EVALUATION OF SPACE-TIME ACCESSIBILITY CONSIDERING ACTIVITY ENGAGEMENT OF THE ELDERLY

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SUMMARY

Toward aged society, it is important to provide better mobility and accessibility for the elderly and disabled people, so that they can live their independent life in community. This paper proposes methods for analyzing space-time accessibility of the elderly people, in terms of activity participation under space-time constraints in their daily life as one of the measures for evaluation of mobility-related social exclusion. Accessibility to general hospitals in a local city is analyzed before and after relocation of a hospital from city center to suburban area. The results suggest that after the relocation it is difficult to maintain the present level of accessibility only by an improvement in public transport services, but an improvement in opportunity side is useful for enhancing space-time accessibility.

Introduction

Toward aged society, it is important to provide better mobility and accessibility for the elderly and disabled people, so that they can live their independent life in community. The elderly have a wide range of constraints on participating in out-of-home activities; for example, physical disadvantages, keeping regular lifestyle for their health and customs, limited space-time areas of activity engagement for both safety problems and limited ability of information acquisition, and monetary budget constraint. In addition, people who cannot drive a car depend more on public transport service and sometimes need their household members' help when they go out. Therefore, their choice sets of feasible activity patterns are strongly restricted by these constraints. Furthermore, especially in local cities, motorization has been promoting relocation of large-scale facilities (shopping centers, hospitals, etc.) to suburban areas, and the level of public transport service has been decreasing. More often, the elderly with lower mobility face the situations that they cannot participate in out-of-home activities as they wish. This is regarded as one of the mobility-related "social exclusion" problems. Kenyon et al. (2002) defined mobility-related exclusion as "the process by which people are prevented from participating in the economic, political and social life of the community because of reduced accessibility to opportunities, services and social networks, due in whole or in part to insufficient mobility in a society and environment built around the assumption of high mobility." From this viewpoint, it should be useful to analyze the feasibility of activity participation of the elderly under personal and environmental constraints they face in daily life.

On the other hand, the space-time prism constraint formalized by Hägerstrand (1970) is a very useful idea for specifying alternative feasible activity-travel patterns in space-time. Burns (1979) expanded the concept of accessibility into space-time dimensions, "space-time accessibility," introducing the activity duration at opportunities based on the prism constraints. Lenntorp (1978) operationalized Hägerstrand's approach by developing PESASP model that calculated the total number of space-time paths given a specific activity program and the urban transport network. In recent studies, Kwan (1998) and Miller (1999) operationalized space-time accessibility under the space-time prism on a real world transport network using Geographic Information Systems (GIS). These accessibility measures represent the potential of activity participation under space-time constraints and could be useful to evaluate the extent of mobility-related social exclusion.

The objective of this study is to propose methods for analyzing space-time accessibility under space-time constraints of daily activity schedule, transport environment and activity opportunities, as one of the measures for evaluation of mobility-related social exclusion. Accessibility to general hospitals for the retired elderly living in a local city is analyzed and the impacts of accessibility-enhancing policies are evaluated before and after relocation of a hospital from city center to suburban area.

Methods for Analyzing Accessibility

A case study was conducted in Akita city, Japan. The population consists of about 318,000 and the ratio of people aged 65 years and over (the elderly) is 17.5%, from 2000 census data. In near future, the ratio of the elderly of Akita prefecture is expected to be the highest in Japan. Accessibility to general hospitals in the city was evaluated as one of the important facilities for the elderly people's daily life.

Three accessibility indices were defined in this study: travel time; generalized travel time; and the feasibility of activity participation under space-time prism constraints which is one of the space-time accessibility measures. Two travel modes, car and bus (or walk), were considered in the analyses. Data on population of the elderly at residential zones (1×1 km^2 mesh areas), road and bus networks, and location of general hospitals with the attribute of opening (consultation) hours were prepared in GIS (MapInfo).

Travel time and generalized travel time

Travel time by car from each residential zone to the hospitals was assumed the travel time traveling the route of the minimum travel time calculated on the road network. Travel time by bus was assumed the travel time traveling the route of the minimum generalized travel time calculated using equivalent coefficients, which change the amount of time of several travel modes in a trip to that of base mode (Nitta et al., 1995). The following coefficients were used referring to the previous research (Shin, 1997): boarding on bus 1.00; walking 2.38; transfer 5.26; and waiting 1.92. In this study, the generalized travel time is the time changed to boarding on bus mode.

Space-time accessibility: the feasibility of activity participation under space-time constraints

Travel time and generalized travel time are basic measures of accessibility, but these represent only the effort (or ease) of overcoming spatial separation. Essentially both spatial and temporal components of accessibility, which represent potential of participating in activities at opportunities, should be evaluated considering that travel is a derived demand from engaging in activities. As one of the space-time accessibility measures, we analyzed the feasibility of participating in medical care activity consulting doctors at general hospitals in space-time constraints, which is the most important activity in the elderly people's daily life. Data on the elderly people's activity schedules were required for determining their daily prisms.

The national time use survey in Japan (NHK Broadcasting Culture Research Institute, 1996) reported that one of the characteristics of the elderly people's activity patterns was that day-to-day variability of their daily time use was smaller than that of younger people's. The results from the survey conducted by the authors in Akita in 1996 showed that the elderly people, especially retired, kept the regularity of location and timing for waking up, going to bed and having meals (Ohmori et al., 1999). Based on the evidence, activities were classified into three types: Activity (a) is fixed activity (sleep, meals); Activity (b) is planned but flexible activity (personal care, housework, etc.); and Activity (c) is discretionary activity (hobbies and entertainment, reading, TV watching, except for Activities (a) and (b)). The feasibility of medical care activity participation in hospitals was calculated according to the advanced space-time prism concept (see Ohmori et al., 1999; 2003a; and 2003b); that is s/he starts traveling after the end time of an Activity (a), arrives at the hospital within consultation hours, spends time for waiting, consulting a doctor and getting some medicine, leaves the hospital and arrives at the location of the next Activity (a) in the start time of it.

Evaluation of Accessibility to Activities at General Hospitals

Travel time and generalized travel time

First, travel times and generalized travel times from each residential zone to 5 general hospitals in Akita, by car and bus, were calculated. These measures were weighted by the population of the elderly at each zone using census data and the average times in the whole city were calculated. The results showed the difference of accessibility between

Table 1 Round-trip travel times and generalized travel times to the hospitals (minutes)

		A	B	C	D	E	Average*	Minimum**
Travel time	Car	23	25	24	30	31	27	14
	Bus	62	82	73	86	100	80	55
Generalized travel time	Bus	107	145	140	154	187	147	99

* The average of (generalized) travel times to the five hospitals
** The average of the minimum (generalized) travel times from each zone to the five hospitals

travel modes and among hospitals (see Table 1). Travel times by bus were about three times as large as those by car. Travel times by car to Hospital A, B and C were almost the same, but the differences of travel times by bus between Hospital A, B and C were relatively large. Generalized travel times by bus to Hospital B and C were larger than travel time to Hospital A, because of longer egress walking time for Hospital B and longer transfer time for Hospital C.

Space-time accessibility

It was assumed that daily activity schedules of the retired elderly depended on age and sex groups. For each 4 segment group, young (aged 65–75 years) men, young women, old (over 75 years) men and old women, a set of activity schedules were created from 71 retired elderly people's activity diary and the evidence of the fixity of timing and location of some activities from the survey data conducted by the authors (Ohmori et al., 1999). The retired elderly of 4 segment groups in each 226 zone in the study area were supposed to have the same set of activity schedules as the sample.

Table 2 shows the consultation hours of department of internal medicine in the five general hospitals. Outpatients were required to arrive at the hospital within these hours. They were supposed to travel by car or bus from their residential zone to hospitals. Activity duration including waiting and consultation at the hospital was set at 120 minutes based on the activity diary and the national time use survey results. Figure 1

Table 2 Consultation hours of the hospitals

	Hospital A	Hospital B	Hospital C	Hospital D	Hospital E
In the morning	7:00–11:30	7:00–11:30	8:30–11:30	8:30–10:30	7:00–11:30
In the afternoon	—	12:00–16:00	—	—	12:00–15:00

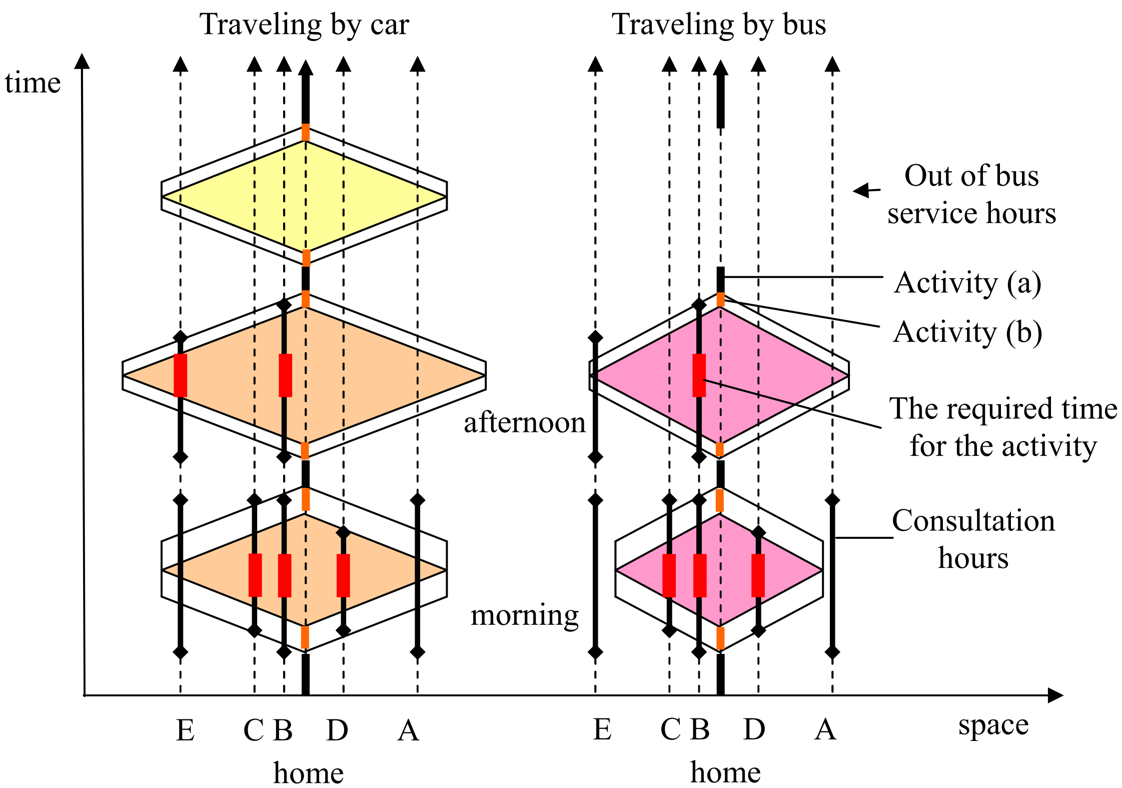

Figure 1 Activity participation under space-time constraints

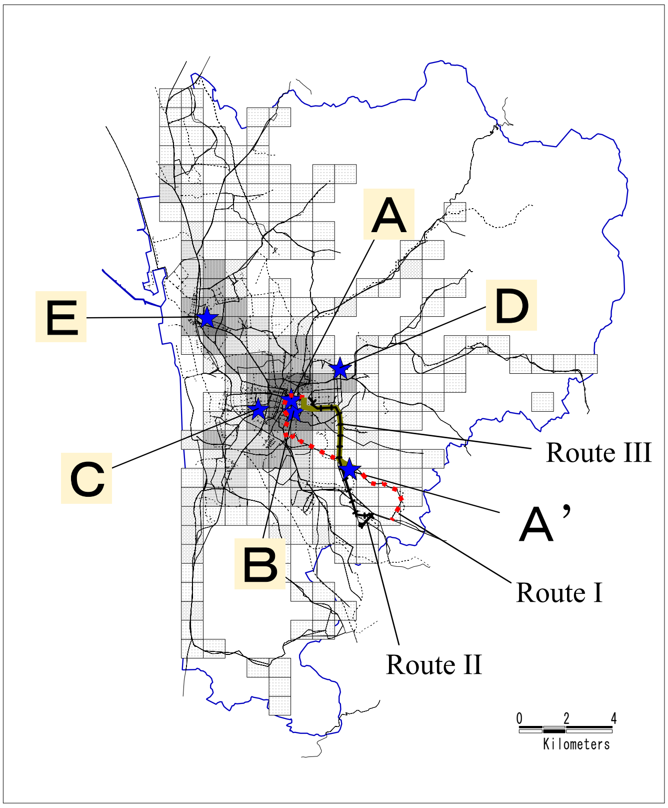

Figure 2 Residential zones (mesh areas), transport network and hospitals in the case study

Table 3 Proportion of the retired elderly who can engage in medical care activity at the hospitals under space-time constraints (%)

	Timing	A	B	C	D	E	At least one*
Traveling by car	a.m.	66.5	66.1	54.6	52.4	65.6	67.7
	p.m.	0.0	79.6	0.0	0.0	78.7	80.6
	a.m. or p.m.	66.5	95.1	54.6	52.4	94.9	95.4
Traveling by bus	a.m.	54.5	45.8	37.0	32.2	37.6	55.9
	p.m.	0.0	65.4	0.0	0.0	55.1	68.0
	a.m. or p.m.	54.5	82.6	37.0	32.2	72.5	85.3
Weighted by license holding	a.m.	56.8	50.1	39.9	36.0	43.7	57.9
	p.m.	0.0	67.1	0.0	0.0	58.6	69.3
	a.m. or p.m.	56.8	83.9	39.9	36.0	75.1	86.2

* % the elderly who can engage in medical care activity at least one hospital among the five hospitals

shows an example of the feasibility of activity participation under space-time prism constraints. Suppose an individual has an activity schedule and lives under the spatial environment as shown in Figure 1. In case he travels by car in the morning, he can engage in the activity at Hospital B, C and D, but cannot engage in at Hospital A and E, because he cannot have enough time at the hospitals under his prism constraint. In the afternoon, he can engage in the activity at Hospital B and E. On the other hand, in case he travels by bus, he cannot engage in the activity at Hospital E in the afternoon, because of longer travel time than that by car. Residential zones (mesh areas), road and bus networks, and locations of hospitals are shown in Figure 2.

Table 3 shows the proportion of the retired elderly who can engage in medical care activity at each hospital under space-time constraints. The result shows the higher percentage in case all the elderly can travel by car than in case travel by bus. The indices depend on both travel times and the consultation hours, not necessarily showing higher values at the hospitals where travel times are shorter. In the afternoon, since the retired elderly were not strongly restricted by prism constraints, the percentages were relatively high.

Evaluation of accessibility after relocation of the hospital and impacts of accessibility-enhancing policies

Hospital A relocated in 1998 from city center to suburban area (A' in Figure 2), because of the worn-out facilities and the shortage of its floor area. The hospital had expected an increase of outpatients and visitors coming by car and prepared more parking lots. But, it had concerned about lower level of bus service comparing the original location and applied to bus companies for bus service improvement. In this section, impacts of accessibility-enhancing policies regarding bus services and hospitals are simulated.

Due to relocation of Hospital A, travel time by car became 1.7 times as long as before, travel time by bus 1.8 times, generalized travel time by bus 2.1 times, respectively. The proportion of the retired elderly who could engage in medical care activity decreased in 20%. These results show the decrease in accessibility after relocation of Hospital A.

Bus companies in Akita were examining to increase the frequency of the existing route I and to introduce new routes II and III (as shown in Figure 2). On the other hand, Hospital A was planning to introduce new management system for reducing patients' waiting time preceding consultation. If Hospital A did consultation for outpatients also in the afternoon, many patients were expected to come to the hospital, but the limited number of medical doctors working at the hospital prevented from doing this. We analyzed how accessibility would be changed by increasing the frequency (decreasing headway) of route I and introducing new routes II and III as an improvement in transportation side, and by decreasing the required activity duration at the hospital and

Table 4 Alternative scenarios for accessibility-enhancing policies

Alternative scenarios		Headway of route I (min.)	Headway of new routes II and III (min.)	Activity duration (min.)	The consultation hours
Do nothing		60	—	120	7:00–11:30
Bus service	B1	45	—	120	7:00–11:30
	B2	30	—	120	7:00–11:30
	B3	15	—	120	7:00–11:30
	B4	45	45	120	7:00–11:30
	B5	30	30	120	7:00–11:30
	B6	15	15	120	7:00–11:30
Activity duration	A1	60	—	90	7:00–11:30
	A2	60	—	60	7:00–11:30
Consultation hours	S1	60	—	120	7:00–11:30 and 12:00–15:00
	S2	60	—	120	7:00–11:30 and 12:00–16:00

Table 5 Proportion of the retired elderly who can engage in medical care activity (%)

Alternative scenarios		Hospital A a.m.	Hospital A p.m.	Hospital A a.m. or p.m.	At least one hospital a.m.	At least one hospital p.m.	At least one hospital a.m. or p.m.
Before relocation of Hospital A	Do nothing	56.8	0.0	56.8	57.9	69.3	86.2
After relocation of Hospital A	Do nothing	36.3	0.0	36.3	54.0	69.3	86.2
	B1	38.8	0.0	38.8	54.2	69.3	86.3
	B2	41.9	0.0	41.9	54.8	69.3	86.3
	B3	45.2	0.0	45.2	55.2	69.6	86.6
	B4	43.0	0.0	43.0	54.5	69.4	86.3
	B5	46.6	0.0	42.6	55.1	69.4	86.4
	B6	49.2	0.0	49.2	55.5	69.7	86.7
	A1	47.2	0.0	47.2	55.7	69.3	86.2
	A2	58.2	0.0	58.2	60.1	69.3	86.2
	S1	36.3	53.2	68.8	54.0	69.4	86.4
	S2	36.3	53.4	68.9	54.0	69.4	86.4

expanding the consultation hours as an improvement in opportunity side. Table 4 shows alternative scenarios simulated.

By increasing the frequency in route I, travel time to Hospital A decreased. New routes II and III contributed travel time decreasing more. But, Hospital A was originally located in the best area of bus service, so that after relocation it was difficult to improve accessibility to the present level by only an improvement in transportation side.

Lastly, the change of space-time accessibility is shown in Table 5, including an improvement in opportunity side. As total time spending for travel and activity engagement decreased by reduction of activity duration, the proportions of the retired elderly who could engage in the activity increased. In case Hospital A did consultation for outpatients also in the afternoon, the proportion increased dramatically. However, the proportion of the elderly who could engage in the activity at least one hospital rarely changed by any scenarios. Since, before the relocation, the distance to Hospital A was long and level of bus service was lower for people living in suburban areas, there remained the retired elderly who could not engage in the activity at the hospitals after the relocation by introducing the accessibility-enhancing policies.

Conclusions

The evaluation of space-time accessibility considering activity engagement under space-time constraints was very useful and this could be used as one of the measures of mobility-related social exclusion. The method made it possible to evaluate the impacts of accessibility-enhancing policies including not only an improvement in transportation side (i.e. increase in frequency of the existent bus route and introduction of new bus routes), but also an improvement in opportunity side (i.e. extension of consultation hours and reduction in the required time for the activity). Further research concerns analyses of pick-up (car passenger) mode availability by introducing car driver's schedule constraints (Ohmori et al., 2003b), use of more detailed GIS data for more micro level analyses (e.g. more detailed zones and pedestrian road conditions) and accessibility evaluation including activities engaged in by information and communications technologies such as telemedicine.

References

Burns, L. (1979) Transportation, temporal, and spatial components of accessibility. LexingtonBooks, Lexington.

Hägerstrand, T. (1970) What about people in regional science?, Papers of the Regional Science Association 24, 7-21.

Kenyon, S., Lyons, G. and Rafferty, J. (2002) Transport and social exclusion: investigating the possibility of promoting inclusion through virtual mobility, Journal of Transport Geography 10, 207-219.

Kwan, M.-P. (1998) Space-time and integral measures of individual accessibility: A comparative analysis using a point-based framework, Geographical Analysis 30(3), 191-216.

Lenntorp, B. (1978) A time-geographic simulation model of individual activity programmes. In T. Carlstein, D. Parks and N. Thrift (eds.), Timing Space and Spacing Time 2, Human Activity and Time Geography. Arnold, London.

Miller, H. (1999) Measuring space-time accessibility benefits within transportation networks: Basic theory and computational procedures, Geographical Analysis 31(2), 187-212.

NHK Broadcasting Culture Research Institute (1996) National time use survey 1995. NHK, Tokyo. (in Japanese)

Nitta, Y. Mihoshi, A. and Mori, Y. (1995) Basic study on special bus service planning for improving mobility of elderly, Journal of Infrastructure and Management No.518/IV-28, 43-54. (in Japanese)

Ohmori, N., Muromachi, Y., Harata, N. and Ohta, K. (1999) A study on accessibility and going-out behavior of aged people considering daily activity pattern, Journal of the Eastern Asia Society for Transportation Studies 3(5), 139-153.

Ohmori, N., Harata, N. and Ohta, K. (2003a) Development and application of GIS-based system for activity-travel patterns under spatio-temporal constraints, Proceedings of the 8th International Conference on Computers in Urban Planning and Urban Management, CD-ROM, Sendai, May 2003.

Ohmori, N., Muromachi, Y., Harata, N. and Ohta, K. (2003b) Simulation model for activity planning (SMAP): GIS-based gaming simulation. In C.-H. Park, et al. (eds.), Selected Proceedings from the 9th World Conference on Transport Research, Pergamon.

Shin, Y. (1997) A study on public transportation systems for the mobility handicapped persons: Evaluation of quality of service and analysis of cost-effectiveness. Tokyo Metropolitan University doctoral dissertation. (in Japanese)