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A HIERARCHICAL MODEL FOR THE FULL RANGE CHOICE OF SHOPPING TRAVEL BEHAVIOR

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This paper aims to develop a hierarchical model based on the nested logit model for the full range decisions of shopping trips, including the choice of frequency, destination travel mode, and parking place. Two kinds of hierarchical structure are tested to determine the ordering of destination choice and mode choice. A two-level substructure model of destination choice is also proposed. This study used the data collected by a questionnaire survey carried out in Nagaoka city for the shopping trips of grocery and non-grocery articles. The results obtained indicate the feasibility of the structure model with the ordering of destination choice as an upper level and mode choice as a lower level. The effects of parking capacity and selling floor area on shopping behavior are compared by using the sensitivity analysis of this model.

Key Words : *hierarchical model, nested logit model, shopping trips*

1. INTRODUCTION

Modelling of shopping travel behavior has been dominated by the disaggregate choice models which are based on the randon utility theory. A useful model is the multinomial logit model which has been considerably applied to the investigation of multiple decisions on frequency, travel mode and destination choice. To consider shopping travel behavior which involves two or more choice alternatives, the joint model was used[1),3),13)]. Adler and Ben-Akiva[1)] applied the joint choice model on a three-dimensional choice of frequency, destination and mode, but no satisfactory results were achieved in respect to frequency choice, since they considered frequency choice as a binomial choice between a travel option (frequency 1) and a no travel option (frequency 0). Then, the nested logit (NL) model which allowed a resolution of the problem of two or more choice alternatives was considered a more general method. Their difference consists only in considering shared observed or shared unobserved attributes[4)]. Applications of the NL model to destination and mode choice[4),24)] yielded adequate results. **Table 1** indicates a brief review of investigations related to shopping travel behavior.

On the other hand, owing to high motorization in local cities, car parking has become a matter of great interest to many researchers[5),6),8),20),21)]. So, parking place choice models were used to analyze the influence of parking service on shopping trips, particularly on their destination choice, since parking improvement constituted an important element in the transport strategies to relieve traffic congestion in central commercial areas. Also, parking characteristics were included in a destination choice model as explanatory variables such as parking accessibility and parking fare[11),12),13),22),24)].

Muramachi and Harata[14)] studied the impact of a large-scale shopping center in suburban zones, and concluded that the new shopping center in the suburbs changed the distribution of shopping trips and caused a decline in the commercial activity of the center area. In a similar study, Yoshida and Shitamura[24)] investigated the effect of central area parking policy on shopping trips by means of revitalizing the depressed urban center.

In order to analyze frequency choice in a different way from the binary model, Sheffi[16)] proposed the ordered logit model. This model was adopted by Yoshida and Harata[23)] in a three-level structure of frequency, destination and parking choice and showed good results. However, their investigations did not include mode choice, and the destination choice model had a structure of multiple choice among CBD and suburban zones. Firstly, what this means is that a decision maker chooses shopping trips only by car mode, which does not allow making clear the impact of parking improvement policy on the mode choice of travel behavior. Secondly, CBD and suburban shopping centers are quite distinct and exclusive, so it is more realistic to assume that destination choice model has a two-level hierarchy:a binomial choice between CBD and suburbs in an upper level;and a

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Table 1 Applications in relation to shopping travel behavior

Author	Year	Model	Choice or sequence	Variables
Alder and Ben-Akiva [1]	1976	Joint Logit	Frequency, destination, mode	Travel time, travel cost, income, attractiveness of destination
Westin and Guillen [20]	1978	Probit - OLS	Mode, parking	Parking fare, walking time
Guillen [6]	1978	Conditional logit model	Parking	Parking fee at location, duration of parking in hours, income
Sobel [17]	1980	Nested Logit (NL)	Slow mode, mode(*)	Travel time, cost, parking cost
Van Der Goot [18]	1982	Logit chance model	Parking	Parking fare, accessibility factors
Galbraith and Hensher [5]	1982	Transfer models	Mode	Travel time, cost, parking cost
Matsumoto, Kumakura and Matsuoka [13]	1983	Joint Logit	Destination, mode	Walking time, parking fare, floor area
Ben-Akiva, Gunn, and Silman [3]	1984	Joint Logit	Destination, mode	Travel time, number of department stores
Vickerman and Barmby [19]	1984	Ordered Logit (OL)	Frequency	Number of trips and cars, expenditure
Ishida, Matsumura and Kurokawa [10]	1988	Multinomial logit model (MNL)	Destination	Parking fare, access distance
Harata and Asano [8]	1989	MNL and NL	Destination, parking(*)	Parking capacity, search time, waiting time, floor area
Yoshida and Shitamura [24]	1989	NL	Destination, mode(*)	Parking capacity, distance, floor area
Kondo and Aoyama [11]	1989	Gravity Model	Destination	Shopping center attractiveness
Yoshida and Harata [23]	1990	NL and OL	Frequency, destination, parking(*)	Parking capacity, number of big stores, floor area
Muromachi, Harata and Ohta [14]	1990	MNL	Destination	Parking fare, travel time, floor area
Kondo and Aoyama [12]	1990	Gravity Model	Destination	Shopping-center attractiveness, travel time
Yajima, Yai and Morichi [22]	1990	LISREL and MNL	Destination, parking	Parking capacity, floor area

(*) sequence

zone choice in a lower level. Therefore, the three-level structure is not good enough to represent the travel behavior of shoppers who make decisions using a full range of alternatives.

From another point of view, a nested structure is also known as a hierarchical structure and the feasibility of a structure should be statistically tested as to whether the structure can be rejected or the IIA property is appropriate for the situation[4),7),9)]. Hierarchical modelling was applied to investigation of multiple decisions on frequency, destination and parking place choice[23)] and frequency, destination, mode and parking place choice[15)] for shopping trips. These papers involved three or four dimensional choices where the feasible structures of a hierarchy were not fully examined. In this paper two kinds of structures were chosen and tested in order to represent shopping behavior more realistically.

As a result, the objectives of this paper were to develop a discrete choice model based on the nested logit model for the full range decisions of shopping trips, including the choice of frequency, destination, mode and parking place. The feasibility of different hierarchical structures were investigated, emphasizing the ordering of mode choice model in a hierarchy and the hierarchical sub-structure of destination choice model. An empirical study was carried out in a local core city to examine and compare the effects of central area parking service and shopping attractiveness upon the shopping travel behavior of an individual.

The paper is organized as follows. Firstly, we briefly outline the model of hierarchical structure and method of its sequential estimation. Secondly, the results of model estimation and its interpretation are presented . Thirdly, sensitivity analysis is examined to get the overall effects of central area parking policies on travel shopping behavior, followed by a concluding section summarizing the main findings.

2. HIERARCHICAL STRUCTURE FOR SHOPPING CHOICE MODEL

Let us consider the full range of travel decisions for shopping of grocery and non-grocery articles, which constitutes choice decisions of alternatives of frequency, destination, mode and parking place. **Fig. 1** indicates two kinds of structures for a five-level hierarchical model.

Overall frequency of shopping is not directly related to destination, mode and parking place, but is strongly effected by factors such as income, business cycle, season and weather. However, shopping frequency will also increase when destination attractiveness or accessibility to destination and parking place improve. So, frequency choice models are located in the uppermost level of a hierarchy.

It is rational to assume that an individual decides the destination of a shopping trip first, then decides a parking place which is situated near the shopping destination. Based on this assumption, the level of parking choice should be lower than that of destination choice.

As for destination choice, Yoshida and Harata[23)] in a nested structure adopted an usual multinomial model in which destination choice included zones of both CBD and suburbs. Although they could obtain good results, the IIA property implied a restriction that made it difficult to evaluate the effect of commercial improvement in a zone of CBD. To avoid this restriction, a nested logit model is also adequate[2)]. **Fig.2** illustrates graphical-

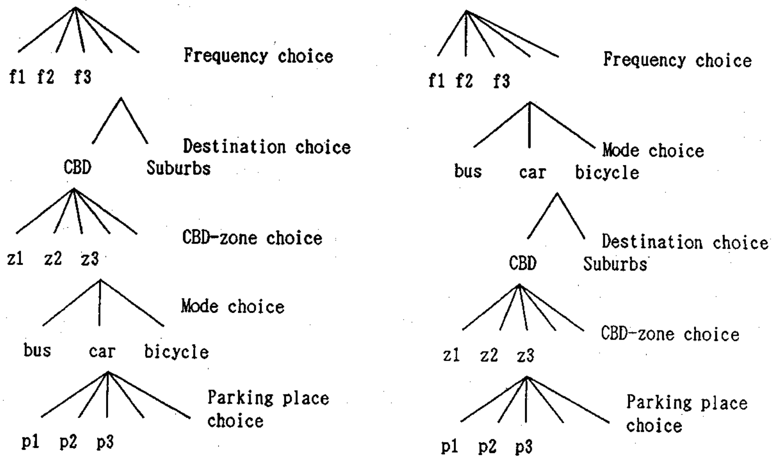

Fig.1 Two hierarchical structures for full range of travel decisions

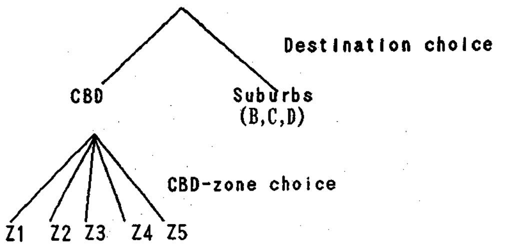

Fig.2 Structure for shopping destination choice

ly a hierarchical substructure for destination, the choice between CBD and suburbs in an upper level, and the choice of CBD zones (Z 1 to Z 5) in a lower level. This structure can make it possible to specify the attractiveness of each zone in the CBD. The composite attractiveness of CBD is represented by the expected maximum utility or LOGSUM variable of zone choice model.

In addition, two kinds of possible hierarchy are presented in **Fig.1.** Hierarchy A has the structure where mode choice model is located between destination and parking place choice. This sequence of destination and mode choice was considered as a classic structure and its feasibility was confirmed by several previous studies[4),15),24)]. Hierarchy B has a different structure from structure A in the ordering of mode choice model. This sequence of mode and destination choice has a possibility of being rejected by a statistical test, but can be considered more appropriate to estimate the effects of parking place on zone choice in the CBD and destination choice between CBD and suburbs. Of course, which structure is accepted or rejected can be determined only by a statistical test[9),17)].

The hierarchical model or nested logit model is a generalization of multinomial logit model and does not suffer from the restrictions of the "independence of irrelevant alternatives" (IIA) property in situations where it is not warranted.

The probabilities in the nesting are conditional probabilities in the lower levels and marginal probability in the highest level at the top. Hence, the hierarchical choice probability can be expressed as the product of marginal and conditional choice probabilities.

For the nested structure A, the mathematical representation is,

$$P(f,d,c,m,p)=P(f)\cdot P(d/f)\cdot P(c/d,f)\cdot P(m/c,d,f)\cdot P(p/m,c,d,f) \quad \cdots\cdots (1)$$

where,

$P(f,d,c,m,p)$ = nested logit choice probability,
$P(f)$ = marginal probability of frequency,
$P(d/f)$ = conditional probability of destination,
$P(c/d,f)$ = conditional probability of CBD zone,
$P(m/c,d,f)$ = conditional probability of mode, and
$P(p/m,c,d,f)$ = conditional probability of parking place.

As is known, the utility function of the NL model becomes composite by including the natural logarithm of the maximum expected utility V'(LOGSUM). In each level of the nested structure the LOGSUM variable V' can be expressed as follows:

$$V_f'=\frac{1}{\mu_d}\ln\sum_d \exp[(\Sigma\beta_d X_d+V_d')\mu_d] \quad \cdots\cdots (2)$$

$$V_d'=\frac{1}{\mu_c}\ln\sum_c \exp[(\Sigma\beta_c X_c+V_c')\mu_c] \quad \cdots\cdots (3)$$

$$V_c'=\frac{1}{\mu_m}\ln\sum_m \exp[(\Sigma\beta_m X_m+V_m')\mu_m] \quad \cdots\cdots (4)$$

$$V_m'=\frac{1}{\mu_p}\ln\sum_p \exp[(\Sigma\beta_p X_p)\mu_p] \quad \cdots\cdots (5)$$

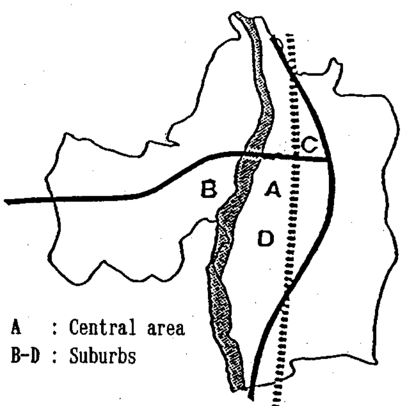

Fig.3 Area of study (Nagaoka city)

where,

X_d, X_c, X_m, X_p = explanatory variables related to the choice of destination, CBD zones, mode and parking place respectively,

β_d, β_c, β_m, β_p = coefficients related to the choice of destination, CBD zones, mode and parking place respectively, and

μ_d, μ_c, μ_m, μ_p = scale parameters or estimated coefficients for V' related to destination, CBD zones, mode and parking place choices respectively.

There is an important restriction on the values that the coefficients of the expected maximum utility (the $\mu's$) can take. Specifically, the $\mu's$ ratios μ_m/μ_p, μ_c/μ_m, μ_d/μ_c, and μ_f/μ_d must be positive and be less than or equal to 1, and therefore must satisfy the condition,

$$\mu_f \leqq \mu_d \leqq \mu_c \leqq \mu_m \leqq \mu_p. \quad \cdots\cdots(6)$$

Structure B has a similar mathematical representation.

3. A CASE STUDY AND DATA

A case study was undertaken in Nagaoka, a city with a population of about 180,000 located in Niigata prefecture. The study area was an administrative area of Nagaoka, where 8 zones were selected which constituted the alternative destinations of shopping trips. Of these zones, 5 are in the center and 3 are in the suburbs. The location of destination zones are indicated in **Fig.3**, where A is the central business district (CBD) and is shown in **Fig.4**. The numbers 1 to 5 in **Fig.4** indicate zones in the CBD. Destinations B, C and D are suburban shopping zones.

There were 17 parking places in the center. But, 11 parking places which are in great demand were selected as potential alternatives indicated in **Fig.4**. The travel modes of choice were car, bus, bicycle and walk. The alternative frequency of

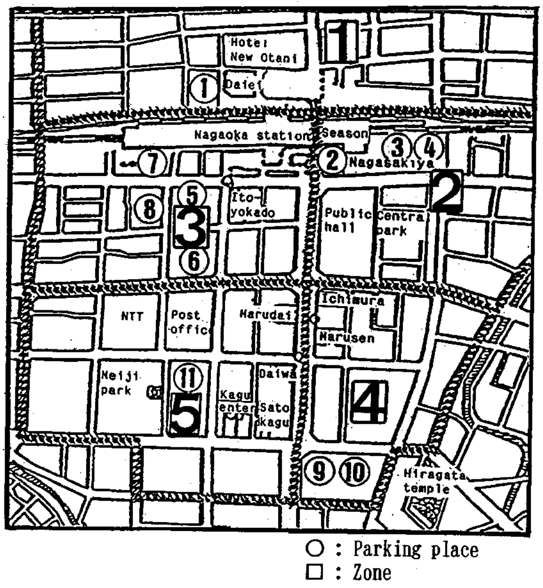

Fig.4 Parking place and zone of central area

shopping trips ranked from 1 time per month to 7 or more times per month.

The data used for model estimation were obtained from the questionnaire survey carried out in October 1989 for householders living in Nagaoka. The survey included 1260 persons of households, and 1184 persons answered effectively. The shopping travel information in the survey included : (a) household data, namely location of residence, household size, auto ownership level and income (by category) ; (b) individual data, nemely, age, possession of driver's licence ; and (c) trip data, namely frequency, destination, mode and parking place used for grocery and non-grocery shopping activities on holidays. Questionnaire responses are separated into the two parts of the shopping travel to central areas and to suburban shopping centers.

The survey revealed that 8.1% of the people generated shopping trips only to the CBD zones, and 6.4% of the people generated shopping trips only to the suburbs, and the rest of them (85.5%) generated shopping trips to both areas. The percentage distribution of zones among suburban destination was 41.4% for Kawasaki (C in **Fig.3**), 30.0% for Kitamachi (B), 20.1% for Miyauchi (D) and 8.5% for other places.

The destribution of travel modes used for shopping trips in the CBD was 72% for car, 17% for bus, and 11% for bicycle. Walk mode was excluded from the analysis due to its low observed choice. In the suburbs, travel by car increased to 86% and by bus mode decreased to 3%. As you might easily suppose, car mode was by far

Table 2 Observed choice of zone and parking place

Parking	Zone					
	1	2	3	4	5	Total
P1	152	6	17	1	0	147
P2	1	6	7	1	1	16
P3	3	11	9	2	0	25
P4	3	11	4	3	2	23
P5	3	3	23	0	1	30
P6	3	2	11	1	2	19
P7	4	23	14	15	2	58
P8	1	0	45	1	0	47
P9	7	6	14	6	9	42
P10	2	2	3	5	0	12
P11	2	1	3	0	1	7
Total	152	71	150	35	18	426

preferred to others for shopping travel toward both areas of CBD and suburbs.

Table 2 shows the choice distribution of destination zones and parking places for the central area. In each of zones 1 and 3, there is a big supermarket which manages its own parking lot. The station building of Nagaoka includes a fashionable shopping center. Zones 1 and 3 are highly preferred shopping districts for customers, in comparison to the other zones.

4. SPECIFICATION, ESTIMATION AND TEST

(1) Parking place choice model

The choice alternatives of this model were limited to parking places located in the central area (CBD) shown in **Fig.4**, and 11 parking places were selected as potential alternatives to be used for modelling. Out of 11 parking places, alternatives for a decision maker were assumed to be ones which were located within 300 m from the shopping center of his/her destination.The distance of 300 m approximately corresponded to an observed walking limit from a parking place to a shopping center.

All of the variables used are defined in **Table 3**. Variables used for parking place choice include parking capacity (CAPAC), the distance between parking place and destination of shopping (DIST), and parking fare (FARE). The location dummy variable (LOCADU) indicates that the parking place of LOCADU=1 is located on a principal street. Parking fare (FARE) was the actual price paid by a user. In the center of Nagaoka, a shopping center or store usually discounts parking fare for a customer who purchases goods of more than a certain price. Even in this case, FARE was the actual money paid by a customer.

The parking place choice model is located in the lowest level for both A and B hierarchical structures. For the estimation of the lowest level, the total disturbance was normalized by taking a scale parameter $\mu_p = 1$. Model estimation for parking choice is given in **Table 4**. The 426 samples included the only persons that parked their cars at the 11 parking places in the central area (**Table 2**). In this model, parking capacity was represented in a logarithmic form because of the relatively large value of parking capacity. The coefficients of all variables had the expected signs, and the log likelihood ratio ρ^2 was 0.298, and the percentage of correctly predicted samples was 56.3%.

(2) Model of structure A

a) Mode choise model

The mode choice model of structure A was to represent shoppers' decisions among the three alternatives : car, bus, and bicycle. The variables used for estimation were ; total travel time (TRAVEL) ; total travel cost (COST) ; the ratio COST/INC variable was specified to capture an income effect ; ALT1 and ALT2 are mode specific dummy variables of bicycle and bus respectively. The LOGSUM variable of parking choice model was added to the utility function of the mode choice model to represent the nested structure preference. For suburbs, the LOGSUM variable was specified on the assumption that parking places in the suburbs have the same utility function with the CBD. Suburban shopping centers and shops usually include their own parking places.

Table 4 shows the estimation results for mode choice in structure A. The number of samples 1120 is the double of observed persons, since a response to mode choice was obtained for both of central area and suburban centers. The ratio of scale parameter (which is the value of coefficients of LOGSUM variable) was μ_m/μ_p=0.3722 and had the expected sign. The log likelihood ratio and the percentage of correctly predicted reveal a good specification of the model.

b) CBD-zone choice model

This model was defined to choose a zone among five alternatives (zone 1 to zone 5) in the CBD. Variables used included the number of big shopping stores (NBIG) and the selling floor area of big stores (FLR), which represented the attractiveness of a zone in the CBD. The variable NBIG is considered as a single-size variable which implies the known size of each alternative[4]. The estimation is made by using a standard linear logit procedure with a scaling restriction such as β_{NBIG}= 1. This procedure allows to examine the effect of only NBIG separating from the effect of FLR[23]. Also, in this model was included the LOGSUM

Table 3 Variables used

Characteristic	Variable name	Explanation
Social & economic attribute of household	INC	Annual income of a householder
	LICD	1 for driving license holder, 0 otherwise (specific to car)
	FAM	Numbers of persons in household (specific to higher frequency)
	CHILD	Number of children (specific to higher frequency)
	NB	Number of bicycle (specific to bicycle)
	NBC	Numbers of bicycles per person in household (specific to bicycle)
	IALON	1 for shopping alone in zone 4, 5; 0 otherwise
	LDTIM	1 for leaving time after 12 a.m. (zone 1, 2, 3); 0 otherwise
	LCTIM	1 for leaving time after 12 a.m. to CBD; 0 otherwise
Destination variable	NBIG	Number of big stores of the first class (floor area more than 1500 ㎡)
	FLR	Selling floor area of big stores
	DISTA	Distance from house to destination (km)
Transportation service level	TRAVEL	Travel time (min.)
	COST	Travel cost (yen)
Parking service level	DIST	Distance from destination to parking place (m)
	CAPAC	Parking capacity (car)
	FARE	Parking fare (yen)
	LOCADU	Location of parking place dummy
Shopping articles dummy	ATCL1	1 for shopping to buy foods, 0 otherwise
	ATCL5	1 for shopping to buy gifts, 0 otherwise
	ARTI	1 for shopping to buy foods and clothes, 0 otherwise
	ATCLD3	1 for shopping to buy both of non-grocery & grocery articles in center & suburbs; 0 otherwise
Mode specific dummy	ALT1	1 for bicycle, 0 otherwise
	ALT2	1 for bus, 0 otherwise

Table 4 Estimated coefficients of structure A

PARKING PLACE		MODE		CBD-ZONE		DESTINATION	
DIST	-0.0152	TRAVEL	-0.0266	LN(NBIG)	1.000	LN(FLR)	1.065
	(-10.78)		(-1.949)		(-)		(5.177)
FARE	-0.0023	COST/INC	-0.6646	LN(FLR/NBIG)	0.4195	LOGSUM1	0.9109
	(-3.282)		(-4.172)		(2.656)	(CBD)	(4.693)
LOCADU	0.463	LICD	1.161	IALON	0.6195	LOGSUM2	0.456
	(3.384)		(6.590)		(1.921)	(MODE)	(1.988)
LN(CAPACITY)	0.6651	ARTI	0.5649	LOGSUM	0.5139	ATCL5	-1.322
	(5.537)		(1.681)		(7.871)		(-2.718)
		NB	1.270			LCTIM	0.6432
			(5.048)				(2.254)
		ALT1	-1.368				
			(-3.464)				
		ALT2	-0.799				
			(-3.437)				
		LOGSUM	0.3722				
			(4.693)				
L(θ)	-384.1	L(θ)	-530.7	L(θ)	-669.5	L(θ)	-240.8
ρ^2	0.298	ρ^2	0.4376	ρ^2	0.4484	ρ^2	0.2848
Per. correctly predicted	56.3	Per. correctly predicted	81.65	Per. correctly predicted	56.9	Per. correctly predicted	69.87
Sample	426	Sample	1120	Sample	560	Sample	560

variable of mode choice model.

The estimated values for CBD-zone choice model is indicated in **Table 4**. In this nesting level, the ratio of scale parameter was $\mu_c/\mu_m=0.5139$, and had the expected value and sign. The log likelihood ratio revealed a good specification of the model, while the percentage of correctly predicted was not so high.

c) Destination choice model

Choice alternatives of destination choice model were limited to a binary choice between CBD and suburbs.The attractiveness of CBD was represented only by the LOGSUM1 variable of the CBD-zone choice model. It was important to mention that variable FLR was only used for suburbs in this model. Variable LOGSUM2

Table 5 Estimated coefficients of the frequency model

VARIABLE	V 2/1	V 3/2	V 4/3	V 5/4	V 6/5	V 7/6
CONSTANT	-0.8965	-2.735	-4.925	-8.147	-13.250	-17.428
	(-1.723)	(-1.956)	(-2.214)	(-2.522)	(-2.844)	(-3.127)
CHILD/FAM	-0.8541	-0.8541	-0.8541	-0.8541	-0.8541	-0.8541
	(-1.858)	(-1.858)	(-1.858)	(-1.858)	(-1.858)	(-1.858)
ATCLD3	0.2316	0.2316	0.2316	0.2316	0.2316	0.2316
	(2.150)	(2.150)	(2.150)	(2.150)	(2.150)	(2.150)
LOGSUM	0.5325	0.5325	0.5325	0.5325	0.5325	0.5325
	(4.123)	(4.123)	(4.123)	(4.123)	(4.123)	(4.123)
Sample	590		L(0)	-1713	ρ^2	0.3701
Case	2471		L(θ)	-1079	$\bar{\rho}^2$	0.3681
Per. correctly predicted			79.85			

Table 6 Estimated coefficients of structure B

CBD-ZONE		DESTINATION		MODE	
LN(NBIG)	1.000	LN(FLR)	0.2045	COST/INC	-0.8713
	(-)		(1.823)		(-5.320)
LN(FLR/NBIG)	0.1768	DISTA	-0.1478	LICD	1.175
	(9.386)		(-4.044)		(6.674)
LDTIM	0.6870	ATCL5	-0.4375	NBC	0.4881
	(2.607)		(-2.905)		(4.396)
LOGSUM	0.6151	LOGSUM1	0.2591	NB	1.335
	(8.10)	(CBD)	(2.153)		(5.471)
		LOGSUM2	0.1366	LOGSUM	1.133
		(PARKING)	(1.837)		(2.691)
				ALT1	-2.049
					(-6.834)
				ALT2	-1.331
					(-6.693)
L(θ)	-430.7	L(θ)	-379.2	L(θ)	-530.3
ρ^2	0.6378	ρ^2	0.2448	ρ^2	0.4275
Per. correctly predicted	64.93	Per. correctly predicted	61.21	Per. correctly predicted	81.36
Sample	560	Sample	560	Sample	1120

represented the expected maximum utility of the mode choice level in the suburbs.

Estimation results are given in **Table 4**. The values and signs were as expected, and the log likelihood ratio and the percentage of correctly predicted revealed an acceptable specification of the model.

d) Frequency choice model

Frequency choice was estimated by a partially constrained Ordered Logit (OL) model which was proposed originally by Sheffi[16]. Estimated coefficients and other information for this model are given in **Table 5**, where $V_{i+1/i}$ $(= V_{i+1} - V_i)$ represents incremental expected utility of the chosen alternative (i) of frequency. Shopping frequencies were ranked from once per month to seven or more times per month. Variables used included the ratio of children to persons in household (CHILD/FAM), a dummy ATCLD3 for shopping to buy both grocery and non-grocery articles, and the LOGSUM variable from the destination choice model. The samples 590 included persons who were not used for the estimation of other models.

The coefficients of constant terms resulted in reasonable values, and the log likelihood ratio and the percentage of correctly predicted indicated a very good specification of the model.

(3) Model of structure B

The estimated coefficients of 3 levels of structure B are indicated in **Table 6**.

In the CBD-zone choice model, the ratio of scale parameter was $\mu_c/\mu_p = 0.6151$. This ratio had the expected value and sign, and the log likelihood ratio and the percentage of correctly predicted revealed a good specification of the model.

The destination choice model was defined similarly to that of structure A, but LOGSUM2 was the LOGSUM variable of the parking choice model in the suburbs and the distance from house to destination (DISTA) was added as a common variable. The coefficients of ATCL5 and LOGSUM variables had the expected signs and values. The log likelihood and the percentage of correctly predicted indicated a satisfactory specification of the model.

The mode choice model was affected by the LOGSUM variable of destination choice level. The ratio of estimated coefficients of LOGSUM was $\mu_m/\mu_d = 1.133$, which did not satisfy the hierarchy

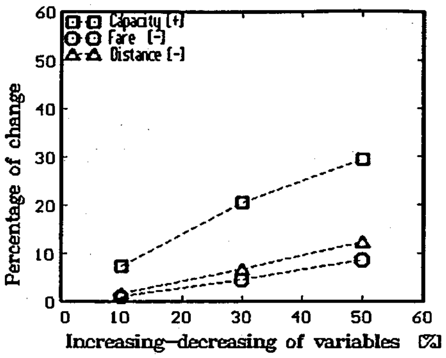

Fig.5 (a) Parking place 1

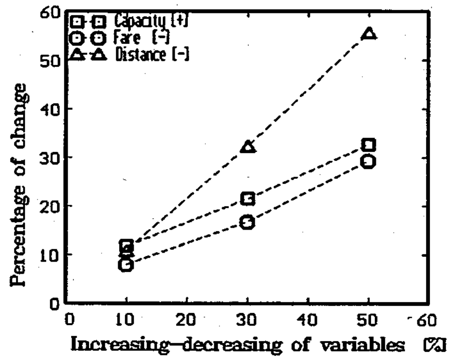

Fig.5 (b) Parking place 7

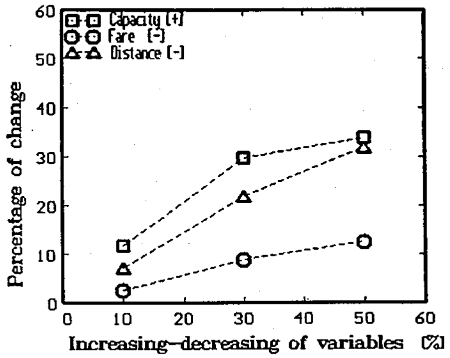

Fig.5 (c) Parking place 8

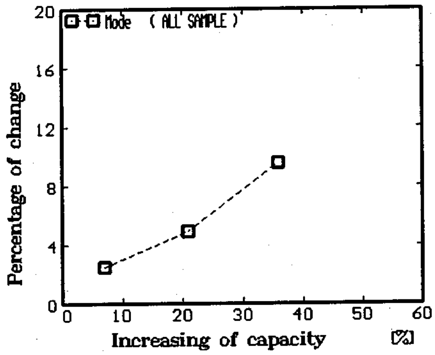

Fig.6 Effect on mode

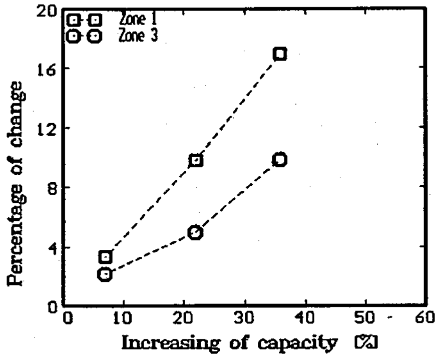

Fig.7 Effect on CBD

restriction that must be positive and be less than or equal to 1. This confirmed that structure B was rejected based on the theory of the nested logit model.

(4) Hierarchical structure for full range decisions

Now that the estimation of two hierarchical structures for the full range decisions of shopping trips have been completed, the whole value of log likelihood ratio for structure A was computed to be 0.3677. The ratio of scale parameters μ_m/μ_p, μ_d/μ_m and μ_f/μ_d (which were the values of coefficients of LOGSUM variables) showed positive results less than 1. And on the basis of the t statistics, the null hypothesis that each of the scale parameter ratios was equal to zero was rejected at the 90% level of confidence. Since structure A satisfied the conditions of the NL model and the goodness-of-fit measures such as the log likelihood at convergence and log likelihood ratios yielded reasonable values, structure A was confirmed to be theoretically adequate to represent the full range decisions of shopping trips.

5. SENSITIVITY ANALYSIS

The purpose of this section is to demonstrate how the hierarchical structure for the full range decisions of shopping trips estimated in this research can be used to illustrate the behavioral effects of various changes of independent variables on the demand for shopping travels. The method used in the analysis was a microsimulation based on the sample of model estimation. So, for example, the competitive relations between the 11 parking places could be investigated. This analysis especially emphasized the varying effects that parking service and floor selling area would have on individual behavior of holiday shopping for grocery and non-grocery articles.

The model of structure A is used to forecast the choice probability of alternatives of parking place,

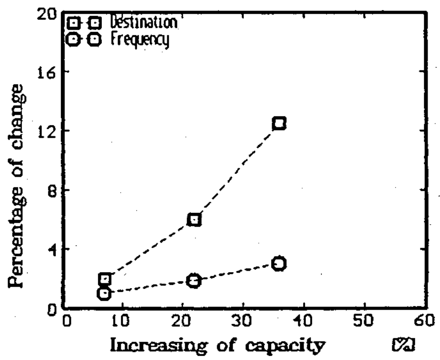

Fig.8 Effect on destination and frequency

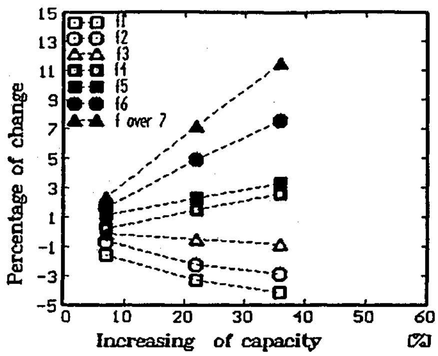

Fig.9 Effect on frequency

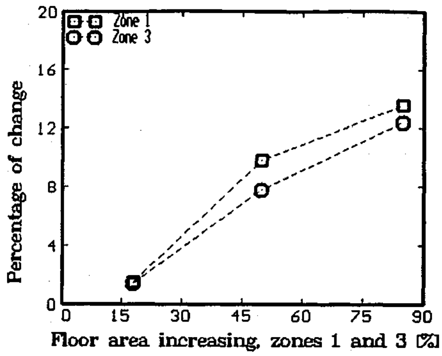

Fig.10 Effect on CBD

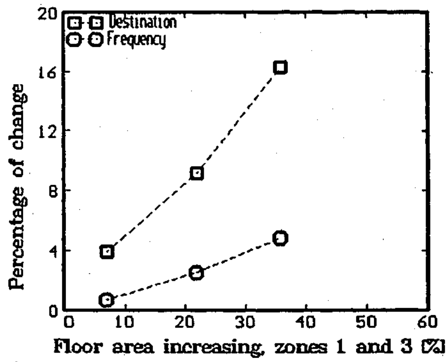

Fig.11 Effect on destination and frequency

mode, CBD-zone, destination, and frequency. Policy alternatives are representative of options currently being considered to revitalize shopping districts, or to relieve traffic congestion in the center. The base case and alternative cases used for comparison are summarized as follows :

a) Base case ; Conditions existing in Nagaoka in October 1989.

b) Case 1 ; Changes in capacity and fare of parking places, and distance from a parking place to a destination for the three parking places of large demand (P1, P7, and P8).

c) Case 2 ; Changes in selling floor area of the 2 zones in the CBD.

Parking places of large demand and capacity may have a significant impact, and the choice behavior of parking place can be understood to be the results of demand and supply equilibrium. However, we have analyzed the sensitivity of demand side only. **Figs.5** (a), (b), and (c) show the percentage of share change of parking places No.1, 7 and 8. Here, the capacity of the three parking places (480, 431, and 405 cars respectively) is assumed to increase by 10, 30, and 50%, while the fare or distance of the three parkings decrease by the same percentages.

The effects of the capacity of the three parking places are similar because their capacities are almost the same. However, the fare and distance elasticities of parking place No.7 are much greater than the other two parking places. This is because parking No.7 is managed by the local government and does not have a discount system, but both parking places No.1 and 8 are located close to big supermarkets and provide fare discounts to their customers.

Fig.6 indicates the percentage of share change of car mode when the capacity of three parking places increases. Here, it may be noted that to increase the capacity of only the three parking places by 10, 30, and 50% corresponds to the increase by 7, 22, and 36% respectively of the whole parking places in the central area. The elasticity of car mode is 0.26 when parking capacity increases by 36%.

Fig.7 shows the percentages of share change of zones 1 and 3 located in the CBD, when the capacity of three parking places increases. The 426 samples for the sensitivity analysis hereafter were only those who chose car mode and might be potentially affected by parking service. Zone 1 is more sensible than zone 3, because the No. 1 parking place of largest demand is located in zone 1, and in zone 3 the No. 7 and 8 of medium demand parking places are located.

Fig.8 shows the percentages of share change of destination and average frequency when the capacity of three parking places increases. Samples for analysis are also car users only. The effect of destination indicates the share increase of CBD choice between CBD and suburbs, and the elasticity of CBD choice is 0.34 when parking capacity increases by 36%, while frequency elasticity is quite small.

Fig.9 shows the percentage of share change of frequency when parking capacity increases. The share percentages of a person whose frequency is more than 4 times per month increase when parking capacity increases, while the share percentages of less than 3 times decrease.

Now, let us proceed to the sensitivity analysis of case 2. **Fig.10** shows the percentage of share change of zones 1 and 3, where the selling floor area of big stores increases by 18, 50, and 85%. Here, the samples for analysis are also car users only. The effects are almost the same for both zones. When comparing with **Fig.7**, the effects of floor area are smaller than the effects of parking capacity as far as the impacts of zone level are concerned.

Fig.11 shows the percentage of share change of destination (CBD) and average frequency, where the selling floor area of big stores in zones 1 and 3 increases. Here, it may be noted that to increase the floor area of only two zones by 18, 50, and 85% corresponds to the increase of 7, 22, and 36% of the whole area of the CBD. The elasticity of destination is 0.45, while frequency elasticity is extremely small.

By comparing the effect of floor area with that of parking capacity on destination and frequency (**Fig.8** and **11**), share changes affected by floor area are a little larger than that of parking places. But, it should be understood that the effects of parking capacity are relatively quite large, and parking services is one of the important options improving the attractiveness of CBD districts. For example, the ratio of parking capacity to floor area is 0.025 cars/m^2 in the CBD, and 0.11 cars/m^2 in the suburbs. This implies the shortage of supplying parking capacity compared with the size of selling floor area in the CBD of Nagaoka.

6. CONCLUSIONS

This paper developed a discreate choice model based on the nested logit modol for the full range decisions of shopping trips, including the choice of frequency, destination, mode, and parking place. Two kinds of hierarchical structure have been empirically investigated.The model structure and estimation methods were mainly based on the results of previous studies, but this paper took an encouraging step forward in the development of a full range of shopping travel demand model. From the specification, estimation and test of the models and their sensitivity analysis, the following conclusions have been obtained.

(1) The goodness-of-fit tests of the models permitted the proposition of a hierarchical structure for travel shopping behavior, including the choice sequence of parking place, travel mode, CBD-zone, destination, and frequency. The nested model structure with the ordering of mode choice as a lower level and destination choice as an upper level was statistically confirmed.

(2) With the proposed hierarchical structure, it became possible to include the mode choice level which allowed clarifying the effects of parking policies on travel mode.

(3) The destination choice model was successfully specified as a two-level model, where the binomial choice of CBD and suburbs was modelled as an upper level and then the CBD-zone choice as a lower level. This model structure proposed a better approach to obtain the impact of parking service on the CBD zones, and also evaluate the attractiveness of the core zones.

(4) The hierarchical structure for the full range of decisions could make possible the simulation of the effects of policy alternatives of parking service and commercial development on the wider aspects of shopping behavior. Particularly, the model was quite useful to distinguish the different behavior between car users and others, and to compare the effects between the improvement of parking service and the size of selling floor area in a highly motorized society of a local city.

REFERENCES

1) Adler, T. J. and Ben-Akiva, M. : Joint-choice model for frequency, destination and travel mode for shopping trips, Transportation Research Record 569, pp.16~150, 1976.
2) Barnard, P. O. : Modelling shopping destination choice behavior using the basic multinomial logit model and some of its extensions, Transport Reviews, Vol.7, No.1, pp.17~51, 1987.
3) Ben-Akiva, M., Gunn, H. and Silman, L. : Disaggregate trip distribution models, Proceedings of JSCE (Japan Society of Civil Engineers), No.347/Ⅳ-1, pp.1~17, 1984.
4) Ben-Akiva, M. and Lerman, S.R. : Discreate Choice Analysis, pp.253~275, The MIT Press, 1985.
5) Galbraith, R. and Hensher, D. : Transferability of modal choice models, Journal of Transport Economics and Policy, Vol.16, pp.7~29, 1982.
6) Gillen, D. : Parking policy, parking location decision and the distribution of congestion, Transportation, pp.69~85, 1978.
7) Harata, N. : Review of studies on nested logit model : The theory and its application to demand forecasting, Proceed-

ings of JSCE, No.353/Ⅳ-2, pp.33~41, 1985.
8) Harata, N. and Asano, M. : The study on the shopping behavior models between downtown shopping complex and suburban SC including parking choice, Infrastructure Planning Review, JSCE, No.7, pp.147~154, 1989.
9) Hensher, D. : Efficient estimation of hierarchical logit mode choice models, Proceedings of JSCE, No.425/Ⅳ-14, pp.17~27, 1991.
10) Ishida, H., Matsumura, N. and Kurokawa, T. : Effects of parking conditions on holiday shopping trip destination choice, Papers on City Planning, City Planning Institute of Japan, No.23, pp.403~408, 1988.
11) Kondo, A. and Aoyama, Y. : A comparative study on consumer shopping behavior to shopping centers in city center and suburb and an analysis of demand for them, Papers on City Planning, City Planning Institute of Japan, No.24, pp.565~570, 1989.
12) Kondo, A. and Aoyama, Y. : Measuring impacts of development of major road on shopping behavior, Proceedings of Infrastructure Planning, JSCE, No.8, pp.113~120, 1990.
13) Matsumoto, S., Kumakura, S. and Matsuoka, K. : Joint-choice model for destination and travel mode for non-grocery shopping trips, Papers on City Planning, City Planning Institute of Japan, No.15, pp.469~474, 1983.
14) Muromachi, Y., Harata, N and Ohta, K. : An Impact analysis of a large-scale shopping center development in the metropolitan suburbs, Papers on City Planning, City Planning Institute of Japan, No.25, pp.487~492, 1990.
15) Rojas, L., Matsumoto, S. and Yoshida, A. : Effect on central parking service on shopping behavior by using the 4-level nested logit model, Proceedings of Infrastructure Planning, JSCE, No.14, pp.153~160, 1991.
16) Sheffi, Y. : Estimating choice probabilities among nested alternatives, Transportation Research, Vol.13B, pp.189~205, 1979.
17) Sobel, K.N. : Travel demand forecasting by using the nested multinomial logit model, Transportation Research Record 775, pp.48~55, 1980.
18) Van Der Goot : A model to describe the choice of parking places, Transportation Research, Vol.16A, No.2, pp.109~115, 1982.
19) Vickerman, R. W. and Barmby, T.A. : The structure of shopping travel-some developments of the trip generation model, Journal of Transport Economics and Policy, Vol.18, pp.109~121, 1984.
20) Westin, R. and Gillen,D. : Parking location and transit demand, Journal of Econometrics, No.8, pp.75~101, 1978.
21) Young, W., Thompson, R. G. and Taylor, M. P. : A review of urban car parking models, Transport Reviews, Vol.11, No.1, pp.63~84, 1991.
22) Yajima, R., Yai, T. and Morichi, S. : Transportation impact of suburban shopping center location using LISREL modelling, Proceedings of Infrastructure Planning, JSCE, No.13, pp.7~14, 1990.
23) Yoshida, A. and Harata, N. : Frequency choice model for non-grocery shopping trips as an aspect of multidimensional travel behavior, Proceedings of JSCE, No.416/Ⅳ-12, pp.107~116, 1990.
24) Yoshida, A. and Shitamura, M. : Effect of central parking policy as one of the means encouraging the depressed urban center, Papers on City Planning, City Planning Institute of Japan, No.24, pp.265~270, 1989.

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買物交通行動の広範囲な選択のための階層モデル

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本論文は，買物交通を対象として，頻度，目的地，交通手段，駐車場選択を含む広範囲な選択のための階層モデルを，非集計ネスティッド・ロジット・モデルを応用して開発したものである．目的地選択については２段階のサブ階層モデルを提案し，また目的地選択と手段選択の順序を検討するために，２種類のヒェラルキー構造を検討している．本研究で使用したデータは，長岡市内において買回り品と最寄り品の買物交通について実施したアンケート調査により収集したものである．得られた結果によれば，有意義な構造は目的地選択を上位とし，手段選択を下位とする順序である．本モデルの感度分析を行うことにより，駐車場整備・政策や大型店床面積が買物行動に及ぼす影響を広範囲に比較できることが示されている．