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**Executive Summary Report**

**GPS-Based Household Interview Survey for the Cincinnati, Ohio Region**

FHWA Report Number:	FHWA/OH-2012/1
Report Publication Date:	February 29, 2012
ODOT State Job Number:	134421
Project Duration:	3 years 4 months
Start Date:	October 17, 2009
Completion Date:	February 2012
Total Project Funding:	\$1,266,223
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**Project Background**

Household travel surveys (HTS) are designed to provide information about daily travel patterns, including trip purposes, time of day decisions, mode choices, trip lengths and distances, activity locations, and routes taken. This information is typically gathered from self-reported information in a diary, with the information retrieved via a computer-assisted telephone interview (CATI), a web-based survey, or mailback of the completed diary. Unfortunately, it has been demonstrated that self-reporting leads to inaccuracies in travel information. The biggest short-coming is trip underreporting. For instance, recent work by Wolf et al., (2003), Pearson (2004) and others has shown that diary information retrieved through CATI when compared with GPS measured travel suggests trip under-reporting ranges from 20 to 30 percent. The diary approach has also shown time inaccuracies and origin-destination location errors; respondent fatigue often results in self-reporting human errors.

**STUDY OBJECTIVES**

As Global Positioning Systems (GPS) recordings become more accurate, reliable, and cost efficient, can they entirely replace travel diaries? By using GPS, the accuracy of spatial and temporal data collected on travel patterns can be greatly improved, and the duration of observation can be extended to better capture variability in travel. Respondent fatigue and corresponding errors are limited. However, to replace the travel diary method with GPS, both travel mode and trip activities/purpose have to be imputed from available data.

The goal of this research was to investigate whether such imputation methods can be sufficiently developed to justify replacing travel diary data collection methods with GPS. A secondary goal was to demonstrate that a fully representative sample of households will cooperate with GPS recording methods. This project was the first GPS-only full-scale household travel survey in the USA.

**DESCRIPTION OF WORK**

The project commenced in early 2009 with the conduct of a pilot survey, which helped establish various parameters and procedures for the main survey. The pilot survey has been documented elsewhere (Transportation Research Record, Journal of the Transportation Research Board, No 2176, Travel Forecasting, Volume 2, pp.26-34). Sampling for the pilot and the main survey used an address-based sampling procedure, with households contacted initially by a combination of mail and telephone.

The main survey commenced in August 2009 and was completed in August 2010. It was designed as a household travel survey to be collected steadily over a twelve-month period. Each household member over the age of 12 was asked to carry a personal GPS device with them everywhere they went for a period of 3 days. The household received travel packets two days prior to scheduled travel dates containing: a one-page GPS instruction sheet, household and person information forms, a GPS for each person aged 13+, 1 charger for every two devices, and postage-paid return mailing materials. Household members under the age of 13 received a simplified “child diary”, which was to be completed on the first day of the travel period. GPS units were set to collect data on a second-by-second basis (since this has been found to provide a superior basis for imputing stops and travel characteristics).

After the three-day collection period was completed, GPS units were retrieved from households, the data were downloaded, and processing of the data commenced. Household and person information forms sent to households were designed for respondents to indicate if they had or had not left home on any particular travel day, or if they carried or forgot to take the GPS with them on one or more days while they travelled. In addition, respondents were asked to provide workplace, school, and two most frequent shopping addresses for household members. Together with the home address of the household these addresses were geocoded and used in the GPS processing.



Figure ES1: The GPS Unit

The GPS unit shown in Figure ES1, is the GPS unit used. It is a personal device that can be carried in a pocket or purse, or clipped on a belt or wristband. It records all modes of travel including car, public transport, bicycle, and walk and can record inside many buildings. For the most part, the units recorded three days of travel. Once the units were returned, data were downloaded. Each data entry (GPS file, forms data, and household recruitment information) had an associated household and person ID. These data were compiled into a metadata file that was referenced to the GPS data.

The GPS unit records all location (latitude/longitude) data. The only errors that can occur in the location data are:

- Cold start problem – when the device does not find position until after a trip has actually started. The data processing software corrects for all except the first trip on the first day, which is corrected by the manual map editing.
- Lost signal – this is only a problem if it occurs near the end of a trip and results in a premature destination recording. This is also normally corrected during the manual map editing process.

Other errors in the GPS record arise if the person did not carry the device for the entire day, or if the battery ran out. In these cases, if the returned status form indicated that the device was forgotten for part of the day or that the battery ran out, then that day was excluded from sampling for the Prompted Recall (PR) survey. Battery problems turned out to be less than 5%.

#### *The PR Survey*

An Internet PR survey was conducted with the respondent provided email addresses and based on Google® maps, providing a playback of the GPS records for one day of their travel. Respondents were asked to fill in certain information about their travel, including mode of travel between stops, purpose of stops, and which household members were with them. This information served two primary purposes: to validate the results of the processing software that imputed trip ends, mode, occupancy, and purpose;

and to provide a means for improving the software by identifying those situations where the software did not perform as well as expected. In this report, the results of the PR survey are documented in terms of response rates and usability of the results from the survey.

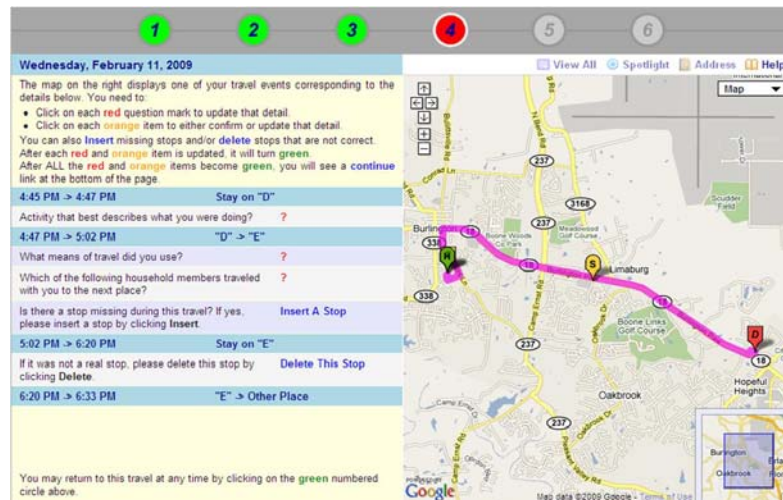


Figure ES2: Example of PR Web Survey Format

## RESEARCH FINDINGS & CONCLUSIONS

The major finding of the project was that it is now feasible to conduct household travel surveys by GPS. While the overall response rate from households was similar to that of more conventional methods of surveying in the US, some of the biases encountered in conventional diary surveys were not encountered and a representative sample of completed households was obtained.

A household was defined as complete only if all persons provided with GPS had at least one common day of travel data recorded, or a claimed no-travel day on that day. A total of 2,059 households provided fully completed GPS data, with an additional 737 incomplete households with significant GPS data. Of the 2,059, there were 17 one-person households that were GPS complete but where the household member did not travel. Hence, there are 2,059 households whose travel is reported in this section. A summary of the responses is provided in Table ES3. The completed households provided 3,849 GPS person records, exclusive of child diaries. Thus, an average of 1.88 persons per household carried a GPS on at least one common day.

The average trip rate of 4.61 trips per person per day for GPS recordings, or 8.62 trips per household per day, is higher than that usually measured in diary surveys (particularly when including only household members over 12 years old who carried GPS units.) The weekday trip rate is higher still at 5.06 trips per person or 9.46 trips per household. A limited analysis of child diary results is included in the report.



Table ES3: Disposition of the Final Sample  
Statistic

Statistic	GPS Complete		GPS Incomplete		TOTAL
	Number	Percent	Number	Percent	
Households	2,059	78.9%	549	21.1%	2,608
Persons	3,849	82.7%	807	17.3%	4,656
Travel Days	13,210	83.2%	2,670	16.8%	15,880
Trips	60,900	84.2%	11,336	15.8%	72,236
Average Daily Household Trip Rate	8.62	--	--	--	--
Average Daily Person Trip Rate	4.61	--	4.25	--	4.55
Average Weekday Household Trip Rate	9.46	--	--	--	--
Average Weekday Person Trip Rate	5.06	--	4.64	--	4.99
Average Trip Distance (all days)	6.11 miles	--	6.29 miles	--	6.14 miles
Average Trip Distance (weekdays)	6.21 miles	--	6.48 miles	--	6.25 miles
Average Trip Travel Time (all days)	0:13:07	--	0:13:17	--	0:13:09
Average Trip Travel Time (weekdays)	0:13:05	--	0:13:21	--	0:13:07
Average Daily Travel Time (all days)	01:22:11.1	--	01:19:27.1	--	01:21:44.4
Average Daily Travel Time (weekdays)	01:21:10.5	--	01:19:26.6	--	01:20:53.7

A total of 601 households completed the PR survey, comprising 989 persons, or 1.65 persons per household. This was lower than the number of GPS persons per household (which was 1.88); however, most households that completed the PR survey did so with all members of the household that carried a GPS completing the survey.

There are clear problems in the completion of the PR data. An in-depth analysis of the PR data revealed that about 6 percent of the responses of the mode of travel used appear to be highly questionable, and about 15 percent of the trip purposes identified also appear to be highly questionable. For mode, the most common issue was a trip claimed to be by walking at a speed beyond the capability of a human being. For purpose, the major issues relate to respondents combining two or more trips into one round trip or tour, and providing an incorrect purpose for the combination. As a general conclusion, the PR data are subject to almost all of the common problems found in self-report diaries, even though respondents have a map showing where the GPS says that they travelled and from which they just needed to fill in the details of their travel.

#### IMPLEMENTATION RECOMMENDATIONS

The primary conclusion to be drawn from this research is that it is feasible to undertake a GPS-only household travel survey, achieving a high standard of representativeness for the sample, while imputing mode and purpose at a sufficiently accurate level to support modeling work. The high level of accuracy attained in this survey for imputing mode and purpose with 96 percent on mode and around 90 percent on activity (other than detailed breakdowns of the "other" category) is far superior to self-report surveys. The richness of the "ground-truthing" of time, location, distance, speed, and route information from this survey surpasses what can be achieved from any other form of survey.

There are improvements that could be made, however, for future GPS-only HTS. The Abt/SRBI Team recommends including in the recruitment script the workplace and school location for every person in the household, as well as the household's four most frequently visited site locations and names. The team also recommends that a longer period of measurement be used in future surveys. A full week (7 days) of GPS data will enhance the ability to identify work trips, as well as providing much richer data on the variability of travel from day-to-day. In addition, this would allow for a larger sample of weekend data, which may have significant future use in a number of policy areas. Finally, a better method than the PR survey is needed for obtaining 'ground truth' for further improvements in software processing; and detailed land use data should be compiled in digital GIS Open Streets Maps format for identification of "other" purposes such eating out, leisure, medical-related, and personal business.