Travel Behavior Data Collected Using GPS and PHS

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Abstract

Generally travel behavior data are collected by self-reported questionnaire surveys. Problems with these methods include lack of reporting for short trips, poor data quality on travel start and end times, travel times, and destination locations. The burden on the respondent is also very large. The detailed and accurate travel data should be needed to evaluate the effects of TDM strategies and ITS technologies on travel behavior, but it would be difficult using traditional questionnaire surveys. This paper aims to develop travel behavior data collecting systems using global positioning system (GPS), personal handyphone system (PHS) and geographic information system (GIS), and to examine the effectiveness of the data collected by these systems and the applicability for travel behavior surveys. We conducted the surveys of collecting travel behavior data by GPS and PHS, with travel and activity diary over a week. We collected GPS data of vehicle trips in two local cities from 15 and 28 commuters respectively, and PHS data of person trips of 30 people in a local city. Examples of day-to-day variability analyses of travel distances, times, speeds and routes of trips, are shown using data collected by GPS. We examined the characteristics of PHS data and the differences of travel start and end times, comparing PHS data with diary data, for elderly and non-elderly people. Also comparison between datasets of the two age groups was done. Improvements of these new systems for practical use to travel surveys are summarized.

Introduction

It is the most basic and important factor to capture people's daily travel patterns

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accurately in urban transportation planning. The traditional travel surveys such as person trip surveys are conducted as self-reported questionnaire surveys. Problems with these methods include lack of reporting for short trips, poor data quality on travel start and end times, travel times, and destination locations. Activity diary surveys which request respondents to record all activities in a day are noteworthy in point of ability of correcting lacked trips compared with travel diary surveys. But the burden of respondents in activity diary surveys is larger than in travel diary surveys. Moreover, it is difficult to record routes of trips because of respondents' burden and the survey cost. The factor of deciding the accuracy of analyses and forecasting depends on the quality of input data, collecting more detailed and accurate travel data is essential to evaluate the effects of TDM strategies and ITS technologies.

There are many possibilities for global positioning system (GPS) and personal handyphone system (PHS) greatly contributing to travel behavior surveys. It is possible to collect data of dates and times, and positions (longitude/latitude) automatically using GPS or PHS (GPS can collect data of speeds), so we can collect the detailed and accurate data of start and end times, origin and destination locations, routes and speeds of trips if people carry the equipment when they travel. Data of locations and speeds collected at 1-second intervals by GPS would give effective information when analyzing the changes of start times, routes and travel times by introduction of TDM and ITS, travel behavior of drivers searching parking places by parking information systems, tourist travel and calculating volume of automobile emissions such as CO_2 and NO_x. PHS could collect detailed spacio-temporal behavioral data, since it has many advantages that it is portable for people in their pocket or bag, and it can also collect location data in the buildings and subway stations. Both of these alleviate the burden of respondents by collecting automatically spacio-temporal travel behavior data, so they would make it easier to conduct surveys of multiple days or to obtain additional data (Jones, 1997).

Recently several studies that examined the characteristics of travel data using GPS, PHS and GIS, have been reported. Murakami and Wagner (1999) compared computer-assisted self-interviewing using GPS with retrospective trip reporting using telephone interviews. They showed the differences of travel distances and travel times comparing both data, and gave examples of the differences of speeds by classes of roads. Quiroga and Bullock (1998) and Schütte, et al. (1999) used GPS to travel time studies. PHS location tracking systems have been available since 1998 in Japan, the characteristics of data and the applicability to travel behavior surveys have been analyzed (Hato, et al., 1999, Takahashi, et al., 1999, Terabe, 1999).

GPS data collecting and analyzing system

GPS is the global navigation satellite system employed by U. S. Department of Defense. The methods of navigation are classified into three types that are "SPS (Standard Positioning Service)", "DGPS (Differential GPS)" and "carrier phase DGPS" (see Table 1.). "Carrier phase DGPS" is very complicated and expensive, so "SPS" or "DGPS" are thought to be proper for collecting OD data and routes of person or vehicle trips.

GPS data may be missed due to satellite “loss of fix”, urban canyons, dense tree cover. There is little possibility to receive signals from satellite inside the wagon of train and bus not to mention in the buildings, so it is available to collect travel data by only mode of walk, bicycle and vehicle.

Devices for collecting and analyzing spacio-temporal data of trips using GPS are (1) GPS antenna and receiver, (2) data collector and (3) GIS software. Two kinds of methods are possible using ready-made goods.

System 1: carrying the hardware combined GPS antenna, receiver and data collector, and collecting data in it.

System 2: carrying GPS antenna and receiver connected portable computer, and collecting data in the computer.

In both of two systems, after collecting data we transfer data to main computer and analyze on GIS software. System 1 has many problems as battery, operation, capacity of memory, and in terms of portability since the device must be kept so that it can receive signals from a clear sky, therefore it is not suited to collecting multiple days trip data. System 2 is exclusive for collecting vehicle trip data but we tried to develop the system that can collect trip data of multiple days by simple operation. Supplying power of GPS and portable computer from vehicle cigarette lighter and using the batch file enhancer software for Windows95 (WinbatchEh), GPS data can be collected by pushing one or two button when people drive a car. Therefore it continually collects GPS data of consecutive days for a week, month or year, within capacity of hard disk of a portable computer.

System 1 use “GeoExplorerⅡ” as GPS receiver and “Pathfinder Office” as data handling software by Trimble corporation. In System 2, small and low-priced GPS, for example, Garmin “GPS35” and Sony “IPS-5000”, is attached through the serial port of the portable computer. We used MapInfo GIS software for displaying and analyzing GPS data.

PHS data collecting and analyzing system

PHS has location tracking systems other than primary function of cellular phone. PHS decide its location using information of plural base stations which PHS access, we can get data of dates and times, positions (longitude/latitude) and the name of buildings where PHS base station is placed. The area, where location data can be collected, is limited to where PHS service is available, but we can get location data of a person even if PHS is in his pocket or bag, or he is in buildings or subway stations. The weak point is that data cannot be collected when he moves with high speeds (more than 50-80 km/h) and the logging intervals are longer than GPS (15 seconds at minimum).

Devices for collecting and analyzing spacio-temporal data of trips using PHS are (1) PHS receiver for location tracking, (2) host computer and PHS (or ISDN telephone wires) for connecting to the location information center and (3) GIS software. In this study, we used PHS location tracking and data collecting systems

Table 1. Comparison of data characteristics and applicable fields of travel data collected by GPS and PHS

			Information needed	Horizontal accuracy	Tracking intervals	Travel Modes	Applicable fields
GPS	SPS		more than 3 or 4 satellites	-100m	1 sec.	Walk, Bicycle, Vehicle	OD, route, speed
	DGPS	Real-time	+base data	5-10m	1 sec.	Vehicle	OD, route, speed
		Post processed	+base data	5-10m	1 sec.	Walk, Bicycle, Vehicle	OD, route, speed
	Carrier phase DGPS		+base data	several mm - several cm	1 sec.	Vehicle	OD, route, speed, position of road
PHS	NTT Docomo		1 or 2 PHS base stations	100-200m	5 min.	modes of speed less than 50km/h	OD, activity location
	Toshiba, Video research, Locus		plural (-10) PHS base stations	50-80m	15 sec.	modes of speed less than 100km/h	OD, activity location, route

by NTT Docomo and Fujitsu SSL. We used MapInfo for displaying and analyzing PHS data on GIS. Table 1 summarizes data characteristics and applicable fields of travel data collected by GPS and PHS.

Vehicle trip surveys using GPS data collectiing system

Probability measures for successful reception of GPS signal and creation of trip data as well as accuracy of locations and speeds are known in previous studies (Zito, et al., 1995, Ohmori, et al., 1998). In this study, we collected GPS data and travel diary data of vehicle trips and investigated travel behavior using these detailed and accurate travel data.

We conducted two surveys for 15 drivers who commute to Tochigi prefecture office for civil engineering works in January, 1999, for a week (survey 1), and for 28 drivers who commute to Toyota municipal office in March, 1999, for a week (survey 2). Respondents were also asked to report travel start and end times, trip purposes and the name of the destination buildings. Table 2 shows travel start times, travel distances and travel times of commuting trips and all trips of a sample from survey 1. He traveled in the same routes but we can know there is the variability of 8 minutes among 5 days (Monday to Friday). Figure 1 shows point speeds of two days commuting trips, one of which is of Thursday with the minimum travel time and another is of Tuesday with the maximum travel time. On Thursday, this road might be congested at the point shown in the figure, so we can identify that it took longer travel time than on Tuesday.

Using data from survey 1 only, Figure 2 shows the amount of variation of commuting travel times traveled in a week by all samples using the same route and the same start time (with a maximum of 10-minutes variation). The variation of travel times ranges from 3 to 11 minutes, so the conditions of road congestions are

Table 2. Trip start times, trip distances and travel times by GPS data

	Commuting trips			All trips	
	Start time	Trip distance (km)	Travel time (min.)	Trip distance (km)	Travel time (min.)
1/26 Tue.	7:52:19	14.02	32	27.67	48
1/27 Wed.	7:51:02	13.93	30	27.61	49
1/28 Thu.	7:53:38	13.94	24	27.56	41
1/29 Fri.	7:52:08	13.87	28	50.44	81
1/30 Sat.	——	——	——	26.38	40
1/31 Sun.	——	——	——	55.63	102
2/1 Mon.	7:51:27	14.47	32	32.83	65

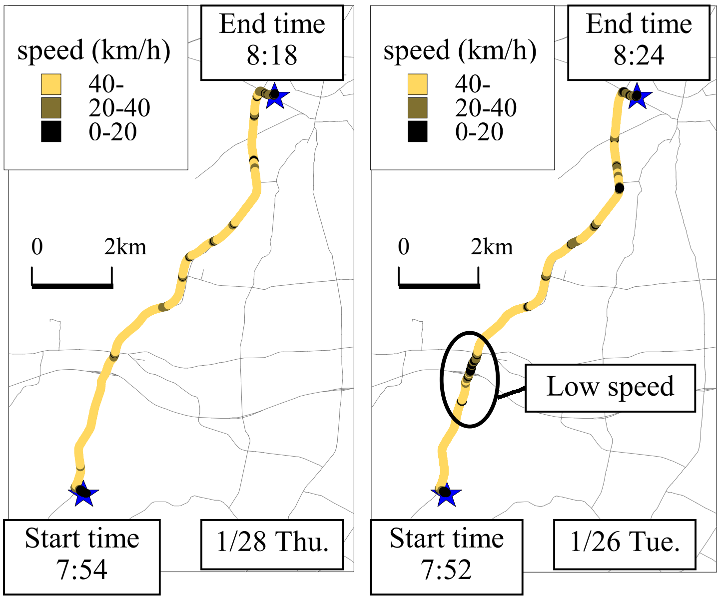

Figure 1. Speeds of two days commuting trips

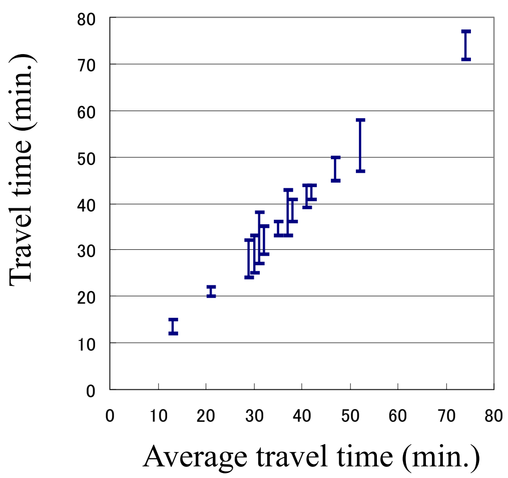

Figure 2. The amount of variation of commuting travel times

not the same everyday. Such data about travel times, routes and speeds are needed for making detailed and accurate before-and-after analyses estimating the effects of TDM and ITS. Therefore GPS is thought to be a very promising tool.

Person Trip Survey Using PHS Data Collecting System

The survey was conducted in Akita city, in February 1999, 30 people over age 15 (20 are over 65 years and 10 are under 65 years) in 13 households. Respondents were asked to record travel diary and activity diary over a seven-day period, and to carry PHS when they go out. We collected PHS data at 5-minutes intervals from AM 5:00 to PM 11:00 during the survey period. Percentages of PHS data successfully collected range from 33% to 97% dependent on locations where they live and visited (Table 3.). We compared the number of trips, which are specified from travel diary, activity diary and PHS data (Table 3.). Trips of 5 elderly and 1 non-elderly samples, which were lacking in travel diary data, were retrieved from activity diary data (Trip (B)). In addition, trips of 12 elderly and 7 non-elderly samples, which were not recorded in travel diary and activity diary data, were also retrieved from PHS data (Trip (C)). But all trips cannot be captured from only PHS data, because we can not specify trips if he visited at the places very near his house or stayed at out-of-home activity locations for very short time, add to the reason of low percentages of PHS data (see Trip (D)). Percentage of not-reported trips in diary data is higher for elderly than non-elderly samples. Comparing diary data and PHS data, we found many cases, which he recorded that he traveled but PHS location data had been in his home at that time, maybe he would have forgotten to carry PHS when he went out. We defined such trips as “Trip (E)” and percentage of Trip (E) is also higher in elderly than non-elderly samples.

Figure 3 shows the difference of trip start and end times between diary data and PHS data. More than 60% of commuting and education trips of non-elderly samples show differences of less than 5 minutes. The difference of other purpose trips of non-elderly is larger, and that of elderly is much larger, 10% of them are more than 45 minutes so they would mistake trip start and end times when they reported.

Recommended improvements of the systems developed in this study

We summarize future direction of improvements of these systems for practical use to travel behavior surveys.

For GPS data collecting system:

- Reduction of starting time at the beginning of collecting GPS data (now respondents have to wait for about 30 seconds before they travel).
- Smaller devices for data collector.
- Stability of data collection systems (some trips were missed due to equipment malfunction).

For PHS data collection system:

- To prevent people from forgetting to carry PHS when they go out.

Table 3. Percentage of PHS data collected and comparison of the number of trips between travel diary, activity diary and PHS data

	HH NO.	ID NO.	% of PHS data	All trips (A)+(B)+(C)	Trip (A)	Trip (B)	Trip (C)	Trip (D)	Trip (E)
65 years and over	1	1	96.8%	21	7	10	4	4	17
	2	2	97.7%	9	7	0	2	7	2
	3	3	76.7%	18	18	0	0	13	0
	4	4	89.7%	18	18	0	0	12	6
	5	5	81.3%	20	20	0	0	8	10
	5	6	62.3%	27	23	2	2	6	6
	6	7	73.7%	22	20	0	2	18	2
	6	8	81.3%	0	0	0	0	0	0
	7	9	72.5%	41	39	0	2	34	0
	7	10	78.1%	17	17	0	0	16	0
	8	11	94.5%	11	9	0	2	6	0
	8	12	93.2%	19	19	0	0	12	0
	9	13	91.6%	27	18	0	9	19	5
	9	14	90.2%	4	3	1	0	3	1
	10	19	96.5%	9	6	2	1	7	2
	11	23	64.9%	18	15	1	2	6	0
	12	24	67.9%	10	10	0	0	5	4
	12	25	84.0%	4	2	0	2	2	0
	12	26	59.9%	32	31	0	1	18	9
	13	30	69.0%	16	15	0	1	5	11
Percentage of each trip				100.0%	86.6%	4.7%	8.7%	58.6%	21.9%
under 65 years	9	15	34.1%	17	15	0	2	11	0
	9	16	70.7%	26	26	0	0	12	7
	10	17	65.5%	16	13	0	3	13	3
	10	18	53.6%	23	22	0	1	18	4
	11	20	68.8%	22	21	0	1	14	8
	11	21	45.9%	42	19	20	3	5	17
	11	22	80.9%	15	15	0	0	10	3
	13	27	97.0%	6	4	0	2	2	4
	13	28	34.7%	58	58	0	0	30	6
	13	29	33.4%	23	22	0	1	17	0
Percentage of each trip				100.0%	86.7%	8.1%	5.2%	53.2%	21.0%

Trip (A): Number of trips from travel diary survey
Trip (B): Number of trips retrieved from activity diary survey
Trip (C): Number of trips retrieved from PHS data
Trip (D): Number of trips specified from only PHS data
Trip (E): Number of trips when respondents forgot to carry PHS

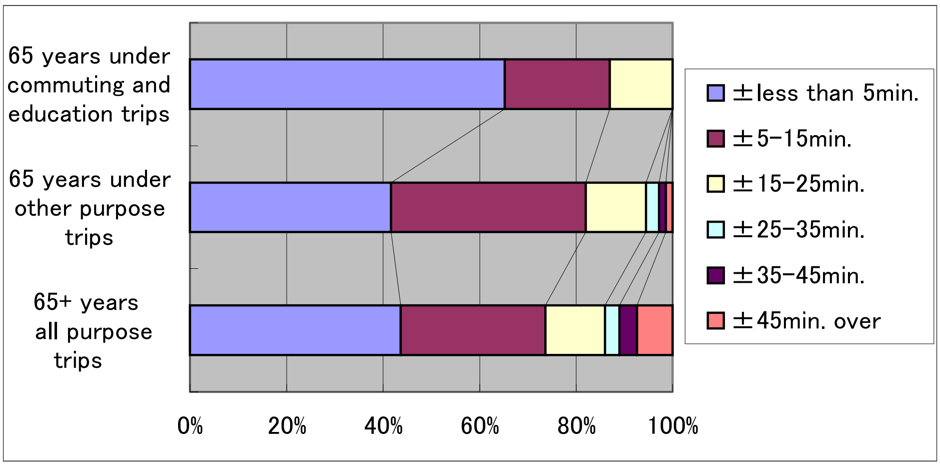

Figure 3. Differences of trip start and end times between diary data and PHS data

- Development of methods or computer algorithms for dividing PHS data into trips and activities (PHS data show variable locations even if it stays at one location).

Conclusion

In this study, we developed the travel data collecting and analyzing systems using GPS, PHS and GIS, and conducted travel behavior surveys over a seven-days period. Simple examples of day-to-day variability analyses about trip start times, travel times and speeds are shown using GPS data of vehicle trips. From PHS data, we found not-reported trips in travel and activity diary data, and error of trip start and end times recorded in self-reported questionnaire survey, comparing elderly and non-elderly samples. Lastly, future direction of improvements of these systems for practical use to travel behavior surveys was summarized.

There are relationships of trade off between accuracy, quantity and survey cost in data collected using these new systems, so we have to investigate appropriate system for travel data needs of analyses. Fast development in the fields of information and communication technology would make cost of equipments lower. The methods of handling and analyzing a vast amount of spacio-temporal data should be examined.

References

Hato, E., Asakura, Y., Kimura, Y., 1999. A Travel Behavior Analysis in Large Scale Events using PHS based Location Positioning Service System. Infrastructure Planning No.22(1), pp. 409-412. (in Japanese)

Jones, P., 1997. Response to New Transport Alternatives and Policies. Summary of Paper for International Association for Travel Behaviour Research, Eighth Meeting, Austin, Texas, September 1997.

Murakami, E., Wagner, D.P., 1999. Can using global positioning system (GPS) improve trip reporting?. Transportation Research C 7, pp. 149-165.

Ohmori, N., Muromachi, Y., Harata, N., Ohta, K., 1998. A study on Applicability of Global Positioning System (GPS) to Travel Behavior Survey. 18th Annual Conference of Traffic Engineering, pp. 5-8. (in Japanese)

Quiroga, C.A., Bullock, D., 1998. Travel time studies with global positioning and geographic information systems: an integrated methodology. Transportation Research C 6, pp. 101-127.

Schütte, C., Bogenberger K., Ernhofer O., 1999. Analyse der Verkehrsqualität mit innovativer Datenerfassung – Beispiel Mittlerer Ring München. Straßenverkehrstechnik 5/99, pp.212-219.

Takahashi, A., Hato, E., Asakura, Y., 1999. Analysis of Travel Data Characteristics Collected through Mobile Communication System. Infrastructure Planning No.22(1), pp. 413-416. (in Japanese)

Terabe, S., 1999. Applicability of PHS Location Data in Transportation Behavior Analysis. Infrastructure Planning No.22(1), pp. 417-418. (in Japanese)

Zito, R., D'este, G., Taylor, M.A.P., 1995. Global Positioning Systems in the Time Domain: How Useful a Tool for Intelligent Vehicle-Highway Systems?. Transportation Research C 3, pp. 193-209.