A STUDY ON ACCESSIBILITY AND GOING-OUT BEHAVIOR OF AGED PEOPLE CONSIDERING DAILY ACTIVITY PATTERN

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Abstract: This paper examines the relationships between accessibility and going-out behavior of aged people in a framework of space-time constraints. We collected activity diary data together with data of desired patterns of time use and satisfaction level in daily life. The analysis shows that some aged people desire to do more in-home discretionary activities and to go out more frequently to do out-of-home discretionary activities. Non-working aged people who satisfied more with their daily life go out more often to do discretionary activities and the amount of time spent on out-of-home activities is larger. By developing a choice model, it is revealed that accessibility to activity opportunities available in the space-time prism effect the choice between in-home and out-of-home discretionary activity.

1.INTRODUCTION

For the aged society it is important in urban planning to provide user-friendly transport environment so that aged people can live their independent life in community. Recently, motorization has been progressing especially in local cities and the trends of large-scale facilities (shopping center, hospital, *etc.*) moving to the suburbs and causing inner city problem. Since the service level of public transport has been lower, the important issue is that the gap in mobility and accessibility becomes larger between people who can use car and not.

Since travel is a derived demand for engaging in activities located at different places, it is a very useful method to analyze activities in order to understand travel behavior. A fundamental descriptor of individuals' activity engagement is time use - how much time is allocated to each type of activity over a span of time, and when each episode of activity starts and how long it lasts. "NHK national daily time use survey (NHK 1996)", a representative time use survey in Japan, reports the following remarkable differences comparing time use for people over and under 60 years old. For people over 60;

-The amount of time spent on mandatory activity increase, for example, sleep, personal care and medical.
-The amount of time spent on paid work and domestic work decrease.
-The amount of time spent on discretionary activity increase.
-The amount of time spent on out-of-home activity decrease.
-The variability between days of week becomes small.

These changes and characteristics would also effect the going-out behavior of aged people.

It is necessary to reveal a demand of latent discretionary out-of-home activities and to relax travel resistance to do mandatory out-of-home activities for aged people. To reveal the relationships between daily activity including in-home activities and going-out behavior, an activity-based approach considering space-time constraints using activity diary and opportunity data should be most useful. There seems to be few previous studies analyzing travel behavior of aged people using activity diary data. This paper aims to analyze the relationships between accessibility and going-out behavior considering constraints of daily activity patterns of aged people using activity diaries, detailed data on activity opportunity and transportation network data in a framework of space-time constraints. First, their desired patterns of daily time use of in-home activities and the frequency of out-of-home activities and the relationships between level of satisfaction with daily life and out-of-home activities are analyzed. Next, accessibility to activity opportunities is measured in space-time constraints and the impact of accessibility on out-of-home discretionary activities is analyzed by modeling the choice behavior between out-of-home and in-home activity participation.

2.THE CONCEPT OF ACCESSIBILITY AND SPACE-TIME PRISM

Accessibility affects travel behavior, it has thus been important indices in urban transportation planning. The concept of accessibility is generally interpreted as a measure of the effort (or ease) of overcoming spatial separation. Accessibility measures can be loosely organized into three types: (a) cumulative opportunities measures, (b) gravity-based measures, and (c) utility-based measures (Handy 1997).

(a) Cumulative opportunities measures

These measures of accessibility count the number of opportunities reached within a given travel time (or distance).

(b) gravity-based measures

This type of measure weights opportunities, usually the quantity of an activity as measured by employment, by impedance, generally a function of travel time or travel cost.

For example:

$$A_i = \sum_j O_j f(C_{ij}) \quad (1)$$

where:

A_i = accessibility from zone i to the relevant type of opportunities

O_j = opportunities of that type present in zone j (employment places, shops *etc.*)

C_{ij}= generalized (or actual) time or cost for a trip from i to j

$f(C_{ij})$ = impedance function – an exponential or power function is generally used.

(c) utility-based measures

This measure is based on random utility theory and present expected maximum utility of choice alternatives.

$$A_n = \ln\left(\sum_{\forall c \in C_n} \exp(V_{n(c)})\right) \quad (2)$$

where:

$V_{n(c)}$ = the utility of choice c for person n

C_n= the choice set for person n

We describe our concept of accessibility and going-out behavior within constraints as embodied by space-time prism (Hägerstrand 1970, Lenntorp 1976, Miller 1991, Wang, *et al.* 1996). A person lives in a location in a city where many opportunities are located at various distances from his home.

We classify activities that he does on that day into three types (Figure 1(a)), which are:

Activity (a) – the activities for which time of day, duration and location are fixed.

Activity (b) – the activities for which duration and location are fixed.

Activity (c) – the activities that do not have to be performed and for which the time of day, duration and location are not fixed.

He must do activities(a) at a fixed time of day, for a certain duration, at a certain location. But he can change schedule of activities(b) and he can do the activities at different time of day, between the stop time for an activitiy(a) and the start time for the next activity(a). Then he has the amounts of time which he can allocate to any kind of activities(c) or travel.

If he changes schedule of activities(b) as shown in Figure 1(b) so that available time can be combined into longer time period to which activities(c) or travel can be allocated ("free time" in Figure 1(b)). The space-time prism or the potential path space (PPS) is determined. Since each opportunity has its opening hours, he can have the amount of maximum available time spent at the opportunity by changing schedule of activities(b).

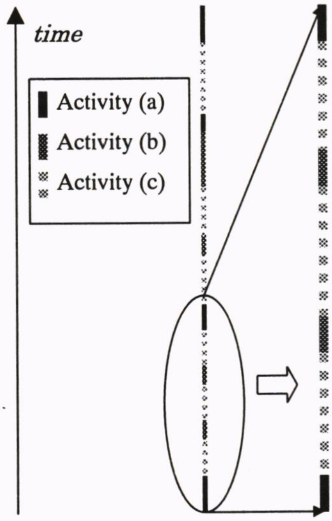

Figure 1(a). Classify Activities in that Day

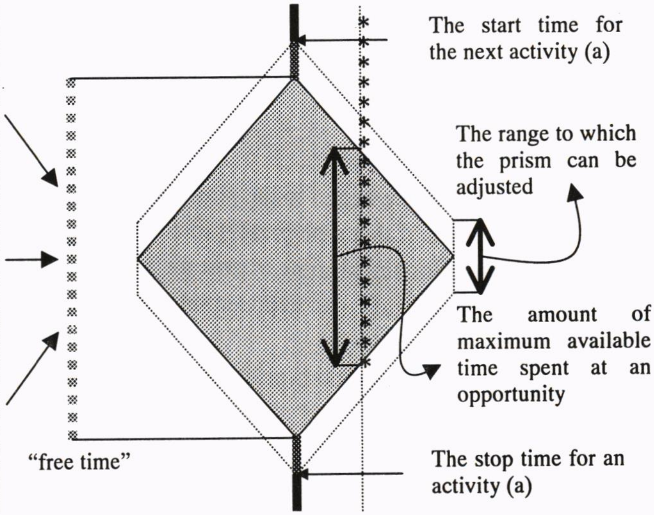

Figure 1(b). Changing Schedule of Activities(b) and Calculating the Amount of Maximum Available Time Spent at an Opportunity

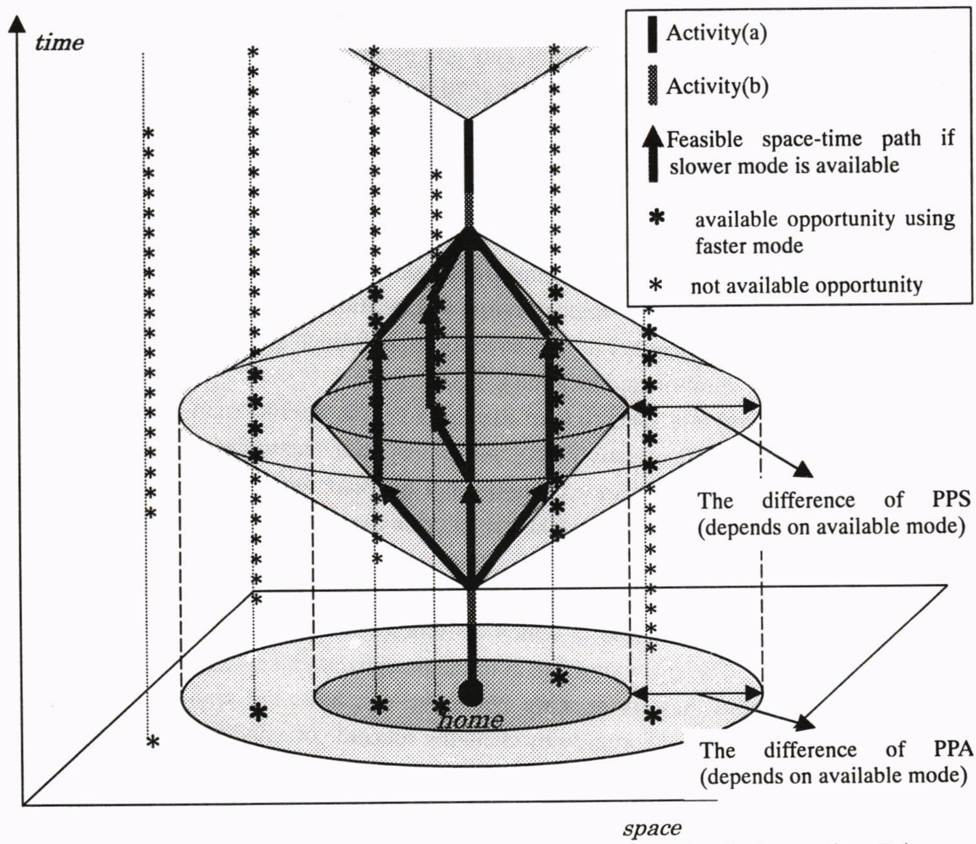

Figure 1(c). Out-of-home and In-home Activity Participation in Space-time Prism

The PPS depends on velocity of his available mode, for example, the PPS is large when he can use a car, but the PPS is smaller when he can't use a car and he must use slower mode (Figure 1(c)). Projecting the PPS onto the planar space provides the potential path area (PPA). The PPA presents his potential area reached at specified times (in a real environment, the PPA is not the shape of a circle but the very complicated shape dependent on the transportation network). Not all opportunities within the PPA are available for him since each opportunity has its opening hours and therefore he can only use activity opportunities of which the opening hours is contained in the PPS. In this study, we define accessibility to an activity opportunity as the travel impedance multiplied by the maximum available time spent at the activity opportunity in the PPS (we call this accessibility "space-time accessibility"). Accessibility A_{ijp} of individual i to opportunity j in prism p is defined the following:

$$A_{ijp} = X_{jp} a_j f(C_{ijp}) T_{jp} \quad (3)$$

where:

X_{jp}= 1 if opportunity j is available in prism p (free time minus travel time to and from opportunity $j > 0$ and opening hours is contained in prism p); 0 otherwise

a_j= attractiveness of opportunity j

C_{ijp} = travel cost from individual i's home to opportunity j in prism p

$f(C_{ijp})$ = impedance function (exponential function)

T_{jp}= the amount of maximum available time spent at opportunity j in prism p

When he faces a prism at a certain time of day, he can choose an in-home or out-of-home discretionary activity participation comparing the utilities of each alternative. Accessibility is considered to be one of the elements of the utility of out-of-home discretionary activity.

Lenntorp (1976, 1978) presented a so-called "Program Evaluating the Set of Alternative Sample Paths (PESASP)" model. The program computes the number of feasible paths between two stations (e.g. home and workplace), given activity programs of individuals and the physical environmental constraints (e.g. the transport system and the locations and opening hours of other stations). Some recent studies evaluated improvement plans considering feasibility of activity programs based on the PESASP model, for example, the activity of a working mother taking child to nursery, the activity of aged people going to hospital (Segawa and Sadahiro 1996, Ohmori, *et al.* 1998, *etc.*). In this study, we consider the effect of feasibility of doing activity at an opportunity on travel behavior, taking into account the amount of available time spent at the opportunity and the time of day.

To do this kind of analysis, we have to prepare the following kinds of data:

-Transport demand – activity diary (time use data), individual and household characteristics and home location

-Transport supply – road and public transportation network (bus stops, routes and time table)

-Activity opportunity – location and opening hours

We did a survey collecting activity diary data of aged people for transport demand data. For transport supply and activity opportunity data, we used the existent road network data, but made by ourselves bus network data, activity opportunity locations and opening hours data using GIS (MapInfo).

3. ACTIVITY DIARY SURVEY AND DESIRED PATTERN FOR DAILY TIME USE OF AGED PEOPLE

We did a survey collecting activity diaries and information concerning daily going-out behavior and consciousness about daily life in Akita City (about 300,000 Population, 14.5% over 65 years old, 1995 Census data), where the ratio of aged people is likely to be very high in near future (Ohmori, *et al.* 1997). This survey was conducted by drop off and mail back method. 190 samples were collected for people over 60 years old, 144 of them have activity diary data on a weekday. All respondents were asked to record not only out-of-home activities and related travel but also in-home activities. Table 1 shows the sample's basic indices about travel behavior. The common trend is seen from this survey that older people go out less.

Table 1. Basic Indices about Travel Behavior

	60 – 64 years	65 – 74 years	75 years -
Frequency of going-out (times／day)	0.90	0.70	0.51
Ratio of going-out	0.82	0.72	0.55
Trip rate (trips／day)	2.32	2.02	1.55
Tour rate (tours／day)	1.05	1.00	0.79
Time spent on out-of home (hours)	5.31	3.82	1.63

In this survey, we questioned respondents about their desired pattern of time use for in-home activities and frequency of out-of-home activities in daily life. Figures 2 and 3 show whether they want to increase or decrease the amount of time spent on each in-home activity. Most people answered "the present amount of time is good enough" for each activity, but some people desired to decrease the amount of time spent on paid work and domestic work (preparing meal, washing and cleaning), and to increase discretionary activities (hobbies and entertainment, social, resting, *etc.*). Since working people would be constrained strongly by mandatory activities, the difference between the present and desired time use pattern is larger among working people than among non-working people. This result suggests that some aged people are not satisfied with their present time use pattern and some constraints prevent the desired time use pattern.

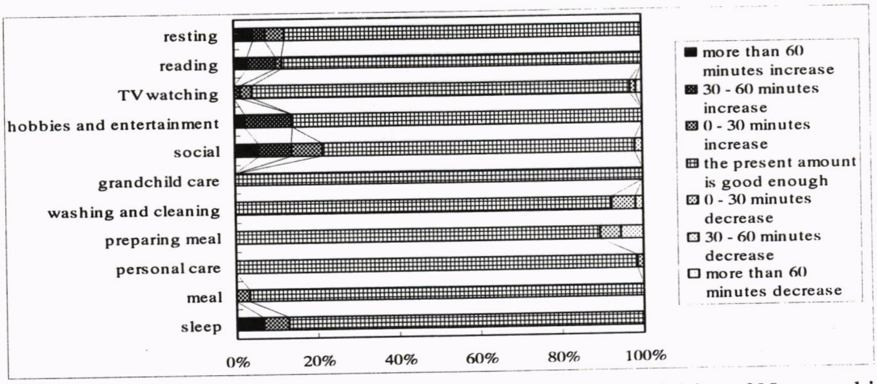

Figure 2. Desire for the Amount of Time Spent on In-home Activities of Non-working People

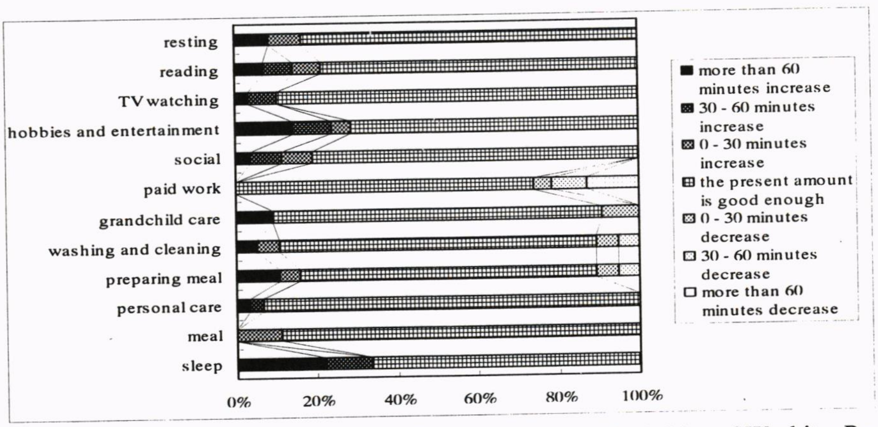

Figure 3. Desire for the Amount of Time Spent on In-home Activities of Working People

Figures 4 and 5 show desire for the frequency of out-of-home activities. The trend is observed that some people desire to decrease the frequency of paid work and medical, and desire to increase the frequency of entertainment, traveling and visiting son's house. The difference between their present and desired condition is also larger among working people than among non-working people.

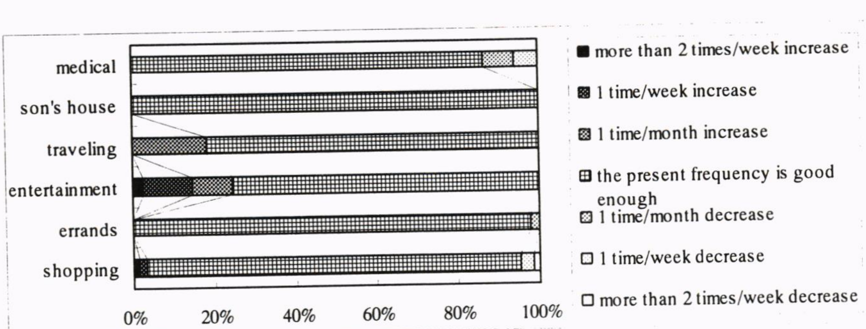

Figure 4. Desire for Frequency of Out-of-home Activities of Non-working People

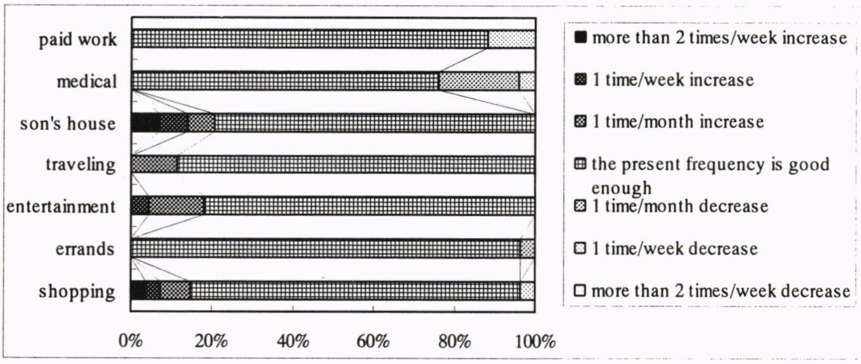

Figure 5. Desire for Frequency of Out-of-home Activities of Working People

Figure 6 shows level of satisfaction in daily life and the frequency of out-of-home discretionary activities for non-working people. Figure 7 shows level of satisfaction in the survey day and the amount of time spent on out-of-home discretionary activities in the day. People showing higher level of satisfaction with their daily life have higher frequency of out-of-home discretionary activities, and people showing higher level of satisfaction in the survey day spend longer time in out-of-home discretionary activities. Among working people, such a trend is not observed.

The results of this chapter suggest that aged people desire more out-of-home discretionary activities and less out-of-home mandatory activities. Out-of-home discretionary activity would affect their level of satisfaction with daily life. Therefore it would be important to provide an environment in which aged people can easily go out to do out-of-home discretionary activities and to relax travel resistance for mandatory out-of-home activities. Since some people desire to do more social activity in their house as shown in figure 2, it is also important to provide an environment in which their friends or other people can easily come to their house. In this sense, accessibility to activity opportunities would be a very important factor in urban transportation planning for the aged society.

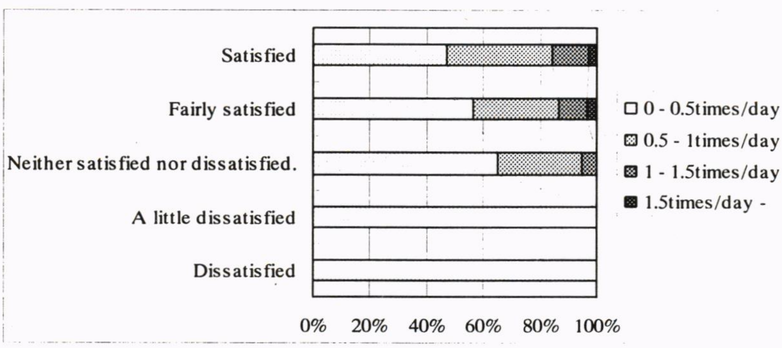

Figure 6. Level of Satisfaction in Daily Life and the Frequency of Out-of-home Discretionary Activities of Non-working People

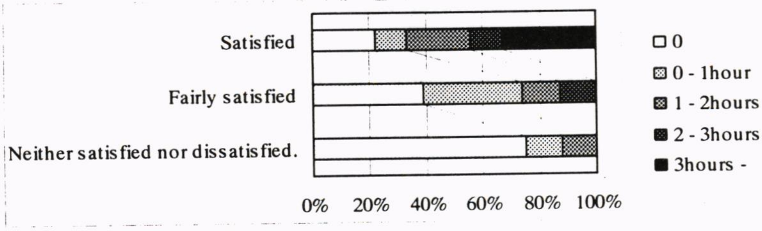

Figure 7. Level of Satisfaction in the Day and the Amount of Time Spent at Out-of-home Discretionary Activities of Non-working People

Comparing aged people with other people, generally aged people have not only stronger physical constraints but also constraints of daily mandatory activities (sleeping, having meals, *etc.*) to keep up their health and their custom. In this survey, we questioned about their regularity of location and time of day for wake-up, go-to-bed and having meals. About 80 to 90% of the respondents reported "Everyday I wake up, go to bed and have meals at fixed time". As concerns location for having meals, non-working people reported "Everyday I have meals at my house", for breakfast 97%, lunch 88% and dinner 98% of the respondents respectively. Based on these results, we classified their activities into three types according to the classification described in chapter 2:

Activity (a) – sleeping, having meals, paid work and medical

Activity (b) – personal care and domestic work

Activity (c) – hobbies and entertainment, reading, TV viewing, *etc.* except for Activity (a) and Activity (b)

Medical activity is classified into activity(a) including related travels, since no respondent did multi-purpose trips with medical trips in this survey. It is considered based on this classification that non-working aged people have three or four prisms in a day (for example, a prism is constructed between get-up and breakfast, breakfast and lunch, lunch and dinner, dinner and go-to-bed), all location of activity(a) is their home, so fixed station is always their home. In the next chapter, we measure accessibility based on these assumptions.

4.MEASURING ACCESSIBILITY USING TRANSPORT DEMAND, TRANSPORT SUPPLY AND ACTIVITY OPPORTUNITY DATA

We prepared location point data (respondents' home, activity opportunities and bus stops) and network data using GIS to measure accessibility. In this study, the index of accessibility to an activity opportunity is defined as the travel impedance multiplied by the amount of maximum available time in the PPS (shown in chapter 2). First we need to calculate travel cost from their home to each opportunity. Travel cost by automobile and walk is assumed travel time using the route of minimum travel time calculated on the road network. Travel cost by bus is assumed generalized travel time using the route of minimum generalized time, which represents physical resistance in traveling, using equivalent coefficients of time spent in various travel modes. Equivalent coefficient means the coefficient which change the amount of time of several travel modes in a trip to the amount of time of base mode (Nitta, *et al.* 1995). For example, in Table 2, the coefficient 2.38 of walking means that aged people feel 2.38 times the resistance to walking than traveling by sitting on bus. In this study, we used the generalized travel time changed to sitting on bus mode, postulated that aged people can sit on bus, using these equivalent coefficients. Table 2 also shows that aged people feel more resistance than other people especially in transfer and walking mode.

Table 2. Equivalent Coefficients (Shin 1997)

	Sitting on Bus	Walking	Transfer	Waiting
Aged People	1.00	2.38	5.26	1.92
Other People	1.00	1.92	3.45	1.82

Bus network includes walking access links, waiting links and transferring links besides on board links, but the bus fare is not considered in this study. Automobile speed is set at 26km/h in DID (Densely Inhabited District) and at 39km/h not in DID, bus speed is set at 20km/h in DID and at 30km/h not in DID (calculated from the time table of bus in Akita City, and automobile speed is set to 1.3 times faster than bus speed referring to the existent person trip survey report). Walking speed is set at 4km/h and the time for waiting and transferring are calculated using the equation to estimate waiting time from headway referring to the person trip survey report.

Travel costs from respondents' home to activity opportunities by walk, automobile and bus are calculated using these transportation network data. In this survey the respondents were asked to report the activity opportunities which they often use in daily life. Based on this data, the acfivity opportunities which they often use are used in this study (department store, public facilities, supermarket, *etc.*). We set the location and opening hours of each opportunity and calculate whether each opportunity is available for a person in a prism using his available mode. If the opportunity is available for him, next we measure the amount of maximum available time spent in the opportunity. We define the accessibility to an opportunity as the exponential function of travel cost multiplied by the amount of maximum available time spent at the opportunity. Figure 8 shows the distribution of respondents' homes and activity opportunities (the major department store, public facility, supermarket), road and bus network in Akita City.

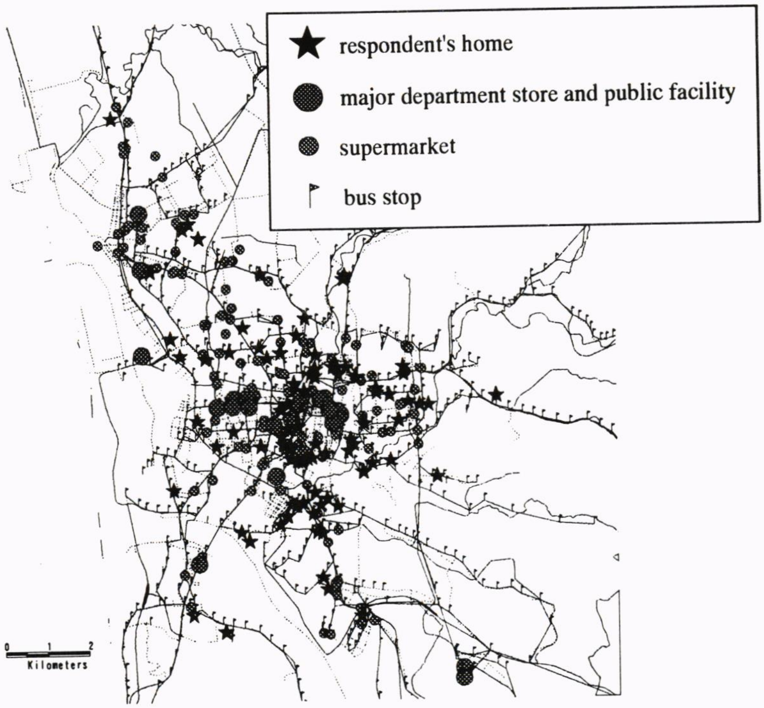

Figure 8. Distribution of Respondents' Home and Activity Opportunities (Department Store, Public Facilities, Supermarket), Road and Bus Network in Akita City

5. EFFECT OF ACCESSIBILITY ON THE CHOICE BETWEEN OUT-OF-HOME AND IN-HOME ACTIVITY PARTICIPATION

In this chapter, we try to develop choice models to examine the effect of accessibility on out-of-home activity participation. Based on the concept shown in chapter 2, the choice between in-home and out-of-home discretionary activity participation is modeled in each space-time prism. We developed the model using only samples of non-working people. The models are binary logit models, and the difference of utility between out-of-home and in-home activity is assumed to be affected by individual and household characteristics (age, gender, household type, *etc.*), availability of automobile, accessibility to opportunities and time of day. We define the probability of participating in out-of-home activity in a prism is:

$$P_{out} = \frac{\exp(V_{out})}{\exp(V_{out}) + \exp(V_{in})} \tag{4}$$

$$V_{out} = \sum_i \alpha_i X_i \tag{5}$$

$$V_{in} = 0 \tag{6}$$

where:
V_{out} = utility of out-of-home discretionary activity
V_{in} = utility of in-home discretionary activity
α_i = parameter
X_i = explanatory variable
The explanatory variables of the models are summarized in Table 3.

Table 3. Variables Used in the Analysis

Variable	Description
Age	Age of individual (years old)
Gender	1 male; 0 female
Household	1 if individual has someone who does domestic work in household; 0 otherwise
Access 1W	Accessibility to the opportunity (1) of maximum accessibility on foot
Access 2A	The sum of the accessibility to opportunities (2) by automobile specific to individual who can use a car
Access 2B	The sum of the accessibility to opportunities by bus specific to individual who can't use a car
ST Access 1W	Space-time accessibility to the opportunity (1) of maximum accessibility on foot
ST Access 2A	The sum of the space-time accessibility to opportunities (2) by automobile specific to individual who can use a car
ST Access 2B	The sum of the space-time accessibility to opportunities by bus specific to individual who can't use a car
Time GB	1 if prism is between getting up and breakfast; 0 otherwise
Time BL	1 if prism is between breakfast and lunch; 0 otherwise
Time LD	1 if prism is between lunch and dinner; 0 otherwise
Out-of-home	1 alternative specific dummy to out-of-home activity

We classify various opportunities into two types according to its characteristics when people use the opportunity:

Opportunity (1) – people use only the opportunity at the minimum cost to travel

Opportunity (2) – people want to use various opportunities dependent on the situation

For example, people tend to use the nearest opportunity in case of traveling to grocery store, post office, bank and so on, but it would be better for them to have many alternatives in case of visiting department store, public facility and so on. According to this hypothesis and the definition in chapter 2, the following accessibility variables are introduced to the models:

$$\text{Access 1W} = \max_{\{j|j\in O_j^1\}} [X_{jp} a_j \exp(-\lambda C_{ijp}^W)] \tag{7}$$

$$\text{Access 2A} = \sum_{j|j\in O_j^2} X_{jp} a_j \exp(-\lambda C_{ijp}^A) \tag{8}$$

$$\text{Access 2B} = \sum_{j|j\in O_j^2} X_{jp} a_j \exp(-\lambda C_{ijp}^B) \tag{9}$$

$$\text{ST Access 1W} = \max_{\{j|j\in O_j^1\}} [X_{jp} a_j \exp(-\lambda C_{ijp}^W) T_{jp}] \tag{10}$$

$$\text{ST Access 2A} = \sum_{j|j\in O_j^2} X_{jp} a_j \exp(-\lambda C_{ijp}^A) T_{jp} \quad (11)$$

$$\text{ST Access 2B} = \sum_{j|j\in O_j^2} X_{jp} a_j \exp(-\lambda C_{ijp}^B) T_{jp} \quad (12)$$

where:

C_{ijp}^W = Travel time by walk

C_{ijp}^A = Travel time by automobile

C_{ijp}^B = Generalized travel time by bus

O_j^1 = Opportunity set 1 (supermarket)

O_j^2 = Opportunity set 2 (department store, public facility, *etc.*)

ST Access 1W, 2A and 2B are space-time accessibility described in chapter 2, while Access 1W, 2A and 2B are space accessibility which does not consider the amount of available time in opportunities. It is assumed that a_j is constant to all opportunity in this study (a_j =1). (ST)Access 1W assumes that individuals only consider the best alternative in the choice set, while (ST)Access 2A and (ST)Access 2B assume that individuals consider the entire choice set. To represent the difference of the time of prism in the day, dummy variables are also introduced setting four time slots, morning, before noon, afternoon and evening, which are divided by sleep and meals activities. Coefficient estimates and t-statistics are summarized in Table 4.

Table 4. Model Estimation Results

Variable	Model 1		Model 2	
	Coefficient	t-value	Coefficient	t-value
Age	-0.0731	-2.931	-0.0906	-3.337
Gender	-0.1844	-0.423	-0.2129	-0.494
Household	-0.1073	-0.263	-0.1999	-0.477
Access 1W	-0.7095	-0.821		
Access 2A	0.1984	2.715		
Access 2B	0.4146	2.340		
ST Access 1W			0.0308	0.478
ST Access 2A			0.0143	3.100
ST Access 2B			0.0322	2.741
Time GB	3.0882	3.099	3.1130	3.174
Time BL	2.1546	2.313	2.1870	2.368
Time LD	2.6112	2.784	2.1112	2.203
Out-of-home	2.2486	0.601	4.7962	1.210
Rho-Square	0.391		0.439	
Hit Ratio	78.8%		81.3%	
No. of Observation	240		240	

In both Model 1 and Model 2, negative and significant coefficient Age shows that older individuals do less out-of-home discretionary activities. Gender and Household are not significant but negative, implying that male do less out-of-home discretionary activities than female, and individuals who have other individuals doing domestic work in his household do less out-of-home activities (maybe shopping). The positive coefficient estimates of Time GB, BL and LD imply that when aged people face the same accessibility, they tend to go out in the morning, before noon and afternoon rather than evening. As for Accessibility variables, except for Access 1W and ST Access 1W, these are significant coefficients, implying that individuals who have higher accessibility tend to do out-of-home discretionary activities. Comparing Model 1 and Model 2, ST Access 2A and 2B that represent space-time accessibility in Model 2 are more significant than Access 2A and 2B in Model 1, and the goodness of fit of the model is higher in Model 2. The result implies that considering the amount of time available in opportunities considering space-time constraints is more useful.

6.CONCLUSIONS

It was obvious that aged people desire to do more in-home discretionary activities and out-of-home discretionary activities but some constraints prevent them from doing so according to the present study. Especially because non-working people, who are more satisfied with daily life, go-out more often and spend longer time in out-of-home activities, participating in out-of-home discretionary activity affects level of satisfaction. By developing the choice model, it was found that non-working aged people, who are older and have higher accessibility, do out-of-home activities more frequently, and when facing at the same accessibility, go out more often in the daytime. In the choice models of out-of-home and in-home activity participation, space-time accessibility is more significant and introducing this variable improves the goodness of fit of the model.

Analyses using more detailed classification of both activity and opportunity, introducing pedestrian environment to accessibility and considering trip chains of activities, would be needed for further research. To better understand travel behavior and various constraints, it would be useful to do in-depth interviews and to collect activity diaries for not one day but multi-day or a week. Send-off trip is an important mode for aged people who can't drive a car, so it would be valuable to collect activity diary data of all members in a household and to use a gaming simulation method to capture interaction among household members. On the other hand, it would be necessary to develop better methods of collecting activity diary data of aged people, because aged people bear the burden to fill in the questionnaire survey. There are possibilities for more detailed and correct space-time travel behavior data being collected automatically and the burden in the questionnaire survey being decreased, using advanced information systems as GPS (Global Positioning System) and PHS (Personal Handyphone System). GIS data concerning transportation and activity opportunity is not enough prepared. For example road network data exists, but not including time dimension, bus network data and activity opportunity data do not exist in most cities, and therefore it was very hard work for us to make bus network data in this study. It would be useful if transportation and activity opportunity GIS data are continuously prepared for this kind of analysis in a framework of space-time constraints.

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