice set changes. These issues are important to build and to use this model.

In a modal choice, it is assumed that a person chooses a transportation mean on the basis of various factors. However, it is difficult to evaluate physical characteristics of every mode including alternatives. From this fact, an Analytic Hierarchy Process (AHP), which is useful to evaluate the consciousness for modal choice of person, can be applied to build up a model of modal choice. But, factors are classified into some levels to obtain easily answer in a questionnaire survey. So, as title of factors at the upper level is abstract expression, it is difficult to correctly understand those factors in AHP analysis. In this sense, AHP model is also inferior in the precision than a disaggregate logit model. Also, realistic evaluation for mode is expected by including fuzzy evaluation, various evaluations for mode are included as explanation variables and the choice set is easily changeable as a characteristic of this model. But, the difficultly to predict explanation variables in future is especially problem.

Characteristics of disaggregate logit and AHP model are summarized in Table-1. Two models are many merits and problems. To construct a useful, meaningful and precise model for modal choice, the problem in those models must be resolved, and approach is the synthesis of both models.

Table-1 Comparison between AHP model and disaggregate logit model

Item	AHP model	Disaggregate logit model
Structure of model	mode and explanatory variables are summarized in herarchy structure.	explanation variables for each mode are selected, and are individualy, independently and definitely evaluated in
	The model is costructed using evaluation values of mode and explanatory variables, including fuzzy evaluation, in a pair of	
Personal attributes, etc.	consciousness data	physical factors data
	similarity of consciousness by personal attributes are classified, and models are constructed in each group of persons	these are directly added to explanation variables
alternative mode data	consciousness data by a pair of comparison	assumed physical factors data
merits and demerits	as fuzzy evaluation is included, realistic evaluation for mode is expected.	fuzzy evaluation is not included
	various evaluations for mode are included as explanation variables	Explanation variables are limited to personal attributes and physical factors for alternative mode, etc.
	The choice set is easily changeable	if settled choice set changes, reconstruction of model is required.
	it is difficult to predict explanation variables in future	prediction of explanation variables is possible in future

This paper aims at constructing an improved model of modal choice by using both AHP and disaggregate logit models and considering how to use those models. At First, factors for modal choice are identified by a preliminary questionnaire, and summarized in a flow chart classifying factors into five steps. Applying AHP technique, the importance of each factor in modal choice is investigated, and AHP weights of factors by questionnaire are scored. AHP weights in each factor are analyzed with personal attributes, using Quantification Theory Ⅰ. Also, a relation between AHP weights for alternatives and various factors for modal choice, such as personal attributes, transport service factors etc., are found by the application of the variance analysis. Then, these AHP weights for alternatives are represented by various factors on the application of Quantification Theory Ⅰ. Choice probability of mode is calculated using these AHP weights (AHP model).

Secondly, a disaggregate logit model for modal choice with the same explanation variables as in the AHP model, is proposed (Traditional disaggregate logit model), and the model is compared with the AHP model. Issues of each model are discussed.

Thirdly, using AHP weights for alternatives as explanatory variables, a disaggregate logit model for modal choice is also proposed. In other words, the consciousness of traveler for modal choice is introduced in a logit model (AHP-type of disaggregate logit model). In addition, the improvement of AHP model is attempted. It is discussed that which factor is important in modal choice by comparing between improved weights and them of the questionnaire. Choice probabilities of modes are calculated using these AHP weights (Improved AHP model).

Finally, these four models; AHP model, traditional disaggregate logit model, AHP-type of disaggregate logit model and improved AHP model, are compared each other. Characteristics of these models are understood, and it is discussed how to use these models.

Questionnaire for modal choice in our study is carried out in Fukuoka urban area as shown in Figure-1. Fukuoka urban area is composed of 8 cities, 13 towns and 1 village. Fukuoka city is the core of this urban area.

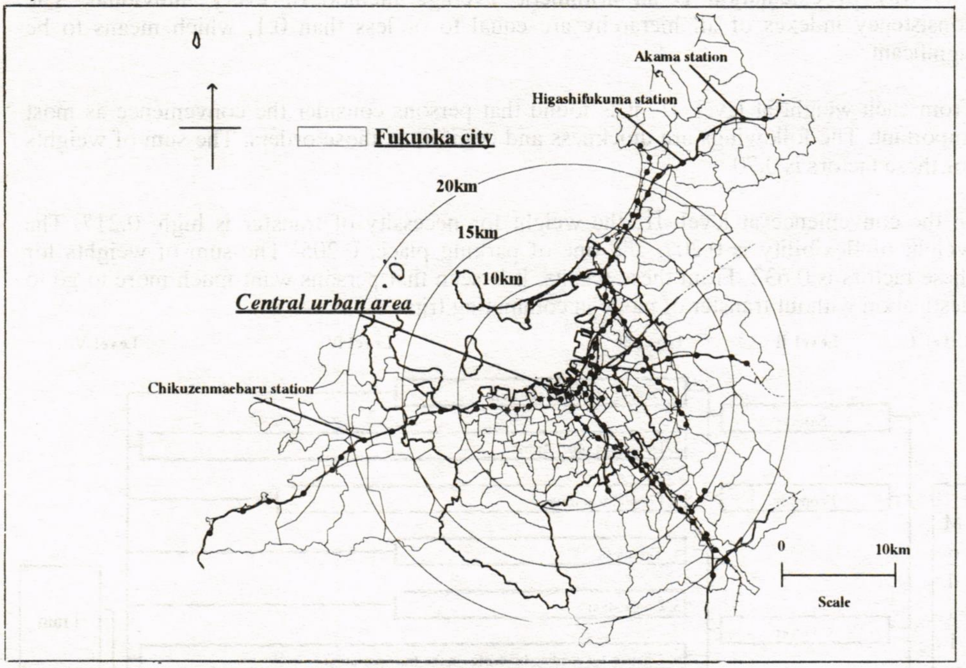

Figure 1. Fukuoka Urban Area and Zoning for the Study

2. SUMMARY OF QUESTIONNAIRE SURVEY

For questionnaire, three station areas of Akama, Maebaru and Higashifukuma on JR Kyushu lines are selected, which are located at residential areas near Fukuoka City in Japan. The questionnaire survey data are analyzed to clear the reason of modal choice of passengers for commuting and attending-to-school trips. Factors for modal choice are identified by a preliminary questionnaire, and summarized in a flow chart arranged into five grades (Figure-2). Number of questionnaire item for AHP is 59 at all in the method of the paired comparison judgment, divided into 9 degrees. The investigation was carried out from 21st to 24th, October 1994. Summaries of questionnaire survey are shown as in Table-1.

Table 1. Summary of Questionnaire Survey

Method of suvey	Leave-and-mail survey		
Days of distribution	21-23. October. 1999		
Days of collection	21-31. October. 1999		
District	Munakata	Chikushi	Maebaru
Distrubuted number	140	140	140
Collected number	47	44	45
Collected percentage of questionnaire	33.6%	31.4%	32.1%

3. ANALYSIS BY ANALYTIC HIERARCHY PROCESS

3.1 Analysis of AHP Weights on Factors

Using an AHP structural model, the importance of each factor is investigated in modal choice, and relevant consciousness for choosing is scored. The result is shown in Table-2. The way of calculation is an arithmetic average method of every individual. The consistency indexes of all hierarchy are equal to or less than 0.1, which means to be significant.

From each weight at level II, it is found that persons consider the convenience as most important. The followings are quickness and comfort in those orders. The sum of weights for these factors is 0.70.

In the convenience at level II, the weight for necessity of transfer is high, 0.217. The weight of flexibility is 0.207, and one of parking place, 0.205. The sum of weights for these factors is 0.632. From these results, it is seen that persons want much more to go to destination without transfer of mode in commuting trip.

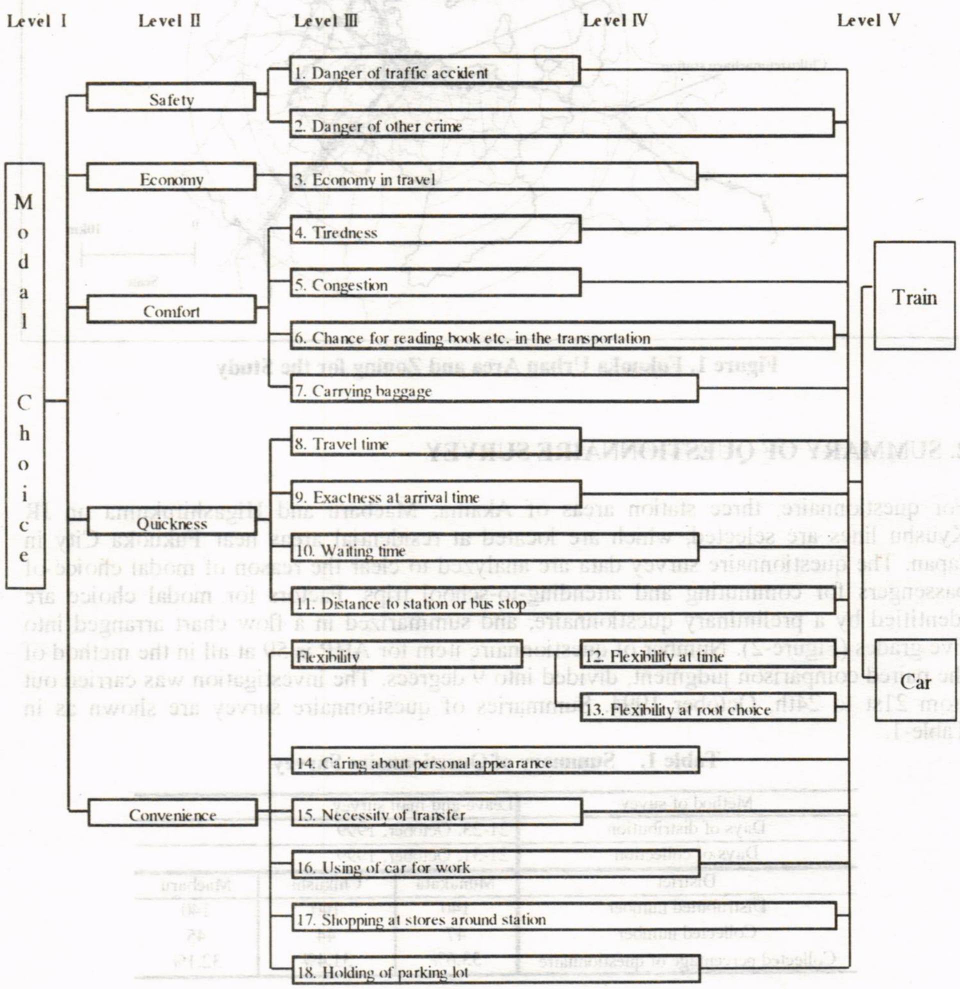

Figure 2. Consciousness Structure of Modal Choice

Table 2. Weights of Factors in Modal Choice

Level Ⅱ		Safety	0.154	
		Economy	0.147	
		Comfort	0.171	
		Quickness	0.251	
		Convenience	0.277	
		C.I.	0.002	
		λ max	5.008	
Level Ⅲ	Safety	Factor1	0.648	**0.100**
		Factor2	0.352	**0.054**
	Economy	Factor3	0.147	**0.147**
	Comfort	Factor4	0.282	**0.048**
		Factor5	0.295	**0.050**
		Factor6	0.218	**0.037**
		Factor7	0.205	**0.035**
		C.I.	0.005	
		λ max	4.016	
Level Ⅲ	Quickness	Factor8	0.303	**0.076**
		Factor9	0.289	**0.073**
		Factor10	0.220	**0.055**
		Factor11	0.189	**0.047**
		C.I.	0.009	
		λ max	4.026	
	Convenience	flexibility	0.207	**0.057**
		Factor14	0.136	**0.038**
		Factor15	0.217	**0.060**
		Factor16	0.116	**0.032**
		Factor17	0.119	**0.033**
		Factor18	0.205	**0.057**
		C.I.	0.005	
		λ max	6.027	
Level Ⅳ	Flexibility	Factor12	0.583	**0.033**
		Factor13	0.417	**0.024**

Notes : Factor number in level Ⅲ or Ⅳ is shown in Figure2 C.I. = Consistency Indexes
[shaded] = relative weight λ max = Max eigenvalue

Table 3. The Result of AHP Relative Weights in Factor Using Quantification Theory Ⅰ

Item	Category	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Factor9
Sex	Male	-0.001	-0.003	0.000	-0.002	-0.002	0.000	0.000	0.003	0.002
	Female	0.005	0.014	0.000	0.010	0.011	0.000	0.002	-0.014	-0.011
	Range	0.006	0.017	0.001	0.013	0.013	0.000	0.002	0.017	0.013
	Partial correlation coefficient	0.072	0.399	0.008	0.415	0.330	0.010	0.082	0.583	0.427
Age	29 years and under	-0.057	0.004	0.012	0.002	0.013	-0.005	-0.008	-0.013	-0.010
	30 years and over	0.017	-0.001	-0.003	-0.001	-0.003	0.001	0.002	0.004	0.003
	Range	0.074	0.005	0.015	0.003	0.016	0.006	0.010	0.017	0.013
	Partial correlation	0.708	0.125	0.202	0.103	0.434	0.344	0.409	0.593	0.435
Occupation	Others	-0.009	0.000	-0.041	-0.004	-0.005	0.003	0.000	0.016	-0.005
	Construction workers	-0.028	0.001	-0.041	0.024	0.026	-0.008	-0.006	0.003	0.006
	Manufacturing and electric workers	0.008	0.001	-0.023	-0.002	0.004	0.004	-0.016	-0.022	0.019
	Transport and communication workers	0.068	0.047	-0.010	-0.006	-0.014	0.009	-0.003	0.021	-0.012
	Wholesale and retail workers	-0.063	-0.016	-0.017	0.008	0.015	-0.013	0.011	0.005	-0.009
	Finance and real estate workers	-0.045	0.002	-0.008	0.009	0.008	0.013	0.003	0.007	0.001
	Service workers	0.051	0.000	0.025	-0.017	-0.026	-0.002	-0.012	-0.010	0.006
	Official workers	-0.017	-0.005	0.016	0.002	-0.006	0.002	0.000	-0.002	-0.013
	Students	0.044	-0.002	0.069	-0.010	0.001	-0.006	0.002	0.011	0.003
	Wives and persons without job	0.010	-0.004	0.015	-0.002	-0.009	0.006	0.049	-0.021	-0.005
	Range	0.131	0.063	0.111	0.041	0.052	0.027	0.064	0.043	0.032
	Partial correlation coefficient	0.816	0.680	0.776	0.757	0.750	0.745	0.851	0.852	0.721
Constant		0.127	0.059	0.171	0.045	0.049	0.033	0.033	0.065	0.060
Multiple correlation coefficient		0.840	0.728	0.854	0.787	0.824	0.811	0.856	0.900	0.803

Item	Category	Factor10	Factor11	Factor12	Factor13	Factor14	Factor15	Factor16	Factor17	Factor18
Sex	Male	0.001	0.002	0.001	0.001	0.000	0.003	0.001	0.001	0.001
	Female	-0.005	-0.010	-0.003	-0.003	-0.002	-0.013	-0.005	-0.003	-0.004
	Range	0.006	0.013	0.004	0.004	0.003	0.016	0.006	0.004	0.005
	Partial co.	0.282	0.476	0.185	0.491	0.154	0.484	0.403	0.228	0.143
Age	29 years and under	-0.003	0.001	0.001	-0.003	-0.011	0.001	-0.011	0.014	-0.022
	30 years and over	0.001	0.000	0.000	0.001	0.003	0.000	0.003	-0.004	0.006
	Range	0.004	0.001	0.002	0.004	0.014	0.001	0.014	0.017	0.028
	Partial correlation	0.210	0.057	0.072	0.456	0.660	0.025	0.771	0.741	0.694
Occupation	Others	-0.014	-0.015	0.006	0.007	0.006	0.021	-0.002	0.012	0.016
	Construction workers	0.000	0.018	0.011	0.002	0.005	0.003	0.003	0.005	-0.003
	Manufacturing and electric workers	-0.007	-0.008	0.007	-0.001	-0.003	0.018	-0.004	0.007	-0.003
	Transport and communication workers	-0.016	-0.022	-0.009	-0.005	0.002	-0.025	-0.018	-0.011	-0.021
	Wholesale and retail workers	0.014	0.006	0.010	-0.001	-0.002	-0.003	0.019	0.001	0.010
	Finance and real estate workers	0.004	-0.011	-0.004	-0.003	-0.009	0.009	-0.011	0.003	-0.007
	Service workers	-0.015	-0.011	0.000	0.000	-0.009	-0.001	0.008	-0.003	0.014
	Official workers	0.002	0.021	-0.004	-0.005	-0.003	-0.006	-0.008	-0.005	-0.003
	Students	0.022	0.009	-0.014	0.007	0.009	-0.016	0.005	-0.011	0.005
	Wives and persons without job	0.006	-0.005	-0.008	-0.005	0.005	-0.015	0.000	0.002	-0.037
	Range	0.038	0.043	0.025	0.012	0.018	0.046	0.037	0.024	0.053
	Partial correlation coefficient	0.862	0.860	0.728	0.831	0.727	0.792	0.912	0.797	0.782
Constant		0.048	0.047	0.031	0.017	0.033	0.052	0.026	0.027	0.055
Multiple correlation coefficient		0.871	0.871	0.762	0.844	0.792	0.847	0.933	0.823	0.853

In the quickness at level II, the most important factor is the travel time, which weight is 0.303. The weight of arrival time is 0.289. The sum of weights of these factors is 0.592. That is to say, factors on time are important to choose a mode.

In the comfort at level II, congestion is the most important for modal choice in commuting trip. The important factor after congestion is tiredness, 0.282. Consequently, it is confirmed that two factors of convenience and quickness are very important for modal choice.

Table 4. Results of Variance Analysis

Factor independent variable	1 Car	2 Car	3 Both	4 Car	5 Train	6 Train	7 Car	8 Both	9 Train
A.sex	0.034 **	0.110	0.510	0.104	0.633	0.365	0.676	0.075 *	0.768
B.age	0.328	0.118	0.053 *	0.108	0.068 *	0.576	0.237	0.024 **	0.585
C.job	0.649	0.371	0.197	0.837	0.823	0.431	0.931	0.122	0.819
D.distance to office by road	0.022 **	0.553	0.111	0.131	0.102	0.272	0.066 *	0.001 ***	0.299
E.distance to office by train	0.089 *	0.067 *	0.416	0.172	0.234	0.110	0.070 *	0.000 ***	0.009 ***
F. access distance to station	0.836	0.664	0.207	0.521	0.775	0.054 *	0.904	0.648	0.575
G.traffic congestion degree	0.541	0.544	0.268	0.419	0.004 ***	0.012 **	0.126	0.004 ***	0.102
H.number of road line	0.620	0.042 **	0.723	0.115	0.607	0.349	0.073 *	0.002 ***	0.001 ***
I.3rd industries employee in generating zone	0.115	0.696	0.673	0.563	0.040 **	0.130	0.398	0.098 *	0.984
J.3rd industries employee in attracting zone	0.395	0.897	0.654	0.556	0.383	0.623	0.411	0.253	0.333
K.number of transfer times by train	0.699	0.415	0.017 **	0.522	0.905	0.158	0.320	0.007 ***	0.260
L.number of train	0.667	0.854	0.280	0.909	0.291	0.515	0.838	0.398	0.384
M.converted difference of distance	0.941	0.118	0.276	0.544	0.213	0.180	0.712	0.137	0.203
N.converted difference of time	0.118	0.754	0.333	0.028 **	0.136	0.197	0.691	0.801	0.481
O.converted difference of expense	0.548	0.528	0.532	0.758	0.732	0.581	0.803	0.018 **	0.081 *

Factor independent variable	10 Train	11 Train	12 Car	13 Car	14 Train	15 Car	16 Car	17 Train	18 Car
A	0.477	0.153	0.520	0.872	0.144	0.659	0.499	0.799	0.779
B	0.563	0.076 *	0.134	0.776	0.256	0.769	0.123	0.199	0.906
C	0.705	0.213	0.522	0.877	0.600	0.754	0.135	0.289	0.215
D	0.018 **	0.070 *	0.015 **	0.256	0.112	0.085 *	0.331	0.188	0.414
E	0.256	0.069 *	0.397	0.959	0.487	0.099 *	0.233	0.289	0.882
F	0.986	0.800	0.898	0.976	0.383	0.654	0.870	0.581	0.479
G	0.154	0.152	0.529	0.944	0.157	0.024 **	0.502	0.564	0.799
H	0.188	0.208	0.281	0.295	0.884	0.326	0.521	0.634	0.190
I	0.663	0.439	0.399	0.502	0.073 *	0.568	0.272	0.844	0.743
J	0.261	0.108	0.321	0.724	0.339	0.354	0.568	0.966	0.090 *
K	0.582	0.620	0.266	0.433	0.430	0.591	0.650	0.561	0.587
L	0.896	0.540	0.880	0.555	0.593	0.647	0.522	0.635	0.370
M	0.392	0.422	0.455	0.131	0.554	0.411	0.173	0.845	0.434
N	0.682	0.226	0.638	0.206	0.112	0.169	0.542	0.293	0.218
O	0.603	0.754	0.885	0.914	0.197	0.484	0.457	0.129	0.031 **

Note : *** is significant level at 1%, ** is significant level at 5%, * is significant level at 10%.
Factor number is shown in Figure2.

It is seemed that the evaluation of weights for these factors is different according to personal attributes. Namely, AHP relative weights are calculated in each personal attribute, and AHP weights in personal attributes can be grouped on the basis of similarity. AHP relative weights in each factor are analyzed with personal attributes using Quantification Theory I. Here, Quantification Theory I predict a quantitative variable (dependent variable) from qualitative variables (independent variable). It means that independent variables of multiple regression analysis are qualitatively defined. The results are shown in Table-3. In items, most of these models for weights have high partial correlation coefficients in occupation. Multiple correlation coefficients are passable results at 0.728～0.933.

3.2 Estimation of AHP Weights for Alternative Mode

Characteristics of weights for each factor at level Ⅴ are analyzed in personal attributes and travel conditions by the use of variance analysis. Personal attributes are sex, age and occupation. Travel conditions are distance to office by train, access distance from home to the station, degree of traffic congestion, number of road lanes, amount of 3rd industrial employees in generating and attracting zones, number of transfer times, number of scheduled trains and converted difference of distance, time and expense. Traffic congestion and number of road lanes are average values in zones through shortest route from a generating zone to an attracting one. These are obtained in the traffic census on road, and are totaled in C zones, which are divided into 197 in Fukuoka urban area in the 3rd Northern Kyushu person trip survey. Number of 3rd industrial employees indicates whether the zone is in the central urban district or not.

Here, converted difference of time, distance or expense is defined by the following equation:

$$X = \frac{d_A - d_B}{\sqrt{d_A + d_B}} \tag{1}$$

where X: converted difference of time, distance or expense,
d_A: time, distance or expense by the concerned mode "A",
and d_B: time, distance or expense by another alternative mode "B".

Table 5. The Result of Quantification Theory Ⅰ in Factor 1

Item	Category	Number	Category score	Range / Partial corr.
Sex	Male	136	-0.031	0.169
	Female	30	0.138	0.269
Age	under 20 years	11	-0.255	0.451
	20 to 29 years	28	-0.012	0.473
	30 to 39 years	27	-0.097	
	40 to 49 years	41	0.196	
	50 to 59 years	40	-0.055	
	60 years and over	19	-0.003	
Occupation	Others	15	0.249	0.404
	Construction workers	16	-0.112	0.488
	Manufacturing and electric workers	20	-0.130	
	Transport and communication workers	10	0.187	
	Wholesale and retail workers	19	-0.011	
	Finance and real estate workers	14	-0.106	
	Services	17	-0.065	
	Official workers	23	-0.006	
	Student	21	0.164	
	Wife and persons without job	11	-0.155	
Distance to office by road	0 to 15km	32	0.069	0.085
	15km and over	134	-0.016	0.131
Degree of traffic congestion	0 to 1.0	39	0.077	0.125
	1.0 to 1.3	106	-0.019	0.167
	1.3 and over	21	-0.048	
Constant				0.458
Multiple correlation coefficient				0.634

In evaluation of a mode, difference or ratio among modes in the time, distance or expense from home to office is important factors. However, it is doubtful to evaluate mode using only this difference or ratio. Therefore, in the evaluation of modes, new explanation variables, that the difference and ratio are converted in the above equation, are required.

AHP weights at level V are analyzed using Quantification Theory I. Variables such as distance, time and expense were categorized considering each frequency distribution. Each factor has weights at level V of car and train. At first, relationships between weights at level V and explanation variables in each factor are understood by the use of variance analysis. Variance analysis is carried out using all explanation variables to find relationships between variables and weights in each factor. Null hypothesis is "weights for factors are not difference among explanation variables". The results of variance analysis are shown in Table-4, marking with *, ** and ***.

Table 6. Results of Quantification Theory I in Factors except Factor 1

Factor	variable	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	R
2	Range	0.057	0.271	0.284		0.036	0.095										0.591
	Partial corr.	0.117	0.441	0.427		0.086	0.219										
3	Range	0.055	0.178	0.380	0.110							0.005				0.221	0.622
	Partial corr.	0.106	0.342	0.539	0.191							0.009				0.347	
4	Range	0.040	0.236	0.271	0.136		0.156					0.052			0.364		0.625
	Partial corr.	0.072	0.321	0.350	0.216		0.254					0.107			0.440		
5	Range	0.046	0.175	0.191		0.029		0.468				0.042	0.001				0.591
	Partial corr.	0.080	0.329	0.227		0.033		0.463				0.084	0.003				
6	Range	0.015	0.142	0.416				0.253						0.109			0.589
	Partial corr.	0.025	0.176	0.450				0.335						0.181			
7	Range	0.042	0.239	0.395			0.004					0.040					0.554
	Partial corr.	0.097	0.428	0.463			0.009					0.085					
8	Range	0.021	0.241	0.217	0.389				0.089			0.064			0.227		0.755
	Partial corr.	0.043	0.281	0.340	0.568				0.135			0.167			0.395		
9	Range	0.102	0.476	0.350		0.084	0.065	0.052	0.034								0.625
	Partial corr.	0.216	0.507	0.518		0.197	0.164	0.107	0.052								
10	Range	0.092	0.196	0.347		0.140						0.077	0.036		0.209		0.597
	Partial corr.	0.179	0.283	0.449		0.253						0.149	0.078		0.321		
11	Range	0.146	0.287	0.313	0.266		0.080										0.608
	Partial corr.	0.268	0.270	0.402	0.414		0.159										
12	Range	0.047	0.185	0.318	0.277								0.029				0.611
	Partial corr.	0.100	0.379	0.470	0.429								0.074				
13	Range	0.039	0.182	0.315	0.136									0.104			0.533
	Partial corr.	0.076	0.292	0.471	0.230									0.261			
14	Range	0.060	0.345	0.202	0.017												0.563
	Partial corr.	0.147	0.474	0.326	0.051												
15	Range	0.096	0.460	0.677								0.011		0.154			0.546
	Partial corr.	0.172	0.319	0.509								0.022		0.327			
16	Range	0.041	0.323	0.352	0.130												0.612
	Partial corr.	0.093	0.473	0.484	0.260												
17	Range	0.045	0.448	0.517			0.071			0.023	0.024						0.661
	Partial corr.	0.081	0.529	0.588			0.140			0.054	0.026						
18	Range	0.177	0.237	0.586	0.213						0.130						0.631
	Partial corr.	0.291	0.205	0.577	0.357						0.249						

Note: R = multiple correlation coefficient. Factor number is shown in Figure-1. Variable alphabet is shown in Table-4

In the factor 8, which is "travel time", many explanation variables are significant. Sex and distance to office by road are significant at level of 5% in the factor 1, which is "danger of traffic accident". Average weights of sex in the factor 1 are 0.462 in male, 0.582 in female. Female is more worried about traffic accident than male. Degree of traffic congestion is significant at level of 1% in the factor 5 (congestion). This factor's weight is influenced by traffic congestions.

In the factor 6, which is "chance for reading book etc. in the transportation", distance by road is significant at level of 5%. In the factor 8 (travel time), age is significant at level of 5%. Also, distance by road and train, degree of traffic congestion, road lanes and number of transfer times in train are significant at level of 1%.

In each factor, weights at level V, which are the evaluated values for alternative modes, are estimated by the use of Quantification Theory Ⅰ. Explanation variables in each factor are selected considering the result of variance analysis. For example, a model for factor 1, which is "danger of traffic accident", is shown in Table-5.

Multiple correlation coefficient is 0.634. Partial correlation coefficient is highest at 0.488 in occupation. Also, those of personal attributes such as sex and age are high. That of distance by road is lowest at 0.131. Evaluation of car is high in short distance and low in the degree of traffic congestion.

Results of models for other factors are shown in Table-6. For the lack of this paper, ranges, partial and multiple correlation coefficients in each factor are indicated. Multiple correlation coefficient is highest in factor 8 at 0.755, which is "travel time" and has many significant variables in the variance analysis. Those of other models are low at 0.53~0.66 By using these models, relative weights of each factor in level III and IV can be calculated with physical variables. Next, weights at level V can be calculated by each evaluation value in a mode. From these weights, probability of modal choice is founded. Hit ratio by this model is 65.6% in all, 60.8% in train and 75.8% in car. On the other hand, hit ratio by AHP weights calculated using the result of questionnaire is 72.4% in all, 66.2% in train and 85.5% in car. Needless to say, the precision of these models is not enough.

4. TRADITIONAL DISAGGREGATE LOGIT MODEL

Disaggregate logit model is applied to analysis and predict the modal choice for the strategies and transportation planning. This model assumes rational choosing behavior of mode, that person chooses most useful mode in available modes, and is an excellent method to explain personal choosing behavior.

Table 7. Disaggregate Logit Model with Physical and Personal Attributes

Explanation variable		Model1 Parameter	Model1 t-value	Model2 Parameter	Model2 t-value
Train dummy		-24.421	-4.176 *	-10.004	-4.642 *
Distance to office		-0.214	-2.248 *	-0.052	-0.837
Expense		-0.013	-2.393 *	-0.001	-0.447
Time		0.195	4.441 *		
Access distance to station		-0.419	-1.757	-0.231	-1.983 *
Traffic congestion		-10.607	-3.517 *	-5.852	-4.019 *
Number of road lanes		-4.245	-4.801 *		
3rd industrial employee in generating zone		0.000	0.539		
3rd industrial employee in attracting zone		0.000	-1.652		
Number of transfer times by train		-0.154	-0.261		
Number of train		0.066	0.942		
Sex		0.587	0.559		
Age		0.637	2.349 *		
Occupation		-0.123	-1.404	-0.118	-2.149 *
Holding of license		-0.268	-0.649		
Holding of car		-4.659	-2.426 *	-3.788	-3.578 *
Number of data		192		192	
Number of mode		2		2	
Likelihood ratio		0.664		0.354	
Hit ratio	Total(192)	92.2%		80.7%	
	Train(130)	93.8%		92.3%	
	Car(62)	88.7%		56.5%	

Notice : * is significant level at 5% in t-value

Then, a disaggregate logit model for modal choice with physical factors and personal attributes as explanation variables, which are used in AHP model, is built up. Difference between this model and AHP model is discussed.

The model is constructed as shown in Table-7. In the model 1, which is constructed using all explanation variables, hit ratio is good result in 92.2%. But, signs of parameters, which are time and number of road lanes, are illogical. Next, models are repeatedly constructed while excluded these variables, which are illogical and have less than 1.96 in absolute t-value. The last model is the model 2. Hit ratio of this model is 80.7%, and likelihood ratio is 0.354. It can be said that this model is better than AHP model.

5. AHP-TYPE OF DISAGGREGATE LOGIT MODEL

In AHP method, weights at levelⅢ and Ⅳfor every choice factor were analyzed with personal attributes as in § 3.2. Also, weights at level Ⅴ in each factor were analyzed with personal attributes and travel conditions. These results were not satisfied. But, characteristics of user's consciousness for mode could understand in detail. The model, which is constructed, based on user's consciousness, is useful to explain the structure of consciousness in modal choice, even if the precision of this model is not enough.

Table 8. AHP-type of Disaggregate Logit Model

Explanation variable	Model1		Model2		Model3		Model4	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Train dummy	-4.480	-1.769	-4.781	-2.506 *	-4.598	-3.076 *	-4.551	-3.054 *
1	-1.992	-1.400						
2	-4.691	-2.100 *						
3	1.175	0.854	-0.637	-0.783				
4	-0.171	-0.143						
5	0.740	0.525	0.912	0.787	0.510	0.503	0.233	0.252
6	-0.682	-0.604						
7	2.893	0.939	-1.170	-0.622				
8	6.817	4.623 *	5.793	5.316 *	5.751	5.975 *	5.695	5.940 *
9	3.146	1.560	0.080	0.071	0.010	0.009	0.070	0.067
10	-0.679	-0.510						
11	1.211	0.639	-0.361	-0.257				
12	1.402	0.524	0.173	0.092	-0.571	-0.685		
13	-3.643	-1.299						
14	1.061	0.347	-0.259	-0.155				
15	0.722	0.548	-0.068	-0.061				
16	-0.773	-0.356						
17	-0.302	-0.204						
18	-0.429	-0.385						
Holding of license	0.107	0.250	-0.124	-0.310	-0.170	-0.424	-0.156	-0.387
Holding of car	-4.836	-3.080 *	-3.941	-3.094 *	-3.890	-3.094 *	-3.964	-3.171 *
Number of data	192		192		192		192	
Number of mode	2		2		2		2	
Likelihood ratio	0.564		0.550		0.556		0.557	
Hit ratio Total(192)	90.1%		90.6%		90.6%		91.7%	
Hit ratio Train(130)	94.6%		95.4%		95.4%		96.9%	
Hit ratio Car(62)	80.6%		80.6%		80.6%		80.6%	

Notice : * is significant level at 5%, Factor number is shown in Figure-2

On the other hand, in the traditional disaggregate logit model, which was built up using physical factors and personal attributes, the precision is high. But, modal choice is essentially influenced not only physical factors but also personal consciousness factors. Namely, even the evaluation of personal physical factors is different among various groups of persons. In modal choice, it is assumed that person chooses the transportation means on the basis of various elements. In addition, it is difficult to evaluate characteristics of each alternative mode. Improvement of precision and significance of model is expected by constructing model considering these issues. Also, it is necessary to get the information of another modes except the chosen mode. But, the accurate information of alternative modes is not expected to obtain.

To solve these issues, it is proposed that the disaggregate logit models for modal choice are constructed using these AHP weights as explanation variables. At that time, the evaluation value for modes in each factor is required as explanation variables. Accordingly, weights at level Ⅴ for 18 factors are only added as explanation variables. The model AHP-type of disaggregate logit model) is constructed with these explanation variables, which are 21 factors including weights at level Ⅴ for 18 factors as common variables, train dummy as train specific variable, and holding of license and car as car specific variables, as shown in Table-8.

First of all, a model was constructed using all explanation variables. T-values of holding of car are most high. In AHP scores, it can be said that t-values of the following two factors are high; "danger of other crime" and "travel time". On the other hand, signs of parameters of nine variables such as "danger of traffic accident", "danger of other crime", etc. are negative and they are illogical.

Model 2 is constructed using explanation variables except nine variables, which are illogical in model 1. In the model 2, t-values of "travel time", holding of car and train dummy are high. However, signs of the parameters of "economy in travel", etc. are illogical further. Model 3 is constructed using explanation variables except five variables, which are illogical in model 2. In this model, t-values of train dummy, "travel time" and holding of car are high as well as in models 1 and 2.

In the same way, the models are simply constructed excluding illogical variables and variables, which is low in t-value, and model 4 is finally founded. In this model, t-values for three variables of train dummy, "travel time" and holding of car are high, and those are significant in 5% level. Moreover, hit ratios are 91.7% in all, 96.9% in the train and 80.6% in the car. Likelihood ratio is 0.557. It can be founded that the model 4 is enough good in precision, significant and simple.

From this result, it is understood that AHP weights are useful as explanation variables in a disaggregate logit model. Also, it is enough to use only weights at level Ⅴ, which are evaluation values to modes for each factor. This model reflects the consciousness in each group of persons. It is possible to improve the precision of traditional disaggregate model. Model can be constructed with fuzzy information of alternative modes.

6. IMPROVED AHP MODEL

In the questionnaire for AHP analysis, factors are summarized into some levels to obtain easily answer. In this case, it is difficult for person to evaluate factors of the upper level of AHP structure, because meaning of these factors become more abstract. Therefore, it can be said that factors in AHP model must be rationally summarized into some levels.

It is important for AHP method to evaluate alternative modes in a pair of comparison in each factor, and to calculate relative weight of each factor. It is advantage to use the weight of factor even though choice set is changed. Therefore, it is requested that more accurate AHP model is constructed. Also, from the result of AHP-type disaggregate logit model, it is understood that a precise model is constructed using only weights at level Ⅴ.

A improved model is constructed by using only weights at level Ⅴ, which are evaluation values of alternative modes. Then, for hierarchy structure, weights are reversibly estimated in each level. Firstly, choice probability of mode j in each person is defined as follows:

$$P_{jn} = \sum_{i=1}^{m} w_i a_{ijn} \qquad (2)$$

Where W_i : estimated AHP weight of factor i,
a_{ijn} : weight at levelⅤ of mode j on factor i,
m : number of factor, n : size of sample

δ_{jn} is defined that $\delta_{jn}=1$ if mode j is chosen and $\delta_{jn}=0$ if mode j is not. Therefore, equation (2) is transformed as follows:

$$P_{jn} = \prod_{j=1}^{2} P_{jn}^{\delta_{jn}} \qquad (3)$$

Joint probability L*, which is appeared by the selecting pattern of all persons, is defined as following equation to calculate backwords weights for every factor at a level in AHP model.

$$\text{Maximize} \quad L^* = \prod_{n=1}^{N}\prod_{j=1}^{2} P_{jn}^{\delta_{jn}}, \qquad (4)$$

$$\text{subject to} \sum_{i=1}^{18} W_i = 1.0 \ \ and \ \ 0.0 \le W_i \le 1.0.$$

Table 9. Comparison Between AHP Relative Weights at LevelⅢ and Ⅳ

Factor	Relative weights by questionnaire data	Relative weights by improved AHP model
1	0.1263	0.0040
2	0.0586	0.0062
3	0.1744	0.1695
4	0.0454	0.2420
5	0.0524	0.0068
6	0.0341	0.0013
7	0.0342	0.0022
8	0.0670	0.4408
9	0.0602	0.0003
10	0.0484	0.0003
11	0.0474	0.0004
12	0.0331	0.0003
13	0.0180	0.0004
14	0.0340	0.0195
15	0.0524	0.0232
16	0.0290	0.0221
17	0.0274	0.0328
18	0.0578	0.0280

Note : Factor number is shown in Figure-2

Results of the application of above equation are shown in Table-9. Weights at levelⅢ and Ⅳcalculated by the questionnaire are also shown in the same table. The weight of "economy in travel" is highest, and those of "danger of traffic accident" and "travel time" are also high in the questionnaire survey. In reversibly estimated AHP weights, weights of "economy in travel", "tiredness" and "travel time" are high, and the result is approximately same in comparison with the case by the questionnaire. But, a weight of "danger of traffic accident" is lower than the one by questionnaire survey. From this result, safety is one of important factors in user's consciousness to choose a mode. But, this factor is not reflected to actual travel behavior.

This model directly reflects the consciousness in each group of persons, and fuzzy consciousness can be directly used. In comparison between improved weights and them of the questionnaire in each factor, weights of "economy in travel" are almost similar. Oppositely, weights of "danger of traffic accident", "tiredness" and "travel time" are different. In weights by questionnaire data, evaluation of the factors in the upper level is difficult as mentioned above. User's consciousness for modal choice can be understood, but reflection of actual travel behavior is difficult. On the other hand, improved weights are calculated by the actual travel behavior. It is said that these weights are user's consciousness, which are reflected the actual travel behavior. Therefore, in a model for modal choice, improved weights are better than weights by questionnaire survey.

7. COMPARISON AMONG MODELS AND CONSIDERATIONS

In previous chapter, the four models such as AHP model, the disaggregate logit mode, AHP-type of disaggregate logit model and improved AHP model are built up. Compared among these models in hit ratio, the results are shown as in Table-10.

Table 10. Comparison of Hit Ratios in Every Model

Method	Mode	Hit ratio
Traditional AHP method	Train	60.8%
	Car	74.2%
	Total	65.1%
Improved AHP model	Train	96.9%
	Car	61.3%
	Total	85.4%
Traditional disaggregate logit model	Train	92.3%
	Car	56.5%
	Total	80.7%
AHP-type of disaggregate logit model	Train	96.9%
	Car	80.6%
	Total	91.7%

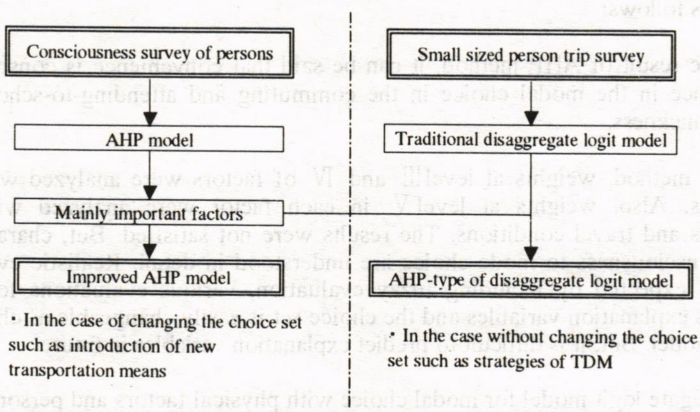

Figure 3. The System of Construction and Application of Model for Modal Choice

In the model by the AHP method, the hit ratio of train is low, 60.8%, that of car is high, 74.2%, and that of all is lowest at 65.1%. In the disaggregate logit model using physical and personal attributes, hit ratio is 80.7% in all. But, that of train is lowest at 56.5%. Hit ratio of AHP-type disaggregate logit model is highest at 91.7%. Also, those of train and car are high at 96.9% and 80.6%. In the improved AHP model, hit ratio is 85.4% in total. It can be said that this model is better than the traditional AHP model and the disaggregate logit model. But, this model is still inferior than AHP-type of disaggregate logit model.

Consequently, it is clear to be able to construct the consciousness model which is reflected correctly selection activities of transportation by reversibly estimating the relative weights of AHP method, and this model is better than the AHP model. From these results, model for modal choice uses only weights at level V, which are the evaluated values for mode in each factor. Therefore, in the questionnaire, only evaluation of mode in each factor is investigated, this model is obtained without complicated questionnaire. Also, it can be said that the improved AHP model for modal choice is useful, meaningful and precise.

From these results, AHP-type of disaggregate logit model is best in four models. But, if the choice set is changed, it is necessary that the model must be constructed once more. On the other hand, as evaluation values for mode by a pair of comparison are used, the choice set is easily changeable in AHP model. In this case, AHP model is advantageous. Therefore, Improved AHP model is also recommended considering these things. As a result, in prediction without changing the choice set, AHP-type of disaggregate logit model is proposed. Also, the improved AHP model is proposed in the case of changing the choice set. The former is useful for the plan such as traffic demand management, and the latter is useful for the plan such as introduction of new transportation means. The concept of construction of model for modal choice is summarized in Fugure-3 based on these studies. AHP weights are analyzed using consciousness data of persons. Traditional disaggregate logit model is constructed using small sized person trip data. Improved AHP weights are calculated by actual travel behavior. In this model, mainly important factors for actual travel behavior are selected. AHP-type of disaggregate logit model is constructed using evaluation values for mode of mainly important factors.

8. CONCLUSION

Merits and demerits of AHP and disaggregate logit model, which is generally used as model for modal choice, understood To solve these problems and construct useful, meaningful and precise model for modal choice, an improved model for modal choice are constructed by using merits both AHP and disaggregate logit models. Summaries of results are shown as follows:

(1) From the result of AHP method, it can be said that convenience is consciously most importance in the modal choice in the commuting and attending-to-school trip, and next is quickness.

(2) In AHP method, weights at level III and IV of factors were analyzed with personal attributes. Also, weights at level V in each factor were analyzed with personal attributes and travel conditions. The results were not satisfied. But, characteristics of users consciousness to mode choice are understood in detail. Realistic evaluation for mode is expected by including fuzzy evaluation, various evaluations for mode are added as explanation variables and the choice set is easily changeable as characteristics of this model. But, it is difficult to predict explanation variables in future.

(3) Disaggregate logit model for modal choice with physical factors and personal attributes as explanation variable, which is used in AHP model, is analyzed. It can be said that the precise of this model is better than AHP model. As merit of this model, prediction of explanation variables is possible in future. But, fuzzy evaluation is not included, and reconstructed model is required if settled choice set changes.

(4) Another of disaggregate logit model is constructed using only personal attributes and the relative weights at levels III and IV. Because hit ratio and likelihood ratio are high

in this model, the result is good. Consequently, while AHP scores are introduced the model as explanatory variables, it is possible to construct the model which reflects the factor of consciousness. Model can be constructed with fuzzy information of alternative modes. Although it is possible to improve the precision of traditional disaggregate model, it can be said that the use of model is built to the relative evaluation between choices.

(5) In comparison between relative weights by questionnaire and improved weights in each factor, weights of "economy in travel" are almost similar. Oppositely, weights of "danger of traffic accident", "tiredness" and "travel time" are different. In weights by questionnaire, evaluation of the factors in upper level is difficult as mentioned above. User's consciousness for modal choice can be understood, but reflection of actual travel behavior is difficult. On the other hand, improved weights are calculated by actual travel behavior. It is said that these weights are user's consciousness, which are reflected actual travel behavior. Therefore, in model for modal choice, improved weights are better than weights by a questionnaire.

(6) In comparison among models included proposed models, AHP-type of disaggregate logit model is best in precision. But, if the choice set is changed in the case of disaggregate logit model, the circumstances of parameters change, and it is necessary that the model must be constructed once more. On the other hand, the choice set is easily changeable in AHP model. Therefore, Improved AHP model is also recommended considering these things. As a result, in prediction without changing the choice set, AHP-type of disaggregate logit model is useful. Also, Improved AHP model is recommended for the plan in the case of changing the choice set. The system of construction and application of model for modal choice using both AHP and disaggregate logit model is proposed in Fugure-3.

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