NON-RESPONSE CHALLENGES IN GPS-BASED SURVEYS

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TRAVEL SURVEY CONFERENCES
WORSHOP ON NON-RESPONSE CHALLENGES IN
GPS-BASED SURVEYS

Dr. Stacey Bricka

PTV NuStats, LLC

206 Wild Basin Road
Building A, Suite 300
Austin, TX 78746
www.nustats.com

Phone: 512.306.9065 x 2261
Fax: 512.306.9077
E-mail: mmccaffrey@nustats.com

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By Stacey Bricka, NuStats (sbricka@nustats.com)

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1.0 INTRODUCTION

Over the past decade, transportation researchers have leveraged global positioning system (GPS) technology to improve the accuracy and increase the depth of spatial and temporal details obtained through household travel surveys. While earlier studies used GPS as a supplement to traditional household travel survey methods, measuring the accuracy of trips reported (Wolf 2006), studies are now underway to identify the methods and tools that will allow us to do away with paper diaries entirely and simply rely on GPS to obtain trip details. The desire to use GPS for travel surveys stems from the ability to glean from the data streams more precise travel times and distances, accurate route information, interim stop locations, and vehicle operation characteristics (Doherty 2006; Kalfs 1997; Madre 2008; Swann 2008). In addition, recent technology advances have led to decreased equipment costs and increased prominence in the consumer market (Kracht 2006).

Adding to the context, recent advances in activity-based travel demand modeling require more detailed travel behavior details, both about the trips themselves as well as variations in travel and household interactions, for longer periods of time than the traditional 24-hour period. These increased demands being placed on traditional household survey participants are being met with resistance, as evidenced by declining response rates and corresponding increases in collection costs. GPS data collection is thought to decrease respondent burden through the passive collection of travel details (Martin Lee-Gosselin 2006). Trip information is subsequently identified in the GPS data streams through algorithms or follow-up prompted recall surveys (Wolf 2006).

Clearly, passive collection of trip details is less onerous than completing paper travel diaries and can be deployed for longer periods of time, at levels of "little or no respondent burden" (Doherty 2006; Kalfs 1997; Wolf 2006). However, few studies examine the deployment of this technology in the household survey context from the perspective of the respondent, the logistics of deployment, or with regards to the representativeness of the resultant data sets. Lee-Gosselin et al (2006) recognize the problems of equipment deployment and recovery, as well as privacy concerns, which, when considered in tandem with factors that influence the decision to participate in these surveys and those that influence consumer acceptance of technology, contribute to unit non-response bias.[1] In addition, while the newer GPS units are smaller with lighter power

[1] Throughout this paper, the references to unit and item non-response are consistent with that of accepted survey literature where, in the context of GPS studies, item non-response refers to the lack of data capture

supplies, respondents must still remember to carry them around and charge them (Doherty 2006; Hawkins 2004; Wolf 2006). As a result, units are not carried around all the time, due to respondent-cited reasons such as a “lack of time” (Draijer 2000) and the “busyness of life (Swann 2008). This creates item non-response issues in the resultant data sets.

The purpose of this paper is to investigate the non-response challenges associated with GPS-based surveys, focusing primarily on the identification of non-response levels at the unit level, in order to determine if the data files ultimately obtained by GPS are statistically different from those obtained through traditional survey methods. Unit non-response is hypothesized to be a function of (1) traditional travel survey non-response factors and (2) technology acceptance levels, and will be identified in this paper using quantitative techniques. Details regarding item non-response will be explored at a qualitative level.

The paper is organized as follows: following this introduction is an international review of the use of GPS in travel surveys. Next, a literature review is presented that focuses on (1) factors influencing non-response, both from the travel survey literature as well as relevant information technology and marketing studies and (2) prior research specifically investigating unit non-response in GPS-based surveys. The fourth section presents an evaluation of unit non-response in two recent US travel surveys in order to identify whether the composition of the GPS data files differ from those collected through traditional means, followed by a qualitative discussion of item non-response in the fifth section. The paper concludes with recommendations for mitigating non-response in GPS-based surveys.

2.0 GPS IN TRAVEL SURVEYS

The purpose of this section is to provide an international synthesis of GPS applications in travel surveys. The details in this section were drawn from published literature, as supplemented by direct inquiries to colleagues in various countries. It is limited to those documents written in English and focuses primarily on papers submitted for consideration to the Transportation Research Board annual meetings from 2001 to the present. One objective of the conference workshop is to fill in missing “blanks” in this section.

2.1 United States

The use of GPS in regional travel surveys throughout the United States began with the Lexington (Kentucky) proof of concept study in 1996 and continues today, with deployment in more than sixteen regional studies. Texas has had the most deployments, with a 10% sample of GPS households in six regional travel surveys since 1997. Other

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by the GPS unit due to respondents not carrying the units as instructed, not charging the units on a regular basis, or unit malfunction.

regions with GPS deployments in travel surveys include Los Angeles, Pittsburgh, St. Louis, Kansas City, Reno, Portland, Seattle, Chicago, Washington DC, and Baltimore (Bricka 2006). In addition, both California and Ohio have deployed GPS as part of their statewide surveys. GPS sample sizes ranged from 46 households (Pittsburgh) to a projected 1,600 households in the ongoing Washington DC/ Baltimore study (NuStats Travel Survey Archives). Except for the Portland proof of concept test and the current Chicago study, both of which deployed wearable GPS devices, all remaining US studies were conducted using in-vehicle units that store the data within the unit and data downloads in between deployments to participating households.

The application of GPS to regional travel surveys in the US has largely been for the purpose of trip rate auditing – identifying the magnitude and characteristics associated with trip under-reporting. Identified trip underreporting levels range from 5-7% in the most recent studies (Kansas City and Reno) to 81% in a 2001 study in Laredo (Texas). In general, levels of trip under-reporting have fallen as research into trip underreporting correlates has been translated into improved survey methods (Bricka and Bhat 2006). In addition, algorithms for identifying trips in the GPS data steams have been strengthened with the use of prompted recall trips. Specifically, earlier studies simply computed missing trips as the difference between trips detected in GPS vs. those reported in CATI while later studies excluded from the GPS detected trips those respondents were told NOT to report in their logs such as trips outside the study area or for commercial purposes.

One additional US project is the Commute Atlanta project. It is important to note that this is a GPS-based instrument vehicle monitoring study, not a household travel survey. A three year project utilizing a random sample of 500 vehicles across 260 representative households, this is the longest-running continuous GPS collection effort to date (Elango 2007; Ogle 2005). Although the burden associated with an extended deployment has not specifically been evaluated to date, Ogle et al (2005) reported difficulties in recruiting low income households into the sample.

2.2 Canada

Based on a review of international efforts, the Halifax STAR project enjoys the designation of the largest GPS sample within the context of a household travel survey project undertaken to date. The project design calls for 2,200 surveys of completed diary and GPS data, and, as of January 2008, data has been obtained from 1,400 households. The wearable GPS devices used in this study transmit the data to a central database as the travel takes place. The retrieval interview phase of the household travel interview includes collection of the diary data, immediately followed by a prompted recall survey using the previously transmitted data. Information is not available about the type of sample used in this study or any indications of non-response bias (Harvey 2008).

The use of GPS to collect travel details in Canada began in 1995 and, with the exception of the STAR project, has largely been focused on methods development and postprocessing techniques using data collected from small scale pilots and other applications using non-random samples (Doherty 2006; Lee-Gosselin 2008; Martin Lee-Gosselin 2006). One example is a study of diabetic patients which included wearable GPS, accelerometers, heart-rate and blood glucose monitoring, and a prompted recall diary administered with a Blackberry. Using a non-random sample of patients from a rehabilitation facility, the majority were elderly patients who were not at all intimidated by the technology (Doherty 2008).

2.3 South America

GPS has not been used within the context of any household travel surveys to date in South America. However, GPS technology has been employed extensively to document level-of-service data for all modes of travel (such as travel time data by auto and transit) (Yanez et al, Strambi).

2.4 Europe

As with Canadian applications, French colleagues are presently conducting a large-scale national travel survey that includes a GPS component. The anticipated GPS sample size is 1,500 households with a two-week deployment, out of a national sample of 17,000 households. While the national survey employs a random sample, the GPS units will only be provided to those participants who volunteer to carry them (this is similar to the practice in the US, where eligible households are asked if they would like to participate in the GPS sample) (Madre 2007, 2008).

According to Wolf et al (2004), the Ratt Fart project in Sweden was a traffic safety project that equipped hundreds of cars in three Swedish cities with GPS for a two-year period. The units provided drivers with feedback if speeding (Wolf 2004). Information was not available regarding whether this was a random sample or if there was any type of non-response bias noted.

In addition to these larger studies, European colleagues have conducted pilot tests of GPS within the context of household travel surveys (and other large-scale GPS studies not linked to travel surveys). Most were focused on the methods and processing, as with our Canadian colleagues. Documentation regarding non-response issues was unavailable.

2.5 Japan

GPS studies in Japan have largely focused on the use of GPS-equipped cellular phones within small scale non-random samples. This includes the MoALS Mobile Activity Logger, which was tested by 31 non-random recruits. The MoALS unit was interactive, with participants logging departure times, transfers of mode, arrival time, and location information with a corresponding web diary that feeds back the reported travel information for confirmation and obtains other trip details. The advantage to the cell-phone GPS technology is the instantaneous transmission of data as it is obtained (Itsubo 2006).

Other Japanese studies include an 18-probe person survey with deployments ranging from 5 to 70 days and non-random samples of 10 to 384 persons to evaluate information provision, measure levels of service, and identify route choice (Asakura 2006). Because non-random samples were used, non-response bias was not addressed as part of this research.

2.6 Australia

Based on available publications, Australian colleagues have made the strongest advances in the transition to GPS-derived trip tables within the context of household travel surveys. Advances here have largely been in support of household travel surveys designed to measure reduction in vehicle kilometers traveled associated with the national TravelSmart program. For example, small-scale (n=200) GPS-based travel studies have been conducted in conjunction with odometer surveys within a panel survey framework in Victoria and South Australia (Stopher 2007). Other GPS-based household travel surveys have been conducted in New South Wales and Sydney (Stopher 2006). These surveys all used random samples and non-response was studied (as discussed in Section 4.0).

2.7 Summary

In sum, based on available English-language publications, the use of GPS in household travel surveys is becoming more common place throughout the world. There has a been a shift in focus from the use of GPS for trip auditing to the use of GPS for building the trip files, based largely on the ability to obtain more accurate trip details, particularly reported times, route choice, and interim stop detection. While large-sample traditional household travel surveys are commonplace, the first round of large, random GPS-based travel surveys is now underway. As this data becomes available, it will provide a rich source of information on the issue of non-response in GPS-based travel surveys, among other topics such as the study of route choice or time-of-day travel patterns.

3.0 LITERATURE REVIEW

The study of non-response within the context of household travel surveys enjoys a strong history of discussion at these international travel survey conferences, as have discussions on how to mitigate that non-response. The purpose of this section is to briefly summarize the key demographic characteristics associated with non-response in household travel surveys, as well as demographics associated with technology acceptance, in support of the underlying hypothesis for this research: that non-response in GPS-based travel surveys is a function of the non-response associated with traditional travel surveys and the characteristics of those that do not quickly embrace new technologies. Supporting literature is summarized in three categories: non-response in travel surveys, technology acceptance, and, for the few sources available, specific inquiries into non-response in GPS-based surveys. An international perspective is provided where possible.

3.1 Non-Response in Travel Surveys

A review of unit non-response in travel surveys suggests that it can be characterized by both demographic as well as travel behavior characteristics. As indicated in Table 1, the most common demographic characteristics associated with non-response in traditional household surveys include being low income, young (under age 25), having a lower education, being a part of a larger household, being of minority descent, and living in an urban area. Travel characteristics typically associated with non-respondents include having lower-than-average trip levels and not using public transit.

Table 1 – Non-Respondents in Travel Surveys

	Low Income	Young	Lower Education	Large HH	Minority	Urban Dwellers	Low Travel Levels	Non-Public Transport User
German Mobility Panel[1]	X	X	X				X	
Sweden's TSU92[2]							X	X
International Review[3]							X	
Zurich Social Networks[4]		X	X					X
US Summary[5]	X	X		X	X			
TMIP Report[6]		X	X		X	X		
Australian Study[7]							X	

[1] (Kuhnimhof 2006)
[2] (Forsman 2007)
[3] (Bonnel 2007)
[4](Frei 2007)
[5] (Bricka 2006)
[6] (*Nonresponse in Household Travel Surveys*)
[7] (Richardson 1996)

3.2 Technology Acceptance

In addition to non-response factors, participation in GPS-based travel surveys is influenced by factors associated with the levels of technology acceptance. The marketing research and information technology literature indicates that those who are most likely to accept technology have the following characteristics:

- Male (de Blaeij 2006)
- Young (de Blaeij 2006; Im 2003; Macklin 2008)
- Highly educated (de Blaeij 2006; Im 2003; Macklin 2008; Vijayasarathy 2004)
- Higher income (de Blaeij 2006; Im 2003; Macklin 2008)

In addition, Vijayasarathy (2004) was the only one to find acceptance higher for those who were married and middle-aged.

Aside from demographic characteristics, characteristics about the technology itself influence acceptance levels. According to the Technology Acceptance Model, acceptance of a new technology is a function of the perceived usefulness of the technology and its ease of use (Childers 2001; Goeke).

Within the context of GPS-based travel surveys, amenability to participate therefore is expected to depend upon how the technology is introduced (for what purpose and how easy will it be to use), as well as the characteristic of the respondent, with non-respondents expected to be older, less educated, and having a lower income.

3.3 Non-Response in GPS-Based Surveys

To date, three studies have specifically evaluated non-response in GPS studies. These include one study from Australia and two studies from the US (both using data from the 2004 Kansas City Regional Household Travel Survey). The purpose of this section is to summarize the findings from these studies.

In Australia, Hawkins and Stopher (2004) investigated non-response among a subsample of GPS participants in the Greater Sydney Metropolitan Region's household travel survey. In this study, wearables and in-vehicle units were offered to 89 households, of which 48 agreed to participate and 41 declined. At the larger survey sample level, non-response bias was minimal, particularly with regard to age, sex, household size, and dwelling type. In the GPS sub-sample, statistically different participation rates existed with regard to county of birth (foreign born less likely), household type (households other than couples only or couples with children less likely), educational attainment (lower educated less likely), income (low income less likely), license status (non-licensed less likely), and household size (households other than 2-person households less likely).

In the United States, the Kansas City Regional Household Travel Survey included a GPS subsample of 228 households. Eligible households from the main survey sample were offered the opportunity to participate in the GPS study. Eligibility criteria included: (1) the household owned at least one vehicle, (2) all household vehicles had a functioning cigarette lighter or 12-volt power adapter (to the best of the owner's knowledge), and (3) the household indicated an interest in participating (NuStats 2004). Of the 3049 participating households, 1640 indicated an interest in participating in GPS and 228 ultimately provided GPS and CATI data. The GPS households were larger than the general survey population households, owned more vehicles (by definition since 0-vehicle households were excluded), and had higher incomes, on average (NuStats 2004).

A second study (Bradley 2005) conducted a more in-depth analysis of the Kansas City GPS sample using a logistic regression. In that study, they found that households with more workers per vehicle and higher incomes tended to be more willing to participate, while older respondents and households with fewer vehicles were less willing to participate. In terms of travel characteristics, the strongest explanatory variable was the number of diary vehicle driver trips per household adult.

3.4 Expectations

As we move from traditional travel surveys with trip details obtained through paper diaries to GPS-based trip files, the question is how representative the GPS-based files will be, given known levels of unit non-response associated with household travel surveys and known biases towards technology. By identifying the presence and magnitude of non-response in the GPS-based files, practitioners can identify methodological and procedural improvements to mitigate that non-response as we move forward with this alternate data collection approach.

The traditional non-response characteristics include the demographic characteristics of being low income, having lower levels of education, being of minority descent, being young, being a part of a large household, and living in an urban area. Travel characteristics include having low travel levels and not using public transit. For most household travel surveys, non-response is present in at least one if not all of these areas (although most studies employ design and process techniques to reduce it, or mitigate it post-collection through the use of weighting and adjustment factors).

The attributes associated with those less likely to be accepting of technology are to be low income, with a lower education level, and older. As a result, it is expected that GPS-based trip files will differ from those obtained through traditional methods by higher than "normal" levels of non-response for the low income households and those with a lower education level. However, the use of technology may mitigate the non-response among younger respondents. This will be tested in the next section.

4.0 UNIT NON-RESPONSE ANALYSIS

The main hypothesis being tested in this study is that non-response in GPS-based subsample of a larger travel survey effort is a function of the non-response existing in the main sample and the factors that influence technology acceptance. The expectation is that the characteristics of participants in the GPS sub-sample will mirror those of the main sample, with higher levels of income and educational attainment non-response. However, the non-response associated with being younger is expected to be diminished, as younger adults are expected to be more accepting of technology. Ultimately, it is expected that the combined influences of demographic characteristics and technology acceptance factors will result in the unweighted GPS-based trip file being different in composition from the unweighted trip file collected through traditional methods.

This analysis relies on two survey data sets, both of which include a traditional household travel survey effort with a smaller GPS sub-sample. The first study is the Kansas City

Household Travel Survey that was conducted in spring 2004 under the sponsorship of the Mid-America Regional Council and the Kansas and Missouri Departments of Transportation. As part of the Kansas City survey, complete demographic and travel behavior characteristics of 3,049 randomly sampled households were obtained, including details about 32,011 trips for 7,570 household members. The GPS component of the study involved equipping the vehicles of 294 households with GPS equipment to record all vehicle travel during the assigned travel period. Of the 294 households, both CATI and GPS data are available for 228 households (NuStats). The GPS subsample in this study was formed through offering the GPS option to eligible households (an "opt in" approach).

The second study is the Washington DC/Baltimore regional household travel survey, which as of January 2008 is in the final stages of data collection. Sponsored by the Metropolitan Washington Council of Governments and the Baltimore Regional Council of Governments, this survey is comprised of a traditional household travel survey of 15,000 households, with a subsample of 1,600 households in the GPS component. The interim data file used for this analysis includes demographic and travel behavior characteristics for 10,836 households, of which 850 participated in the GPS sub-sample. The GPS subsample in this study was formed through a two-stage process. First, households were randomly assigned to a GPS or non-GPS condition in the sample. During recruitment, those in the GPS condition were not offered the opportunity to participate but simply introduced to the study as being one where they keep a log for 24-hours and use the GPS in-vehicle units for 72-hours. Respondents could "opt out" of the GPS portion of the study, but non-GPS condition households were never offered the opportunity to "opt in." By including this survey in the analysis, it will allow for a general comparison of the impact of an "opt in" vs. "opt out" design for future studies. It also provides for an alternative GPS approach to how most are conducted in the US and other countries.

The analysis of each sample is conducted in two stages: first, a descriptive comparison of the GPS-sample to the main sample will be undertaken, benchmarking both against census. The purpose of this comparison is to identify the extent to which non-response bias, as reflected by deviation in each sample from the general population characteristics, is present. Second, using the approach from Hawkins and Stopher, a chi-square test of the key demographic and variables is undertaken, to determine if statistical differences between the composition of the main and GPS samples exist. Finally, the differences in non-response associated with each approach (opt in vs. opt out) for identifying the GPS-samples will be compared and discussed.

The results of this analysis are reflective of travel surveys in which households are asked to both keep travel logs and use the in-vehicle GPS devices for a short period of time. For wearable GPS studies, longer deployment periods, and GPS-only travel surveys, these non-response issues are likely to change as a reflection of variations in respondent burden.

4.1 Kansas City GPS-Sample

A summary of the demographic characteristics of households is shown in Table 2. This includes those that were recruited into the study, those that form the main sample (3049 households), the 228 households that comprise the GPS sample, and census data for the region.

As indicated in the table, non-response for the main sample (defined as lower proportions than what is present in the census data) is characterized as:[2]

- Slight non-response for households in the urban area (2% lower than census)
- Low income participation is 6% below census levels
- Minority participation is about 5% lower than census
- Hispanic participation is 2% lower than census
- The proportion of young adults (ages 18 to 24) is 3% lower than census proportions
- With regards to educational attainment, considering only those age 25+, those with a high school education or less are under-represented by about 12%.

In comparison, the non-response for the GPS-subsample includes the following:

- Larger households are under-represented by 4%
- There is an increase in non-response for urban dwellers from 2% in the general sample to 8% in the GPS sample. In addition, those living in the first suburban ring are under-represented by 6% in the GPS sample.
- Low income participation is now 15% below census levels (it was 6% for the full sample)
- Minority participation is now 15% lower than census (it was 5% for the full sample)
- Hispanic participation is 3% lower than census (a 1% increase)
- The proportion of young adults (ages 18 to 24) doubles to 6% below than census proportions. In addition, the proportion of elderly, which were over-represented in the main sample, is now 1% under-represented in the GPS sample.
- With regards to educational attainment, considering only age 25+, those with a high school education or less are now under-represented by 18% (was previously 12%)

In reviewing the GPS sample non-response, the growth in non-response among low income households, those with lower education levels, and the elderly is consistent with the literature regarding technology acceptance (these groups are less likely to accept the technology).

[2] While most travel surveys have non-response among larger households and those living in urban areas, those variables were used as controls during data collection and thus levels are consistent with census.

Table 2: Kansas City Non-Response

CHARACTERISTIC	RECRUITED HH	MAIN SAMPLE	GPS SAMPLE	CENSUS DATA
Household Size				
1	27.50%	27.6%	17.5%	27.4%
2	32.90%	34.2%	41.2%	32.9%
3	16.20%	16.1%	21.5%	16.2%
4+	23.50%	22.1%	19.7%	23.5%
Household Vehicles				
0	7.40%	4.6%	0.0%	7.4%
1	33.90%	31.9%	27.6%	33.9%
2	41.70%	44.8%	57.9%	41.7%
3+	17.00%	18.8%	14.5%	17.0%
Geography				
Urban	20.60%	18.2%	12.3%	20.6%
Suburban 1st Ring	26.00%	26.2%	19.7%	26.0%
Remainder	53.40%	55.5%	68.0%	53.4%
Household Income				
< $15k	9.60%	8.1%	3.6%	12.2%
$15k - < $25k	9.70%	9.3%	5.0%	11.3%
$25k- < $50k	29.80%	29.9%	27.2%	30.1%
$50k - < $100k	36.10%	38.0%	46.2%	33.6%
$100k +	13.70%	14.6%	18.1%	12.8%
Income refusals	5.50%	5.5%	3.4%	--
Minority Status				
Minority	N/A	15.1%	5.7%	20.1%
Non-Minority	N/A	84.9%	94.3%	79.9%
Hispanic Origin				
Yes	N/A	3.2%	2.2%	5.5%
No	N/A	96.8%	97.8%	94.5%
Age				
Child (under 18)	N/A	27.3%	28.6%	26.6%
Young Adult (18-24)	N/A	5.3%	2.6%	8.6%
Adult (25-64)	N/A	53.5%	58.3%	53.6%
Older Adult (65+)	N/A	13.9%	10.4%	11.3%
Educational Attainment (age 25+)				
< or = High School	N/A	28.6%	22.3%	40.6%
Some College/Technical	N/A	28.2%	30.9%	30.0%
College	N/A	27.1%	27.3%	19.5%
Post-College	N/A	16.2%	19.5%	9.9%

Sources: Kansas City Regional Household Travel Survey (unweighted) and Census 2000. Includes the 4,001 recruited households, the 3,049 regional households that completed the general travel survey (and comprise the "main sample" and those 228 households that participated in the GPS component.

A descriptive review of the data suggests differences in the GPS sample as compared to the main survey sample. However, this provides only a cursory review of the differences. A stronger technique to test for differences between the two samples is the chi-square statistic at the 0.05 level of significance (replicating the approach used in Hawkins and Stopher). Table 3 shows the key variables tested, the chi-square degrees of freedom, the calculated and critical levels of chi-square, and the result (reject or do not reject). The results of the chi-square testing indicate that the composition of the main and GPS samples are statistically different with regard to the distributions of household size, geography, income, presence of minorities, and ages of the household members. The samples are the same with regard to the proportions of Hispanic households and educational levels of the adults in the households.

Table 3: Kansas City Sample Differences

	df	X^2 calculated	X^2 critical (0.05)	Result
HHSize	3	17.665	7.82	Reject
Area	2	15.110	5.99	Reject
Income	6	22.563	12.59	Reject
Minority	1	16.967	3.84	Reject
Hispanic	1	0.769	3.84	Do Not Reject
Age	3	17.021	7.82	Reject
Education	3	7.329	7.82	Do Not Reject

In sum, the differences between the two samples suggest that non-response issues present in traditional household travel survey samples do carry through to the GPS-based samples, and indeed become greater, particularly with regard to size, urban dwellers, low income, minority, and the age of the household members. This is true for the “opt in” approach, where households are offered the opportunity to participate in GPS studies. In the next section, an alternative method for securing household participation in samples is evaluated – one in which households are randomly assigned to the GPS condition and the survey package (diary plus GPS) are presented as one option to the households (opt out).

4.2 Washington DC/Baltimore GPS-Sample

A summary of the demographic characteristics of households included in this interim sample is shown in Table 3. This includes those that comprise the main sample (10,836 households), the 850 households that comprise the GPS sample, and census data for the DC/Baltimore urban area (recruitment data is not available). As indicated above, in this study, households were randomly assigned to the GPS condition. When recruited into the survey, they were told the survey task included both keeping a log for 24-hours and having an in-vehicle unit for 72-hours. Households that objected to the GPS unit could “opt out” of the GPS condition. However, non-GPS condition households could not “opt in” as they did in the Kansas City study.

In terms of non-response in the main sample, there is evidence of bias against large households (about 14% lower then census), low income households (3%), minority households (11%), Hispanic households (5%), and children and young adults (9%) [note that these characteristics are unique to the interim file and not representative of the distribution of the final data set].

In comparison, the GPS sample shows improvement in the proportion of larger households and proportions of children and young adults in the sample. This reflects mitigation of non-response through the key technology appeal to young adults. Also in line with the technology acceptance literature is the fact that the GPS sample non-response levels for low income households, minorities, and Hispanics further degrades as compared to the main sample.

Table 4: DC/Baltimore Non-Response

CHARACTERISTIC	ALL HOUSEHOLDS	GPS SAMPLE	CENSUS DATA
Household Size			
1	33.0%	17.5%	26.4%
2	37.6%	41.2%	30.9%
3	13.3%	21.5%	17.0%
4+	16.1%	19.7%	25.7%
Household Vehicles			
0	8.6%	0.0%	10.8%
1	36.2%	27.6%	34.3%
2	37.6%	57.9%	37.3%
3+	17.6%	14.5%	17.7%
Household Income			
< $15k	5.9%	3.6%	5.5%
$15k - < $50k	22.3%	5.0%	25.5%
$50k- < $75k	19.3%	27.2%	20.9%
$75k - < $100k	14.9%	46.2%	16.9%
$100k - < $150k	23.4%	46.2%	18.5%
$150k +	14.2%	18.1%	12.7%
Income refusals	11.8%	3.4%	--
Minority Status			
Minority	29.0%	5.7%	39.9%
Non-Minority	71.0%	94.3%	60.1%
Hispanic Origin			
Yes	3.2%	2.2%	8.8%
No	96.8%	97.8%	91.2%
Age			
Child (under 18)	19.9%	22.7%	25.3%
Young Adult (18-24)	4.8%	4.8%	8.7%
Adult (25-64)	59.2%	56.5%	56.9%
Older Adult (65+)	16.0%	16.1%	9.1%

Sources: Interim Washington DC/Baltimore Household Travel Survey (unweighted) and Census 2000. Includes the 10,836 regional households that completed the general travel survey through December 2007 and those 1,008 households that participated in the GPS component to date.

According to a chi-square test, the proportions of the GPS-based sample with regard to household size, income, minority status, Hispanic status, and age are statistically different from the main sample files (as shown in Table 5). With regard to household size, the difference is largely attributed to the increased proportion of large households. For income, it is the large imbalance of too few low income households and too many high income households. For age, the increase in children in the GPS sample (correlated with the larger households) resulted in the statistical difference.

Table 5: DC/Baltimore Sample Differences

	df	X^2 calculated	X^2 critical (0.05)	Result
HHSize	3	25.559	7.82	Reject
Income	5	67.776	11.07	Reject
Minority	1	19.687	3.84	Reject
Hispanic	1	4.964	3.84	Reject
Age	3	11.245	7.82	Reject

Again, the factors that influence technology acceptance can be seen in the decreases in low income households and minority households, and the increase in the children's participation.

4.3 Summary

The purpose of this analysis was to identify levels of non-response in both the main and GPS samples for two studies, and to identify differences within each pair of data (that collected by traditional methods and that collected by GPS) related to the factors that influence technology as well as those associated with general participation levels in household travel surveys. In addition, two different approaches to the creation of GPS samples were considered: those where households can "opt in" (they are invited to do the GPS along with their diaries) and those where the households can "opt out" (they are introduced to the study as being diaries plus GPS, but if they object to the GPS, they are removed from that condition). Again, these findings are reflective of GPS studies conducted in tandem with a log-based household travel survey and with short deployment periods.

With both approaches, the distributions of the respondent characteristics are statistically different between the GPS and main samples. However, the 'opt out" approach used in the DC study resulted in a higher proportion of large households with children in the sample (offsetting even the non-response introduced through traditional methods), an important group for travel behavior studies. This suggests that the "opt in" approach is preferable to the "opt out" approach currently employed in most US studies.

Regardless of the approach employed, the influence of technology acceptance factors can be seen. In Kansas City, there is a decline in the proportion of the elderly, low income, and minority participants as one moved from the main to the GPS samples. For the DC study, there is a decline with regards to participation by the low income and minorities, but an increase in younger participants in the sample. This suggests that as methods and processes for conducting a GPS-based trip collection study are identified, techniques to mitigate non-response associated with the traditional approach must be enhanced with particular attention to the low income, minorities, and the elderly participants to provide a more representative sample.

5.0 ITEM NON-RESPONSE INSIGHTS

As indicated earlier, the use of GPS to obtain more accurate trip details is seen by practitioners to be associated with “little or no respondent burden” (Wolf 2006, Kalfs 1997, Doherty et al). Still in its infancy (but growing rapidly) the study of GPS deployment to date has focused primarily on the methods and processes needed to translate the data streams into trips and subsequent analyses. Very few studies to date have considered respondent burden with regard to GPS deployment, although some of the methodological studies have made passing reference to this issue:

- Lee-Gosselin et al (2007) recognize the problems of equipment deployment and recovery, as well as privacy concerns
- Doherty et al, Wolf et al 2006, and Hawkins and Stopher (2004) all recognized that while the newer GPS units are smaller with lighter power supplies, respondents must still remember to carry them around and charge them.
- As a result, units are not carried around all the time, due to respondent-cited reasons such as a “lack of time” (Draijer 2000) and the “busyness of life (Swann 2008).

The purpose of this section is to review the GPS process to assess the level of respondent burden as compared to the traditional household travel survey burden, and provide a review of the one study available that specifically addressed this issue with respondents.

5.1 Respondent Burden

In a traditional household travel survey, respondent burden is defined as “the perceived “difficulty”, dissonance, or intrusion that individuals associate with a survey that they are being asked to do” (Ampt 1997). It can be measured in terms of the representativeness of the households that agree to participate (unit non-response). It also can be measured with regards to how complete the households complete the survey task (item non-response).

Most research into the replacement of traditional travel survey methods with GPS cite improved collection of more details and reduced respondent burden as benefits of this technology (Wolf 2006, Kalfs 1997, Doherty et al). However, none of the publications identified to date attempt to quantify the differences in respondent burden. This summary is an initial attempt to at least identify the differences in response burden.

In a traditional survey [Traditional Survey], where household members keep travel diaries for a specific travel period, the burden is typically associated with time on the telephone, reviewing mail (if advance letters are used), keeping a log, reporting results over the telephone, and coordinating with other household members (in the case of the main household respondent). If the traditional survey uses both diaries and GPS [Traditional + GPS], the burden is actually increased, because of the presence of a GPS unit. Burden is highest for those studies that ask include both the traditional diary recording and GPS deployment as well as a prompted recall survey (where the GPS data is “fed back” to the respondent and he/she is asked to fill in “blanks” in the data with regard to missed trips, trip purpose, etc.) [Traditional + GPS + Prompted Recall]. If the survey uses GPS-only to collect trip data [GPS only], the level of burden may decrease some, but would be offset if a prompted recall survey is conducted [GPS + Prompted Recall]. An attempt to illustrate this is shown in Table 6. Note that the actual level of burden varies for each stage while this example treats each stage with the same weight. Thus, the focus here is on how many stages are present for both traditional and GPS-based travel surveys.

Table 6 Levels of Respondent Burden

Survey Stage	Traditional Survey (1)	Traditional + GPS (2)	Traditional + GPS+ Prompted Recall (3)	GPS + Prompted Recall (4)	GPS only (5)
Recruitment Call	X	X	X	X	X
Provision of Diaries	X	X	X		
Provision of GPS Units		X	X		
Record Travel (manual)	X	X	X		
GPS Maintenance		X	X	X	X
Telephone Retrieval	X	X	X		
Equipment Return		X	X	X	X
Prompted Recall Survey			X	X	
Total	4	7	9	4	3

Clearly, the reduction in respondent burden occurs for studies where GPS is used to obtain the travel details, with subsequent imputation of trip details as the trip file is created (option 5). What is interesting is that using GPS to obtain trip details followed by a prompted recall survey (option 4) effort has about the same level of burden as the traditional survey (option 1), while studies that employ both traditional methods and GPS, with or without a prompted recall survey follow-up (options 2 and 3) have almost twice the level of respondent burden. This results in the unit not being used as planned (so not all trip data is collected by GPS), units being refused (non-increased non-response bias), and respondents forgoing activities, as detailed in the next section.

5.2 Respondent Perspective

Only one paper to date directly addresses the GPS burden issue faced by respondents with actual interviews of respondents. As part of an effort to reduce respondent burden, improve data quality, and capture more complete travel by GPS, Swann and Stopher (2008) conducted a series of focus groups with household travel survey participants who had actually used GPS devices during the survey effort. Four groups were conducted, with good and bad performers who carried GPS units for one-week and one-month periods. The findings from these groups include the following:[3]

- For optimal use, the GPS units should be similar (in terms of size, shape, and battery length) to the types of devices that respondents are familiar with: mobile telephones, iPods, and commercial GPS units for example.

[3] The following details come directly from Swann and Stopher.

- The most common complaint was short battery life (particularly with regards to expectations based on the types of devices that respondents are used to).
- The level of understanding about the task varies across households, with those understanding technology better tending to ignore instructions and rely on their own knowledge with regards to what to do with the units. All households understood the importance of charging batteries nightly.
- Many participants reported kept their units near their keys and cellular phones to remind them to carry it with them, or charged them in an "obvious and visible location."
- Participants who do not use the devices tend to be someone other than the primary household respondent.
- Most participants denied deliberately leaving the unit behind. However, those jogging or going out indicated they did so because the unit was too bulky. Others suggested that they would accidentally leave it behind due to the "busyness of life" or because it needed to be charged and they did not have time to wait.

These focus groups are the first published dialogues with GPS survey participants regarding respondent burden issues, and were enlightening with regards to the intra-household organization in response to the survey request (who kept the survey going within the household, for example). They also show the importance of the GPS technology matching other known and widely accepted technology (cell phones and iPods), both in terms of proper "upkeep" (charging nightly, ensuring signal reception, etc.) as well as reducing item non-response (less likely to leave the units behind).

6.0 CONCLUSIONS

The purpose of this paper was to address the non-response challenges of GPS-based travel surveys. The underlying hypothesis was that non-response is a GPS-based trip file is a function of the non-response existing in the general sample as well as bias that is related to technology acceptance. The issue of non-response in traditional household travel surveys has been explored in-depth in the literature base, as well as at these conferences. The issue of non-response in GPS-based travel surveys has received little attention to date, but is likely to become of greater importance as the industry transitions from traditional to GPS collection techniques, and as the analysis of large-scale random-sample GPS studies currently being conducted in Canada, France, and the U.S. begins.

6.1 Unit Non-Response

Prior studies suggest that non-response in the general travel survey sample is a function of income, age, education levels, household size, race/ethnicity, and the density in which one lives. The information technology and marketing literature points to income, education levels, age, and gender as factors that influence technology acceptance. This analysis captures both elements, with the non-response in GPS-based subsamples increasing for low income, lower educated, and minority households. Clearly, efforts to mitigate non-response in GPS studies must match or increase those in place for mitigating non-response in the traditional household surveys.

Given that the study of non-response in GPS-based studies is not well documented, some standards or commonly accepted reporting indicators are needed. These include the type of sample (random or choice-based), the recruitment method (part of a traditional study or a GPS-only study? Opt in or opt out?) and recruitment rates, completion rates, use of incentives, and any other design factors that influence the level of non-response in the GPS data. Reporting of these elements was not available for the studies reviewed in this paper, but are essential for these and the upcoming GPS studies in order to develop standards and identify best practices with regard to GPS study designs that minimize unit non-response.

6.2 Measuring Respondent Burden

Given the characteristics of the non-responders, the mitigation of non-response for GPS-based surveys clearly must be at the forefront of the survey design and process specifications, making the effort as easy as possible for the respondents to participate. In addition, the literature is clear that the units themselves must "mimic" widespread technology (Swann and Stopher 2008) and the introduction of the technology portion of the study to respondents must clearly convey that the units are easy to use and useful (Childers 2001; Goeke). Accompanying materials should be targeted to lower-literacy levels. Although not directly discussed, the use of incentives (to help balance the "cost" of participating in the survey) should be strongly considered.

The measurement of respondent burden is a difficult task. This is sometimes considered in units of time – how many minutes/hours did it take the participating household to move through the survey process? Clearly GPS reduces the amount of time to record travel in a log, but the battery life and portability of the unit are factors that may increase respondent burden and offset the "time savings." One approach for measuring respondent burden may be that developed by Axhausen (2007) to estimate response rates prior to fielding a survey. This approach entails reviewing the survey instrument and process and assigning then summing points based on question type and action (Axhausen 2007). In this case, the need to charge the unit daily would incur a point penalty, as would the need to participate in a prompted recall survey. The points are summed and, per Axhausen's example, higher point surveys are associated with lower participation rates. Making the process and tasks simpler will help to maximize participation rates and possibly overcome the identified non-response bias.

6.3 Item Non-Response

As the survey design and processes are being developed, it is important to also consider the factors influencing item non-response: so you can get the household to agree to take the units, but will they use them as instructed? Again, here the equipment design is critical: smaller, slimmer, less bulky units that have longer battery lives are preferred (Swann and Stopher 2008). Respondents should be reminded to keep the units near their keys or phones, so that they remember to take the units with them on all trips. An important note is that as we mitigate unit non-response and have more low income, low education, and higher minority GPS-samples, similar qualitative research is needed to ensure that these design and process improvements work for all GPS-participants, not just the technophiles.

As with unit non-response, it would be useful to document how the study is introduced to respondents, what instructions were provided to aid in obtaining complete and accurate travel details via GPS, and how to handle possible unit malfunctions. These details will help in identifying the factors that influence (both to increase as well as decrease) the levels of non-response within the GPS data.

6.4 Conclusion

In conclusion, this is an exciting time for the transportation industry. As technology advances, so do our models, our data requirements, and our options for ensuring high quality and increasingly detailed data is obtained for longer periods of time and with greater accuracy. The GPS technology "fits the bill" but can we identify the appropriate techniques to mitigate non-response and ensure representative samples? That is the challenge for this workshop and our colleagues.

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