CONDUCTING A HOUSEHOLD TRAVEL SURVEY WITH GPS: REPORTS ON A PILOT STUDY

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ABSTRACT

For the past decade, GPS devices have been used increasingly as a means to validate household travel surveys and more recently as a means to determine response to travel behaviour change policies. However, although several papers have put forward arguments that GPS is now ready to be used as a potential substitute for conventional travel surveys, there has been somewhat of a reluctance to proceed in this direction. This paper describes such an effort. In late 2008, a team of consultants was put under contract by the Ohio Department of Transportation to conduct a GPS survey of households in the Greater Cincinnati area of southwest Ohio, northwest Kentucky, and southeast Indiana. A pilot survey was conducted in March-April 2009, and this paper reports on the outcome of that pilot study. At the time of writing this paper, the main study is underway, with a goal of having at least 3,000 households use GPS devices for a three-day period within the 12 months from mid-August 2009 to mid-August 2010.

In this paper, the procedures for recruitment of households, delivery and collection of GPS devices, and the rates of completion of the survey are described. A prompted recall survey, using a web-based survey is also described. The purpose of the web-based prompted recall survey is to collect sufficient data to allow improvement and addition to existing processing software, so that the GPS data will provide sufficient information to allow travel demand models to be estimated, as well as informing various policy issues. Preliminary results from the pilot survey indicate some issues with completion of the GPS task and also with the prompted recall survey. These issues have suggested the use of variable incentives in the main survey to improve overall response levels and significant changes to the prompted recall survey, which have been implemented. Statistics are also provided on some of the sociodemographic characteristics of the pilot sample, and this is compared to Census data for the Greater Cincinnati area. However, it was not expected or intended that the pilot sample would be a representative sample of the population. Preliminary analysis of the data collected by GPS indicates a substantially higher rate of trip-making than has been measured in the past, using conventional diary methods. While this latter result was expected, the magnitude of the increase is larger than expected.

INTRODUCTION

This paper describes the pilot survey for the first large-scale GPS-based survey conducted in the United States and, possibly, in the world. It is, of course, not yet known to what extent a 100% GPS-based survey is able to capture all the information available in a diary-based survey. This paper describes the processes used for the Spring 2009 GPS pilot survey and presents the findings from it. The results of the recruitment and response by households, the resulting data, and the analyses are documented with a view to understanding whether a fully representative sample of households can be completed, using solely GPS devises to collect travel information for all household members over 12 years old-- without the aid (and burden) of respondent recorded trip diaries and to assess whether this information is likely to be more accurate than conventional self-report data.

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, which, in the US, is most often used as the basis for retrieving information via a computer-assisted telephone interview (CATI), although other countries may use face-to-face interviews, or postal surveys to retrieve the data. Unfortunately, it is well documented that self-reporting leads to inaccuracies in travel information. The biggest short-coming is (arguably) trip underreporting. For instance, recent work by Wolf et al., (2003), Bradley et al., (2005), Stopher et al. (2007a), Stopher and Greaves (2009), and others comparing a subset of diary reported household travel with GPS recorded data has shown that diary information retrieved through CATI suggests trip under-reporting ranging from 20 to 30 percent, with a worst case of as much as 60 percent.

In addition to the failure to report the number of trips correctly, comparisons of CATI and GPS data have found that respondents tend to overestimate trip times and underestimate (seriously) the distance of their travel. Non-motorised travel (particularly walking) is also thought to be poorly recalled compared to motorised travel, although the extent of this discrepancy has not yet been established scientifically. Location information tends to be even more problematic, with people rarely able to provide address information for even commonly visited destinations such as work, school and the local grocery store to the degree of specificity required for geocoding and planning purposes (Stopher, et al., 2007b). The situation is even more problematic when trying to determine the route taken, with few people able to detail the route taken in terms of a sequence of street names. Indeed, it is rarely the case that household travel surveys try to collect information on routes, because of the known difficulties of having people report such information.

An additional perceived problem with diary-based approaches and for that matter any type of phone or Internet survey of this nature is respondent burden (Stopher et al., 2008a). This burden obviously increases as the level of detail required and the number of days of

observation increases. While most HTSs are one or two day surveys, evidence suggests that extending the survey period for three days or longer results in greater statistical efficiency (Wolf et al., 2006; Stopher et al., 2008b).

These issues aside, arguably the most pressing problem faced by *all* surveys is non-response. While there is marked variability dependent on the exact strategies employed, as a rule we can anticipate around 20-30 percent response from a mail-back survey, 25-40 percent from a telephone survey, and 60-75 percent for a face-to-face interview. However, non-response rates are not evenly distributed across the population, with certain groups (teenagers, larger households and those who travel more) under-represented in surveys (Stopher et al., 2007a). This leads to the potential for significant bias, which can only partially be accounted for in post-survey weighting of data results. With the many recent developments in improving the capabilities and the user friendliness of small portable GPS devices, the time appears ripe to test the potential for GPS to replace travel diaries.

THE SURVEY DESIGN

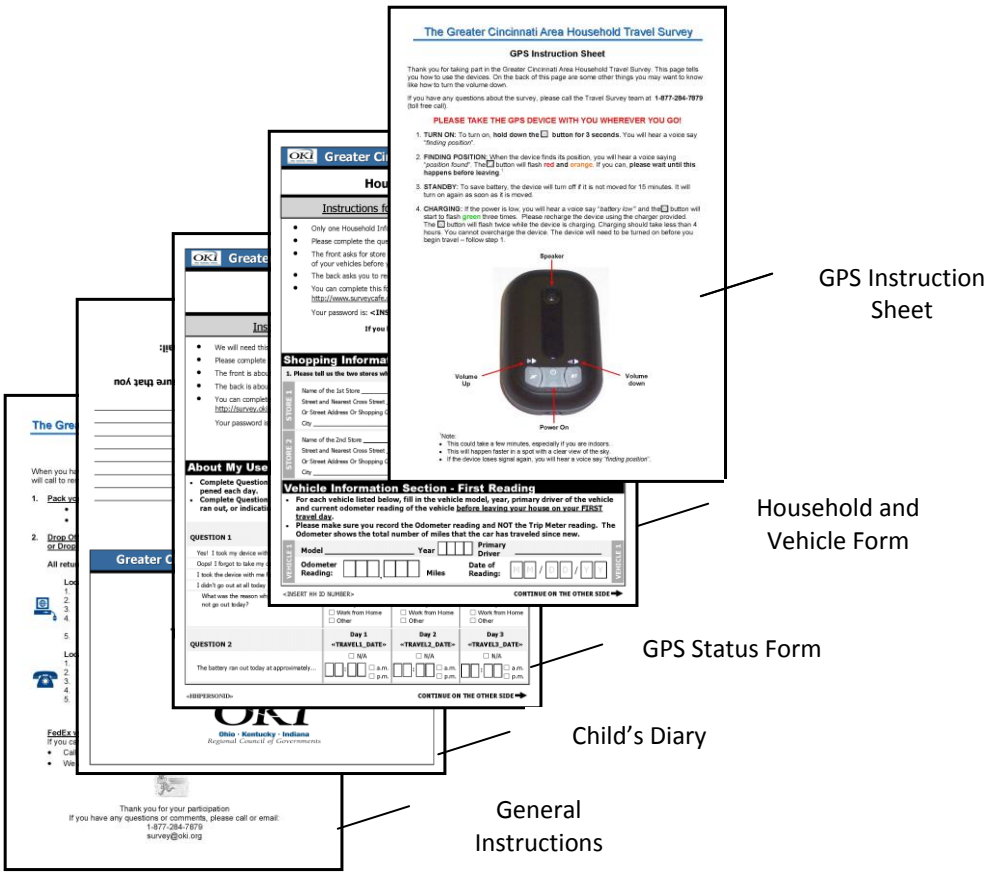
The design of this survey is to provide each household member over the age of 12 with a GPS device, which he or she will be asked to carry everywhere for a period of three days. This period is to start the day after the GPS device is delivered to the home. Sufficient devices are to be delivered to each home so that each person over the minimum age has a device to carry and devices are labelled to the specific individual so that the travel recorded is hopefully that of a single designated person. Each GPS device is also accompanied by a GPS status card that allows the individual to indicate what they did each day in terms of: taking the device with him or her all day, taking it for only part of the day, leaving it at home, or not travelling outside the home that day. There is also a place to indicate if the device ran out of power part way through the day.

Each household is also provided with a household and vehicle form, which collect basic social and demographic data about the household and its members and also collects information on the vehicles that are owned or used by the household. The household forms also importantly collect data about a number of addresses that the household uses. These are the addresses of the workplaces of each person in the household who works outside the home, the address of each school or educational establishment attended by members of the household, and the two most frequently-visited grocery stores. These addresses are used in the processing of the GPS data, as discussed later in this paper. For households with children 12 years and under, a brief travel diary is provided so that the loss of data by not providing GPS units to these children can be assessed. Figure 1 shows the package of paper forms that are sent to the household.

It is intended that each household member carry the GPS devices for about 3 days. This was decided at the outset of the survey on the basis that the battery charge on a device in normal use would usually last about 3 to 4 days and it was desired not to require households to recharge devices. Devices are set up for pick-up by a courier on Monday through Thursday of each week, with the courier providing next day delivery of devices. Therefore, devices are

normally received by households on Tuesdays through Fridays. This means that most households will carry devices on Wednesday through Friday, Thursday through Saturday, Friday through Sunday, and Saturday through Monday. However, because courier delivery is not always on the following day and because some households do not elect to start carrying the devices the very next day after delivery, there are some variations on the actual days that the households will carry devices. Some households, although receiving devices on Friday, will elect to start carrying their devices on either Sunday or Monday.

Figure 1: Paper Materials Distributed with GPS Units



After the respondents complete the GPS survey and the forms, these are picked up and processed. Following downloading of the GPS data and preliminary processing and editing, a prompted recall survey is conducted with a sample of households. In this prompted recall survey, household members are sent a private URL that takes them to a web site that displays one of their days of recorded travel and asks them to answer a few questions about their travel on that day. More details are provided on the prompted recall survey later in this paper. The purpose of the prompted recall is twofold. First, it is intended to provide additional data about the travel that cannot be collected by the GPS device but for which we currently do processing to determine the information. The prompted recall permits checking and validation of the results of the processing. Second, it is intended that the prompted recall data will be used to develop improved software tools for processing GPS data for eventual use in modelling applications.

SAMPLING PLAN

The Greater Cincinnati Household Travel Survey will be enhanced by recruiting from address-based samples within the eight county survey study area rather than from traditional Random-Digit-Dialling (RDD) sampling frames. When all sources of under-coverage in RDD frames (i.e., households with no telephones, those in zero blocks, and cell-phone-only households) are considered, the percentage of US households not covered by RDD frames may be as high as from 11 percent to 30 percent depending on the metropolitan area. The survey households are being sampled from the USPS Delivery Sequencing File (DSF) frame, which is based on residential housing unit addresses (commonly referred to as deliverable residential addresses). The frame includes both city-style addresses and P.O. boxes, and it covers single-unit, multi-unit, and other types of housing structures. Known business addresses are excluded. By sampling USPS addresses, rather than random telephone numbers, the survey can focus on more specific geographic areas. This improves the geographic representativeness of the sample and allows for oversampling of hard-to-reach but interesting household groups, such as those in transit-oriented neighbourhoods, while maintaining the ability to expand the sample to be representative of the population as a whole by using differential expansion weights.

The Main Survey Sampling Plan

The sampling plan for the main survey provides for 3,000 to 3,600 completed households with GPS-based travel inventories, with 750-1,000 households completing the prompted recall survey for verification, over a continuous timeframe of one year. For the main data collection effort, 500 households per month will be recruited. Census block groups within the region with a higher transit propensity and near universities will be oversampled. Regional household characteristic distributions will be monitored independently for specific targets by number of autos and number of workers, number of autos and household size, income categories, and lifecycle (household type) using PUMS data. Specific household characteristic distributions will be expected to be met each month. The three geographic sampling areas will be controlled on a quarterly basis. Distributions by political jurisdiction (counties and states) will also be monitored on a quarterly basis.

This paper reports the results of the pilot test with 100 completed households (and 30+ GPS/prompted recall surveys) conducted during the spring of 2009. For the pilot survey, census block groups with higher transit propensities were oversampled. It was expected that this oversample would provide what is needed in terms of overall household characteristic distributions (especially for adult students, low income, and zero autos).

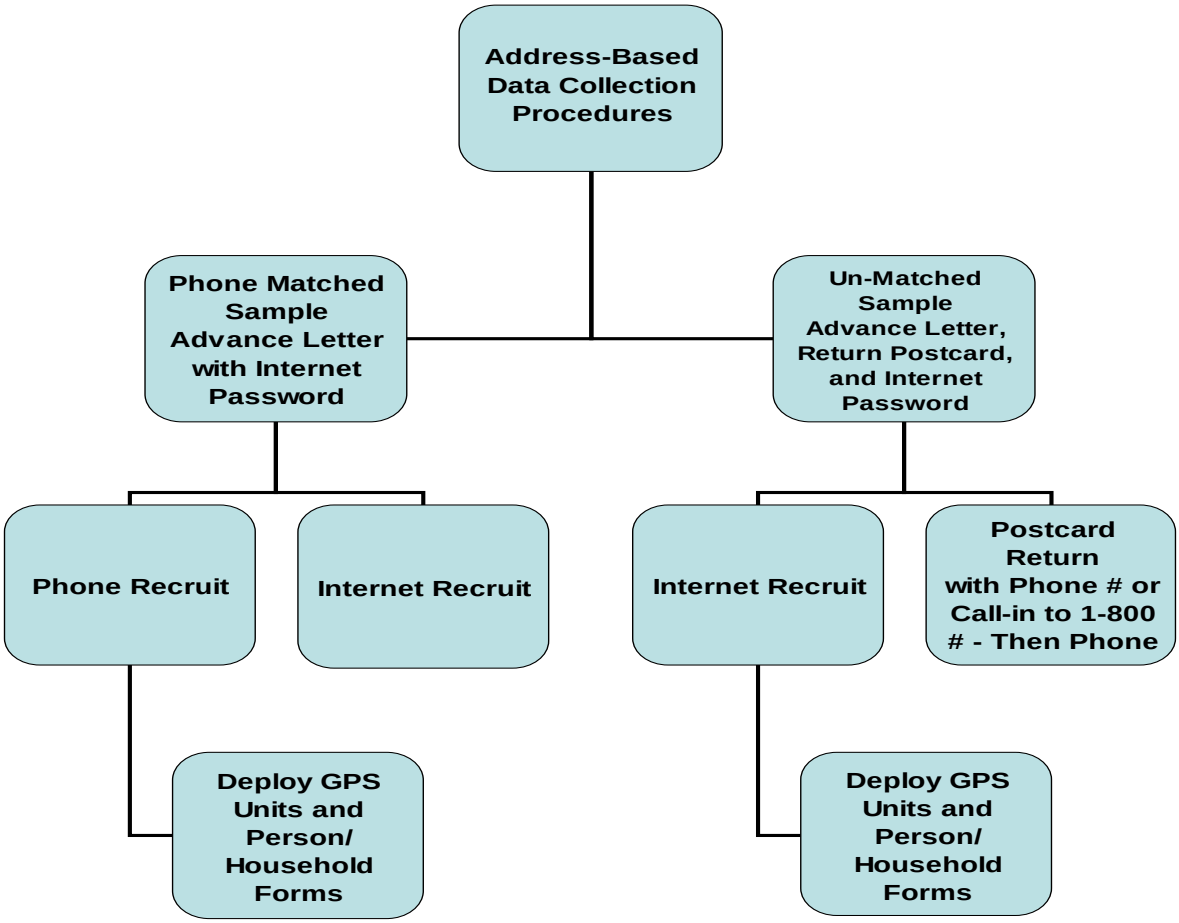
SURVEY PROCESS

Once the sample is selected according to specifications, land-line telephone numbers are attached to the addresses in the selected sample. It is anticipated that a phone number will be matched with an address for approximately 60 percent of the sample. These addresses

are called 'matched samples'. The 'unmatched samples' without phone numbers are households with unlisted land-line telephone numbers, no telephones, or mobile telephones only.

The survey process uses a two-pronged approach for recruiting households for the GPS-based household travel survey (HTS), depending on whether the sample household is within the matched sample or the unmatched sample stratum. Figure 2 shows this process flow.

Figure 2: Address-Based Sample Recruitment Procedures for the GPS-Based HTS



Because addresses are available for all sample households, all households are sent advance letters explaining the survey and each household is given a password and directions for accessing the project recruitment interview on the Web. For the pilot, those households without phone numbers (the unmatched sample) were also given a short 'hot button' transport issue questionnaire with such questions as: 'Do you think it is more important to build a light rail system or focus on highway improvements in the Greater Cincinnati region?' The household was asked to complete the survey and return it (in a postage-paid return envelope) with their phone number for participation in the GPS-based

survey (if they did not complete the recruitment on line). In addition, they had the option of calling a 1-800 number to provide a phone number.

After one week, if a sample household has not completed the recruitment interview online and a phone number is available either from the matching process or from postcard returns or 1-800 call-ins, the household is called (as in an RDD survey) to complete the recruitment interview over the phone. During the six-minute phone or Internet recruitment interview, three consecutive travel days are assigned. Once recruited, GPS units and instructions, household and vehicle forms, and children's diaries for those under 12 years old are deployed.

The GPS devices used are personal units (less than the size of a small mobile telephone) that can be carried in a pocket or purse, or clipped on a belt or wrist band. Thus, they record travel by all modes, including car, transit, bike, and walk. For the most part, the devices record three days of travel. In the pilot survey, chargers were not provided to respondents, but this has been changed for the main survey, based on results in the pilot survey. It was found that some respondents continually jogged the devices so that the devices would not transition into 'sleep' mode, resulting in a rapid power down of the battery.

Finally, it is a goal of this large-scale GPS-Based HTS to develop an efficient (low cost) means of deployment of the units to and from widely scattered sample households around a metropolitan region, because the costs of full personal courier delivery and collection are prohibitive. The pilot survey used courier primarily for deploying the units. This is changed in the main survey. The survey procedure plan for the main survey is to send out the GPS units and forms packages by Federal Express (at a government rate of approximately US$8 per package). The outgoing package will contain pre-paid return shipping labels and a return package that can be deposited in any Federal Express or US Postal Service drop box. Household respondents will also be given the project 1-800 number to call to arrange a Fed Ex or personal courier pick-up if they prefer. Extensive follow-up phone calls and Internet reminders will be made to arrange courier pick-ups as needed, as the second most expensive and difficult logistics challenge presented by GPS-based surveys can be an excessive loss of GPS units.

Pilot Objectives

In the pilot survey, the research team sought to obtain an early understanding of cooperation and completion rates for different survey respondent groups and to test the potential effectiveness of respondent incentives. Specifically, the pilot was designed to explore differences in response rates between:

1. Respondent households within and outside the transit propensity area;
2. Respondent households in the matched sample (a land-line telephone number is available) and in the unmatched sample (no telephone number is available);
3. Completion incentives of $0 and $10 for the matched address-telephone number sample;
4. Completion incentives of $10 and $25 for the unmatched sample;

5. Completion rates for all key household characteristic segments

For the pilot, the researchers sought the ability to analyse response rates for different realistic combinations of treatments. Thus the sample deployed had the following characteristics:

1. Equal sample for higher transit propensity and medium-lower transit propensity households
2. Equal sample for phone matched and un-matched sample
3. Equal proportion of matched sample offered $0 and $10 incentive to complete
4. Equal proportion of un-matched sample offered $10 or $25 incentive to complete

The design is shown in detail in Figure 3.

Figure 3: Pilot Sample Design

Matched Sample **Higher Transit Access Subsample** **$0 Incentive**	**Un-Matched Sample** **Higher Transit Access Subsample** **$10 Incentive**
Matched Sample **Lower Transit Access Subsample** **$0 Incentive**	**Un-Matched Sample** **Lower Transit Access Subsample** **$10 Incentive**
Matched Sample **Higher Transit Access Subsample** **$10 Incentive**	**Un-Matched Sample** **Higher Transit Access Subsample** **$25 Incentive**
Matched Sample **Lower Transit Access Subsample** **$10 Incentive**	**Un-Matched Sample** **Lower Transit Access Subsample** **$25 Incentive**

Allocating the pilot sample in this way enabled us to compare the outcomes statistically between the transit and non-transit areas, the matched and unmatched sample, and the different incentive levels. In the pilot survey, all respondent households that completed the GPS portion were recruited for the prompted recall survey.

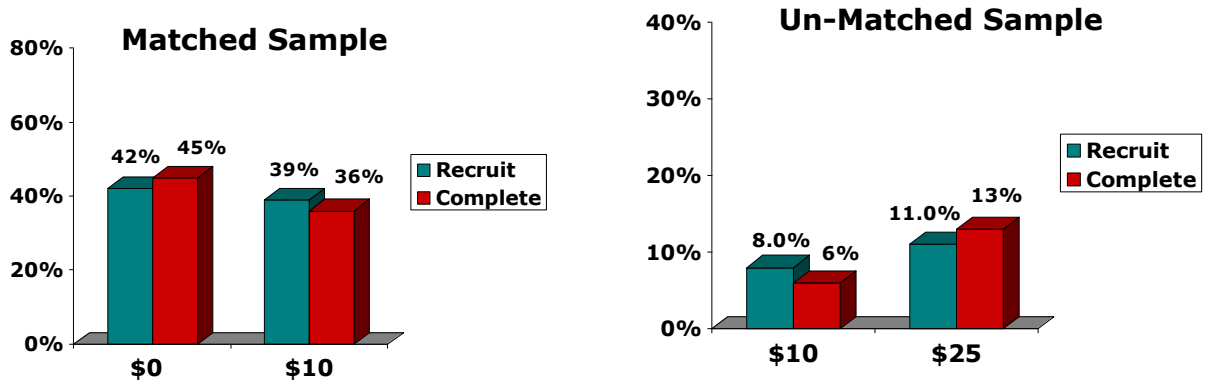
PILOT RESULTS

Overall, the ratio of completes to recruitments was relatively stable for all geographic and demographic segments. In other words, the make-up of the household sample that completed the GPS Survey was similar to the sample that was recruited, in terms of both matched and unmatched sample, and higher and lower transit propensity areas.

As shown in Figure 4, there was no difference in response/completion rates for $0 and $10 offered incentives among the matched sample (with telephones). However, among the

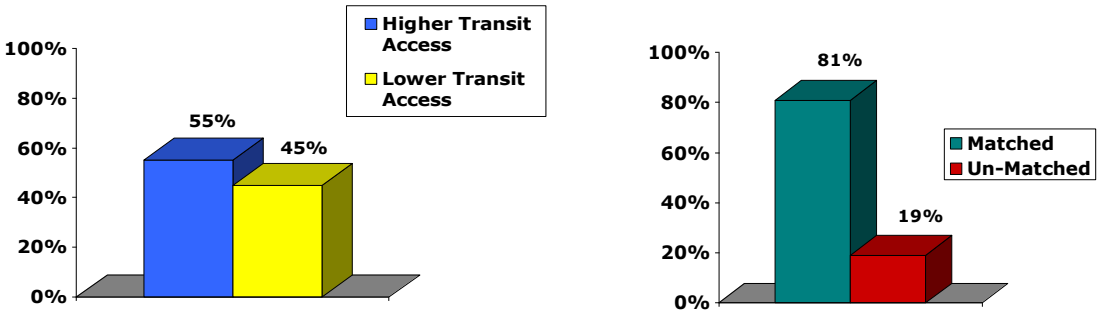
unmatched sample (mostly mobile telephone only households) a $25 incentive doubled completion rates, although it had much less effect on recruitment rates.

Figure 4: Completion to Recruitment rates for sample segments



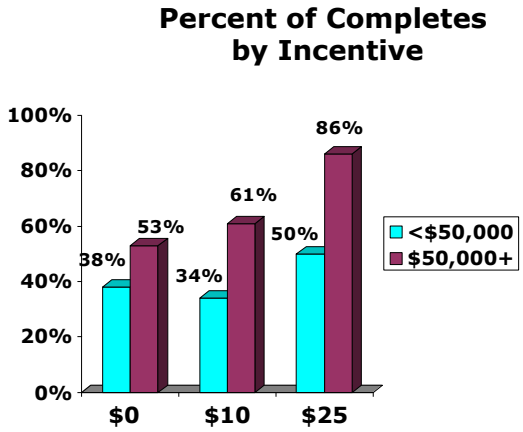
With respect to higher and lower transit propensity areas, the results are shown in Figure 5. This shows that, in line with the pilot sampling plan, nearly equal percentages of pilot GPS completes were from transit and non-transit areas — there was little difference in participation rates. However, of the total completes, 81 percent were from the matched telephone sample, while 19 percent were from the unmatched sample (mobile telephone only).

Figure 5: GPS Completions as a Percent of the Total for Matched and Un-Matched Sample and for Higher Transit and Lower Transit Areas



The pilot also provided data for evaluating the impact of different incentive levels on GPS completion among different income groups. Figure 6 shows that a $10 incentive versus no incentive made no difference among households with less than $50,000 incomes, and only a slight difference for those with $50,000+ incomes. Offering a $25 incentive did make a significant improvement in the percent of completes among all income groups. Significant incentives are needed to improve completion rates among households with less than $50,000 incomes.

Figure 6: Differential impacts of Incentives on Income Groups

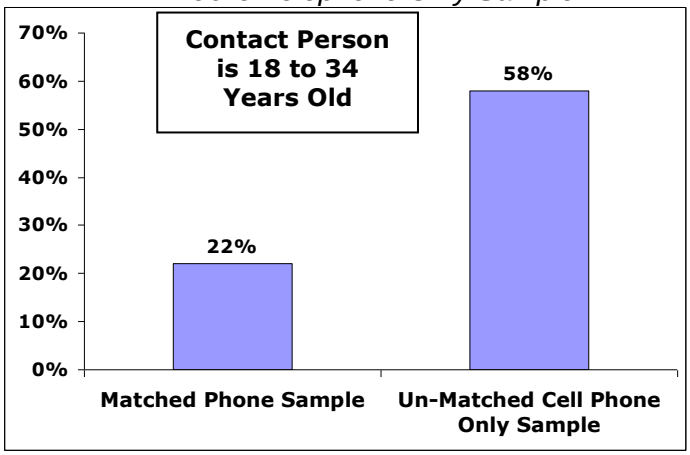


It is interesting to note that the $25 incentive increased completions among households with over $50,000 incomes as well as among lower income households, but without incentives the representation of these household in the completed sample was sufficient.

Comparing recruitment of the matched and unmatched samples, it was found that Internet was the most viable means of obtaining recruits from households without land-line telephones. Additionally, 19 percent of recruits from the matched sample responded to the advance letter by completing the recruitment on-line. Only one phone number was obtained from the unmatched sample via a return postcard/reply to a hot button issue survey. Therefore, this option is being eliminated for the main survey. Regardless of recruitment method, completion rates for the matched and the unmatched samples were equivalent – once recruited.

Respondents 18-34 years old are typically under-represented in diary Household Travel Surveys and comparisons of diary recorded trip inventories with subsamples of GPS surveys show their trips and tours to be under-reported. Figure 7 shows that this underreporting age group (who are the most likely to be mobile-telephone-only households) were captured for the GPS-based HTS through an advance letter and go-to Web-based recruitment interview.

Figure 7: Contact Person Age 18-34 Years old for Matched Phone Sample and Unmatched Mobile Telephone Only Sample



With respect to the representativeness of the pilot sample, based on key household characteristics, it was found that a very representative sample was recruited and completed by household size. The requirement that all household members age 12 or older carry GPS units did not prove to be a 'respondent burden' barrier. Looking at number of household vehicles, a representative sample was also completed. However, while an appropriate percent of zero vehicle households were recruited, extra effort in the form of incentives ($25) will be needed to complete zero vehicle and low income households in the main survey.

Tables 1 through 5 show the breakdowns of completed households by the key household characteristics compared to the latest available PUMS data. It is interesting to note that retiree households are well represented, so that the technology of the GPS device does not deter these households.

Table 1: Distribution of Pilot Completed Households by Household Size

Household Size	Percent of HH Recruitments	Percent of HH Completes	PUMS 2000 Data (Percent)	Difference in Percentage Points
1	29.2	29.3	27.3	+2.0
2	31.1	34.1	32.0	+2.1
3	15.3	15.9	16.6	-0.7
4 or more	24.4	20.7	24.1	-3.4
Total	100.0	100.0	100.0	--

Table 2: Distribution of Pilot Completed Households by Car Availability

Car Availability	Percent of HH Recruitments	Percent of HH Completes	PUMS 2000 Data (Percent)	Difference in Percentage Points
0	9.1	2.4	9.7	-7.3
1	28.2	28.0	32.3	-4.3
2	40.2	46.3	38.8	+7.5
3 or more	22.5	23.2	19.2	+4.0
Total	100.0	99.9	100.0	--

Table 3: Distribution of Pilot Completed Households by Household Type

Household Size	Percent of HH Recruitments	Percent of HH Completes	PUMS 2000 Data (Percent)	Difference in Percentage Points
Adult Household	48.3	43.9	46.0	-2.1
Household with Children	32.5	34.1	36.6	-2.5
Retiree Household	14.8	18.3	14.5	+3.8
Adult Student Household	4.3	3.7	2.9	+0.8
Total	99.9	100.0	100.0	--

Table 4: Representativeness of Pilot Sample by Number of Workers

Number of Workers in the Household	Percent of HH Recruitments	Percent of HH Completes	PUMS 2000 Data (Percent)	Difference in Percentage Points
0	29.7	32.9	24.0	+8.9
1	37.8	35.4	37.4	-2.0
2	26.8	30.5	31.3	-0.8
3 or more	5.7	1.2	7.3	-6.1
Total	100.0	100.0	100.0	--

Table 5: Distribution of Pilot Completed Households by Household Income

Income Category	Percent of HH Recruitments	Percent of HH Completes	PUMS 2000 Data (Percent)	Difference in Percentage Points
>$25,000	21.8	9.1	20.6	-11.5
$25,000-$49,999	26.9	28.6	25.1	+3.4
$50,000-$74,999	19.3	20.8	20.2	+0.6
$75,000 and over	32.0	41.6	34.1	+7.4
Total	100.0	100.0	100.0	--

Pilot Survey Process Logistics Issues

A number of logistical problems were encountered in the pilot survey, which impact both the timing and the costs of the main survey. It was found that the retrieval of GPS units in a timely manner for redeployment was a greater problem than anticipated. The loss rate for the pilot was 2.7 percent – mostly among low income/urban households. In the pilot survey, no incentive was offered for the return of the GPS units. For the main survey, more units will be needed than originally expected to cover this ongoing estimated loss rate. Also, incentives of $25 will be offered to the unmatched sample, to households with incomes below $25,000, and to zero vehicle households upon completion of the GPS survey and return of the GPS devices.

Some battery outages were experienced over the three assigned travel days, resulting in some households without a complete travel day recorded for each member over 12 years old. As a result, battery chargers and instructions will need to be supplied to households in the main survey.

GPS Data Imputation and Verification – Processing Methodology

The processing methodology used has been documented elsewhere (Stopher et al., 2007b; Stopher, 2009) and is not repeated in this paper. Suffice it to say here that the initial step is to break up the GPS data stream into trips, following which a visual check and possible

manual editing takes place. After this step, the data are processed to identify the mode of travel and the purpose of the travel, using a set of rules that have been developed over a number of previous projects using GPS data.

In this project, however, as mentioned earlier, a prompted recall survey is being used. The first purpose of this prompted recall survey is to gather data that can be used to verify the results from the processing software (as documented further by Stopher et al., 2010) and second to provide data from which improvements could potentially be made to the software, as well as adding new software to estimate occupancy of private vehicles. The prompted recall survey was originally intended to be conducted by both Internet and post, but it was decided during the preparation for the pilot survey that it would not be possible to create a postal version of the survey that would be comparable to the Internet version. This mainly arises because of the difficulty of accommodating in a paper and pencil version of the survey the ability to insert a missed trip or stop, or to combine two trips into one by deleting a stop, both of which are important functions in the prompted recall survey. Therefore, only an Internet version of the survey was piloted and only an Internet version is to be included in the main survey. While this is likely to result in a somewhat biased sample for the prompted recall survey, the bias in the sample is actually not important, because the purpose of the survey is to provide verification of the processing and to contribute information for further improvements to the processing, neither of which purposes requires a representative sample of the population.

The prompted recall survey went through several revisions during the Pilot phase. Approximately 27% of households completed the prompted recall, but there was a fall-off among larger households. The purpose of the prompted recall is for the respondent to provide feedback on the GPS interpreted travel information for the assigned and recorded days. Figure 8 provides a screen view of the prompted recall in its pilot form.

Basic Design Principles for the Prompted Recall

The GPS devices record all location data. The only errors (provided that all downloading and processing is done correctly) that can occur in the location data are:

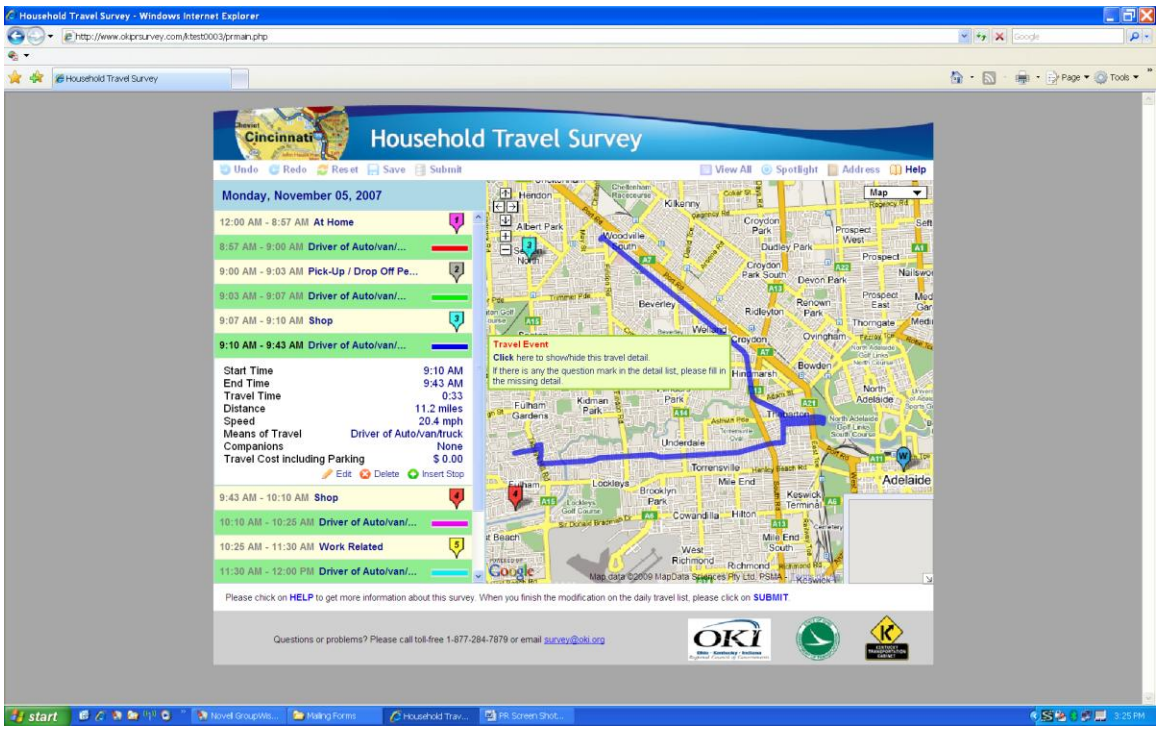
1. Cold start problem – the device experiences a delay in fixing position until after a trip has actually started. This is fixed for all except the first trip on the first day by the software, and the first trip on the first day is fixed by the map editing that precedes setting up the URL for the Prompted Recall survey.

2. Lost signal – this is only a problem if it occurs near the end of a trip and results in a premature destination recording. This should normally be fixed in the map editing process prior to setting up the URL. If the signal is lost in the middle of a trip, the processing software automatically repairs it.

The other things that can be wrong with the GPS record are that the person did not carry the device with them all day, or that the battery ran out. In these cases, if the person marked on

their form that they forgot the device for some of the day or that the battery ran out, then that day is excluded from the sampling for prompted recall. Apart from these issues, the start and end times of travel on the GPS record must generally be correct, and, provided that the travel is also along the street or rail networks, then a trip must have taken place.

Figure 8: Prompted Recall Web Format



Possible Errors and Omissions in the GPS Record

This leads to the assumption that the only things that can be wrong with the GPS record for prompted recall respondents which necessitates editing of the data are:

1. GPS processing has missed identifying a brief stop (usually one that lasted less than 120 seconds). In this case, the respondent should be allowed to insert one or more stops, thereby splitting one trip into two or more trips.

2. GPS processing has identified as a stop what was actually just a traffic stop or other delay that lasted at least 120 seconds. In this case, the respondent should be allowed to delete one or more stops, thereby linking together two or more trips.

Proposed Design for Deletion or Addition of Stops

Based on these assumptions, questions of confirmation of the start and end times of the travel, which were asked in the pilot version, are not asked in the main PR Survey. First, to allow for deletion of a stop, a stop is displayed to the respondent, followed by travel, followed by the next stop, followed by the next travel. Because the respondent can see and edit the

second stop and can see the second travel event, then the respondent can have the option of deleting the second stop, thereby joining together the first and second travel event.

Second, the respondent is asked whether she or he travelled from the first to the second stop without stopping. If the response is no, then an edit box pops up that allows the respondent to insert the time they stopped and the time they started to travel again. This also automatically updates when confirmed by the respondent and will shorten up the display to show two stops and two travel events. If the person tells us reasonably accurately when they stopped for each added stop, then the GPS record (with speed) will allow identifying where the additional stop was, with reasonable accuracy. For each travel event, the respondent is also asked to indicate the mode of travel and which family members, if any, accompanied them on that trip. Following completion of these other travel details and the purpose of the stops, the respondent will click on continue, which will then display the second stop, the second travel event, the third stop, and the third travel event of the day. This continues in pairwise fashion to the end of the day.

After all of the travel events recorded by the GPS device have been reviewed by the respondent, a closing PR question asks whether there is any travel or any other stops that the respondent remembers making on that day that they were unable to record on the survey. If yes, they are asked to record stops and approximate times. The Prompted Recall survey is then complete. Following the results of the prompted recall survey from the pilot survey, additional changes were made to the format and the final version, currently being used in the main survey, is shown in Figure 9.

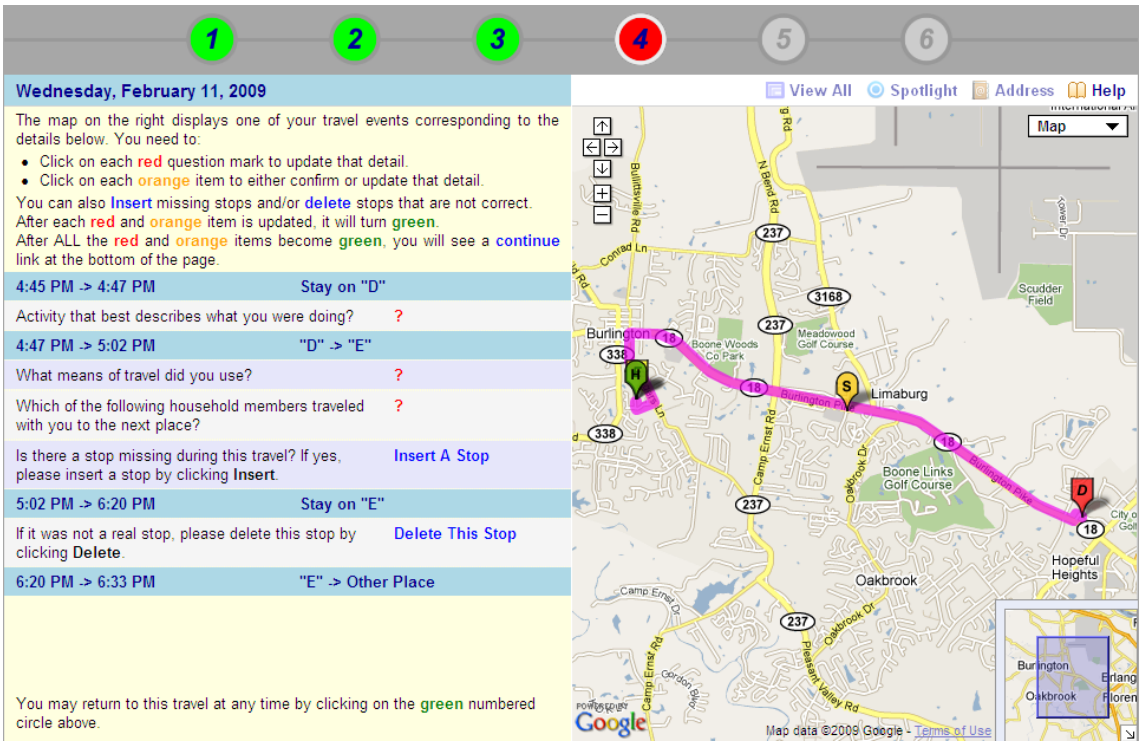


Figure 9: Revised Format for the Internet Prompted Recall Survey

A number of changes are evident from a comparison of Figures 8 and 9. The first is the display of travel events shown across the top of the screen, where the colour codes show green if the respondent has already edited the travel event and show red if the travel event is yet to be edited. (The greyed out numbers are for possible trip events that are not currently used for this day, but would become live if the respondent added one or more new trips.) The presentation of information has been changed and the left part of the screen has been uncluttered with information about previous trips and stops. The questions about the travel have been spelt out more completely and there is less information that the respondent appears to need to edit. Clicking on the red question marks will, in each case, produce a drop-down list. For the activity, it will display a list of activities that have been developed as part of the data dictionary, but will also allow an 'Other' option, which will also lead to a question to specify what this means. The same type of drop down list occurs for the means of travel. For the accompanying household members, a list of first names of the other members of the respondent's household are provided, from which to choose the names of those accompanying the respondent. Insertion and deletion of a stop has been made clearer with more instruction showing as to what to do and when to do it.

Other improvements made to the prompted recall include improved help instructions and context sensitive help as the respondent works through each page of the prompted recall survey. Because of a rather low response to the prompted recall survey in the pilot, two changes were made to the prompted recall survey. First, it was decided that all households would be asked to complete the prompted recall, rather than just a sample. This also allowed the inclusion of explanation about the prompted recall survey in the recruitment process for the GPS survey. In the pilot survey, respondents were unaware of the possibility of the prompted recall survey at the time of recruitment to the GPS survey. It was felt that this contributed to the low response rate to the survey. Second, it was also decided to add an incentive to the prompted recall survey. This incentive is in the form of a quarterly sweepstakes that is run for those respondents who have completed the prompted recall survey during a three-month period. A modest prize is offered.

PRELIMINARY ANALYSIS OF EDITED GPS DATA

We have undertaken some analysis of the preliminary edited GPS data, without using the edits from the Prompted Recall Survey. These analyses present some interesting results that would suggest both a vindication of using GPS for a household travel survey and also provide some pointers to changes needed in the execution of the main survey.

From the pilot, there were 546 valid person days of data from 227 persons from 119 households. At the person-day level, the average trips per person per day are 5.42, which based on just the GPS carrying household members comes to an average of 10.32 trips per household per day, with no correction for children in the household or for persons in the household for whom we did not get valid GPS data. An average of 1.91 persons per household provided GPS data. Assuming an average household size of 2.56 in the region, then a corrected average trip making per household would be 13.88 trips per day. These

statistics are generally quite a bit higher than those normally found from traditional diary surveys, and clearly show the issue of underreporting in diaries.

At the person level, the 5.42 trips averaged 14.5 minutes long and covered a distance of 10.23 kilometres, or about 6.30 miles. On the average, people spent 73.67 minutes per day in travel and travelled a total of 31.85 miles. The shortest trip recorded was 809 feet, and the longest one was 39.42 miles. The shortest duration trip recorded was 1 minute and 19 seconds, and the longest one was 56 minutes and 18 seconds.

On average, data were obtained for 2.41 days per person, with a minimum of 1 day and a maximum of 4 days. The days of the week were not evenly distributed, however. There were data for 5 persons on a Sunday, 96 on Monday, 97 on Tuesday, 154 on Wednesday, 101 on Thursday, 83 on Friday, and 10 on Saturday. Looking at the time periods, the majority of the respondents started their GPS recording on Monday (94) or Wednesday (97), with only 18 starting on a Tuesday, 13 on a Thursday and 5 on a Saturday. Not surprisingly, the last day of data recording was predominantly on Friday (71) and Wednesday (59), with 4 ending on Sunday, 8 on Saturday, 16 on Monday, 30 on Thursday, and 39 on Tuesday. These statistics show that the 3-day recording periods tended to start on Monday and end on Wednesday or start on Wednesday and end on Friday. This tends to give the maximum number of observations to Wednesday, which ends up with nearly twice as many observations as any other day of the week.

If it is desired to obtain a significant level of weekend data, then the distribution from the pilot suggests that some changes need to be made. Similarly, if weekdays are more important and a more even distribution of data over the five weekdays are desired, then again, this suggests that there needs to be some change in the distribution of devices through the week. Probably, more households need to be starting GPS recording on a Tuesday and on a Thursday, although the latter will generate a lot more Saturday records. If more weekend data are required, then more households should receive devices on Thursday and Friday, so that there are more 3-day sequences that include Saturday and Sunday. The distribution suggests that the devices were generally received on Friday or Saturday and were not used until Monday, or were received mainly on Tuesday with a start into use on the following day, with rather few being received on any other day of the week. This may have been an artefact of the short period for the pilot survey and is potentially less likely to occur in the main survey, which is to be spread over an entire year.

In terms of the use of GPS devices, 40 households provided data from 1 GPS device, 58 from 2 devices, 13 from 3, and 8 from 4 devices. No household recorded data on more than 4 devices.

CONCLUSIONS

The pilot survey of the Greater Cincinnati GPS-Based HTS has demonstrated that:

- Address-based sampling can be successful in recruiting mobile telephone only households to a GPS-Based HTS via an Internet recruit. Once these households are recruited, they complete the GPS HTS in similar proportion to other households.

- A fully representative sample by the household characteristics of household size, number of autos, number of workers, income, lifecycle, and geographic region can be completed by a GPS-only HTS, recording up to three days of travel.

- GPS household completion rates are adequate as well as representative.

- Requiring every household member (over 12) to carry a GPS unit for three days was not considered an undue burden – paperwork was greatly reduced.

- Significant incentives and additional efforts are needed to complete unmatched households and households with low-incomes and/or zero vehicles.

- Added trip accuracy reporting has been demonstrated in the analysis of the completed GPS surveys by households in the pilot survey.

- The value of route and location with speed data (as collected via GPS) needs to be demonstrated upon completion of the pilot and main survey trip files.

In addition, in another paper offered to this conference, details are provided of a comparison between the prompted recall results and the GPS processed results that underscore the value of the prompted recall survey and also show that the existing processing software is remarkably accurate, although there is still room for improvement. However, it is still also clear that work is yet to be done to determine whether the data resulting from this survey can be used to estimate travel demand models of a similar specification to those normally estimated from conventional travel diary surveys.

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