Using GPS for Measuring Household Travel in Private Vehicles

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Abstract

Personal travel and how it changes is of continuing concern to transportation planners and policy makers. Information about daily travel patterns are generally captured using self-reported information using a written diary and telephone retrieval. This project developed a small, user-friendly, mailable unit including a Global Positioning System (GPS) receiver to capture vehicle-based, daily travel information. The unit is a Sony MagicLink® 2000, a Personal Digital Assistant (PDA) with a backlit screen, weighing about 1.5 lbs. A Garmin® GPS antenna/receiver is attached through the PDA serial port. Finally, a power cord connects the data collection unit to the vehicle electrical system via the vehicle cigarette lighter. The vehicle driver uses a touch-screen menu to enter variables such as trip purpose and vehicle occupancy, but other data such as date, start time, end time, and vehicle position (latitude and longitude) are collected automatically at frequent intervals. Finally, after mail-back return of the units, the data are processed using a geographic information system (GIS) to include calculated results such as travel speed, trip distance, and trip time by road classification and other variables.

This method of data collection has two potential benefits: (1) improving the quality of travel behavior data, and (2) reducing respondent burden, for example, interview time on the telephone for reporting travel. Using GPS technology, while increasing privacy concerns, is expected to improve overall survey responses in travel behavior studies.

The proof-of-concept field test, conducted September through December 1996, placed the units in 100 household vehicles in Lexington, Kentucky. Respondents were asked to use the unit to record personal travel information for six days. Respondents were also asked to participate in a post-usage telephone interview that included a recall interview about travel information for one day of machine usage and also captured information on ease of use and the respondent's attitudes and reactions to this data collection technique. Technical issues related to hardware, software, field implementation, and analysis and comparison of results between self-reported travel and machine-recorded travel are provided.

Personal travel and how it changes is of continuing concern to transportation planners and policy makers. Information about daily travel patterns is generally captured using self-reported information using a written diary and telephone retrieval (or mail-back of diary forms). Problems with these self-reported methods include lack of reporting for short trips, poor data quality on travel start and end times, total trip times, and destination locations. Also, the burden on the respondent may be 20 minutes per person for reporting of one-day (24 hours) of travel, and more than 60 minutes per household using telephone retrieval methods[1].

Nearly 90 percent of person trips in the U.S. are made in a private vehicle. This project combined Global Positioning Satellite (GPS) and Geographic Information Systems (GIS) technology with small hand-held computers (Personal Digital Assistants -PDAs) to capture vehicle-based, daily travel information.[2] The resulting device is a small, user-friendly, mailable unit designed to capture variables that would be entered by the vehicle driver using a touch sensitive menu, such as trip purpose and vehicle occupancy, and to capture automatically-recorded variables such as date,

Figure 1. Lexington Field Test Equipment

start time, end time, and latitude and longitude at frequent intervals. In addition, respondents were mailed an instructional training video to assist with installation and use of the equipment. Finally, after mail-back return of the units, the data are processed to include variables such as travel speed by road classification, trip distance, and trip time. The unit allows for collection of travel data over several days to avoid potential short-term, survey-induced travel behavior changes.

By combining self-reported information with GPS-recorded information, this technology has the potential for both improving the quality of data on travel behavior and reducing respondent burden for reporting this behavior.

Field Test Equipment

The hardware selected for the field test included a Sony MagicLink 2000, a Personal Digital Assistant (PDA) with a backlit screen, weighing about 1.5 lbs (700 gm). A Garmin GPS antenna/receiver (weight is about .5 lbs (225 gm)) is attached through the PDA serial port. Finally, a power cord connects the machine to the vehicle electrical system via the vehicle cigarette lighter. Figure 1 is a photograph of the test equipment. The vehicle driver uses a touch-screen menu to enter variables such as trip purpose and vehicle occupancy, and other data such as date, start time, end time, and vehicle position (latitude and longitude) are received by the GPS unit and stored in the PCMCIA card in the PDA at frequent intervals.

The user's acceptance of this type of data collection device is key to the future use of this technology for large scale data collection efforts. Ease of use issues were addressed by incorporating a touch screen interface in the device for user input. Operationally, the device mimicked an automatic teller machine (ATM) which is familiar technology to most of the people in the field test. Also, since each household was individually recruited, the data collection unit includes an administration screen so that the menus were personalized to list the names of the individuals in the household. This personalization makes it easy for the driver to select the names of the driver and household members who are in the vehicle.

Components of the software included (1) administration, (2) user interface, and (3) communication between the GPS receiver and the PDA. The administration portion included the screens for entering the individual driver and passenger names, data uploading to a desktop PC, measures of memory availability, and when to "go to sleep" to conserve battery power. The user interface (Figure 2) required the driver to select the vehicle occupants (driver and passengers) and a trip purpose for each trip. Finally, the software stores the GPS data being received by the GPS unit.

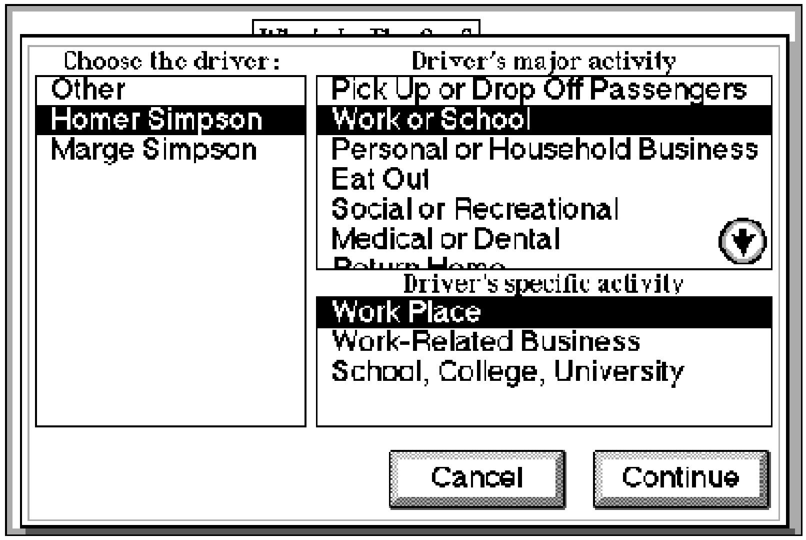

Figure 2: Example of the user interface screens

Field Test Site Selection

The Lexington Metropolitan Planning Organization (MPO) was selected to assist with the field test. The metropolitan planning area of Fayette and Jessamine counties covers 461 square miles with a total population of about 350,000. The MPO was selected based on the willingness of the MPO to provide staff support during the field test, and on the positional accuracy, currency, and completeness of their geographic base file. The street centerline file for Fayette County is positionally accurate within 5-7 feet, and address ranges and street names are updated within 45 days of the changes. Boundaries for Census tracts and block groups are also included on the file.

The field test was conducted in Lexington, KY in fall, 1996, with 100 households. The sample of drivers was stratified by age, gender, and presence of children under age 16 in the household. Respondents were asked to use the machine for six days, with the expectation that data from Day 1 and Day 6 may not be usable. Respondents were also asked to recall all their travel for one 24-hour period (Day 5). This process resulted in a complete 24-hour report of trips made by the selected driver by all modes, and a 4- day report of trips made in the selected vehicle by all drivers and passengers.

Field Test Operations

Recruitment of eligible drivers was more successful than anticipated. The Lexington MPO had arranged for both newspaper and television coverage of the field test shortly before recruiting began. A presolicitation letter from the Lexington MPO, with an enclosed copy of the article from the local newspaper, was sent to approximately 1,300 households with listed telephone numbers. Once the telephone interviewers determined that there was an eligible driver in the household, 67% of those eligible consented to participate in the field test. Their agreement to participate was followed by a mailing including the informed consent papers to read, sign, and return before the equipment would be released for their use. Only two of the households declined to participate after reviewing the informed consent papers.

For the 100 households, the average household size was 2.94 persons, with an average of 2.17 vehicles. The sample of drivers was quite highly educated, with 20 percent completing college, and 20 percent with post-graduate education. The average estimate of annual miles driven was 13,118. This average should be higher than a typical average, because the sample selection process excluded persons who drove less than 3 days per week.

Figure 3 is a general diagram of the activities that took place during the field test. The staff of the Lexington Area Metropolitan Planning Organization had their first training session on the hardware at the end of August 1996. This training session also provided an opportunity for a local TV station to put together some footage for a news spot on the effort, which greatly facilitated the recruitment of volunteer participants.

The survey effort used a total of twenty survey instruments and included 100 households in the Lexington MPO planning area. The survey plan anticipated that the "turn-around time" for each instrument would be an average of nine days for each household.

The first notifications of eligible participants were received by the MPO staff on September 10. The participants were required to complete and sign an Informed Consent form, which discussed responsibility and liabilities, before they could receive a survey instrument. Within the first week, all fifteen available machines were shipped to participants (throughout the first two and a half months of the study, only fifteen survey instruments were available).

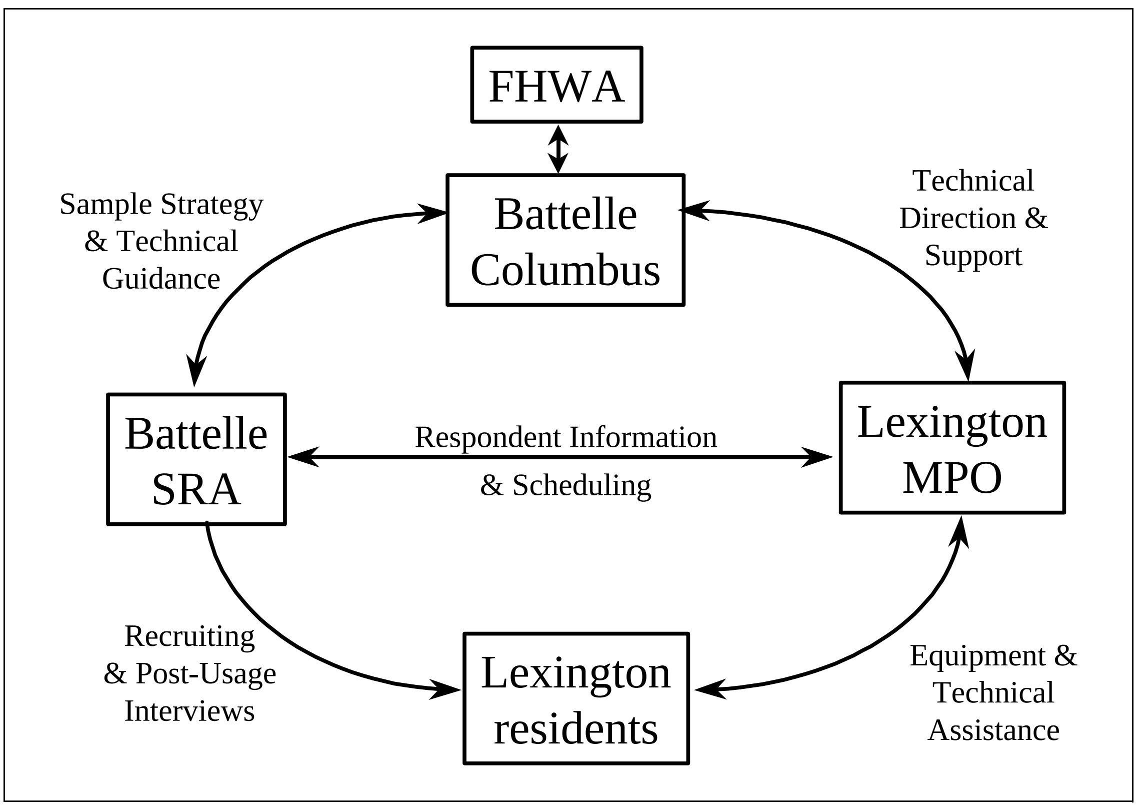

Figure 3: Flowchart depicting general field operations

The Lexington MPO recognized early in the project that organization would be the key to the success of effort. An Administrative Coordinator was assigned to the project and the tasks were divided into two categories: Clerical and Technical. The clerical work included such things as keeping up with the paper work, programming the machines with participant names, and assuring the return of the forms and machines. The technical side dealt with trouble shooting, installation, field assistance and equipment checking. These efforts were conducted concurrently, rather than sequentially, in order to minimize the turn-around time and keep as many machines in the field as possible. The greatest number of machines turned around in one day was seven.

The organization implemented by the MPO allowed the staff to continue their other job responsibilities and the project never consumed more than one quarter of the staff's time.

The tasks undertaken by the Lexington MPO are listed as follows.

- Contacting the Participants,
- Preparing and Sending the Machines,
- Helping the Participants,
- Assuring the Return of the Machines, and
- Receiving and Checking the Machines.

Battelle Survey Research Associates (SRA) was responsible for the recruitment and first contact with the participants. After their selection process was completed, SRA notified the MPO of the names of the participant household. The MPO would then send out an Informed Consent form to the participants. Return of the Informed Consent form by the participants averaged 8.6 days. The minimum turnover time was two days, while the maximum was over three weeks. Delivery of the survey instruments averaged twelve days after receipt of the Informed Consent form. The objective was to ship the survey instruments on the day the Informed Consent form was received, however, after the second or third week a month's backlog of participants were waiting for survey instruments.

When a survey instrument was returned, the data were retrieved and sent to Battelle. The physical condition of the machine, its component parts and connecting wires were checked. Each piece was examined for damage to assure that it would operate in the field again. Some of the software settings were also checked to ensure that they hadn't changed during field use. After checking the physical condition of the equipment, a new PCMCIA card was inserted and programmed for the next participant. Each participant received a survey instrument that was programmed specifically for their household. The settings of the software was checked and the instrument was packaged for shipment. Included in the package was an incentive money order, return shipping instructions (including how and when to return the machine), instructions in both video and written formats and the address of the MPO. A local courier service was contracted to deliver and pick up the instruments.

While the survey instruments were in the field, the MPO staff had several responsibilities. If requested, the staff would install a machine in the participant's car. This happened in only three percent of the cases. The MPO staff also maintained a "hot line" to answer any question or respond to any difficulties that the participants experienced, and would also travel to the participants' homes if they had problems.

Very few problems were experienced with the software or hardware. The most significant problems usually involved discharged batteries, and a battery recharger was generally left with the participant overnight to solve this problem. There were only two occasions where a survey instrument needed to be taken out of the field and returned for repair. These problems were solved quickly and the machines were returned to the field in several days. The survey instruments held up well and none were lost to damage or theft. The public response was enthusiastic and the Lexington MPO staff found the experience to be very positive.

Results

The results of the project include both a post-usage survey and analysis of the collected data. The post- usage survey examined the equipment installation, use of the equipment, and general concerns about the field survey process. Analysis of the collected data characterized the travel behavior of the sample population and compared the machine-recorded data with a "recall" telephone interview for one of the travel days.

Post-Usage Survey

The post-usage survey focused the travel day recall interview on Day 5 of the household's test period. Since the test was designed for six days in each household, Day 5 was expected to be the last full day that the equipment was used by the household. The post-usage interview also included questions about the installation and use of the equipment, general concerns and issues for the households (e.g. privacy), and additional demographic information. Evaluation of the travel recall data is not yet complete. The following results are from the post-usage interviews focusing on evaluation of the equipment and general concerns and issues for the households.

<u>Equipment Installation</u>. Although most people installed the device themselves, women were much more likely to have someone in their household install the GPS device for them. Twenty seven percent (27%) of the women, compared to 10 percent for men, had assistance from someone in their household.

People aged 24 and under were more likely to use the instructional video to learn to install the GPS unit (57 percent compared to about 50 percent for all other age groups). For those who installed the unit themselves, there was no difference by gender in preference between the written manual and the instructional video. Those who used the video for installation guidance rated it higher than those who used the written guide. Eighty-eight percent (88%) of video users, compared to 77 percent of written guide users rated the guide "very clear."

<u>Use of the GPS Equipment</u>. Similar to questions on installation, younger age groups (age 24 and under, and 25-49) were more likely to use the instructional video to learn how to use the equipment compared to older groups. And also, there was no difference by gender between using the written guide or the video for learning to use the equipment.

Over 70 percent rated the device "very easy" to use. The groups which were more likely to rate it "somewhat easy" were: Females 25-49 with children; Women 50-64 and, both Females and Males age 65 and over.

Households with children were hypothesized to be more easily distracted and thus more likely to forget to use the computer each time they got into the vehicle. However, self-reporting on use

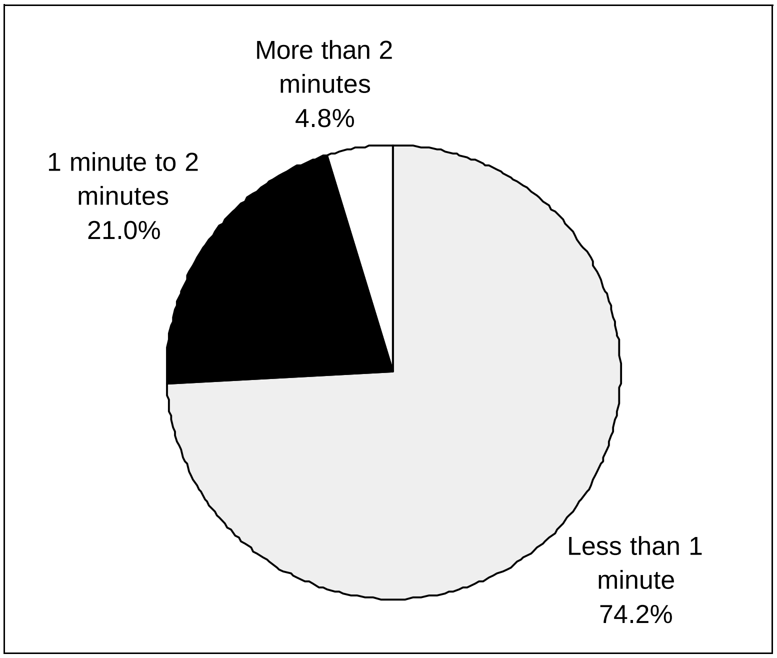

Figure 4: Time required to enter data for one trip

indicates the contrary. Households with children were more likely to report that they used the machine "all of the time." Respondents age 24 and under were the least likely to report that they used the machine "all of the time."

Entering trip data was expected to be easy and require little of the respondent's time once they became familiar with the menu choices. Approximately 74% reported that entering trip information took 1.0 minute or less per trip, and over 95% reported 2 minutes or less (Figure 4).

One of the reasons that the MagicLink PDA was chosen for the field test was because it has a backlit screen and adjustable screen contrast. However, as lighting and glare conditions changed, the contrast setting for the screen needed frequent adjustment to clearly see the screen. Approximately one third of the respondents reported this frequent need to readjust the screen contrast as a problem, making the screen contrast the most frequently reported problem during the field test.

Acceptance of the equipment was also assessed in the interview. The respondents preferred the computer data entry over a written log by almost a 9 to 1 margin, and nearly all indicated that they would use the device again for this type of study. Only one respondent reported changing their driving habits during the field test and that change was reported as omitting a regular, brief stop at a convenience store on the way to work.

General Concerns. Most respondents indicated no concerns about the type of data collected and the government's role in collecting personal travel data. Most of the concerns that were expressed, from about 5% of the respondents, focused on individual privacy concerns. More respondents, approximately 26%, expressed concerns about the safety of their vehicle. These concerns focused on possible break-in and/or theft related to the device. Some respondents reported that they routinely removed the device from their vehicle every evening and reinstalled it in the morning to prevent theft. Others reported other tactics, such as placing a towel over the device to conceal it when they were away from their vehicle.

Data Analysis

Several types of data were generated by the field test for subsequent analysis. These data include participant self-reported information recorded by the hand held computer; GPS records of date, time, and position; travel time and length data derived from matching the GPS data to the GIS map; and recall travel data obtained from the participants during the post-usage interview. The following paragraphs provide some highlights of the analysis results.

Travel Characteristics. The Lexington sample population averaged approximately 4.7 trips per day per household based on their inputs to the hand held computer. Average trip length was approximately 6 miles and average daily travel was 25 to 27 miles. Vehicle occupancy during the field test was approximately 1.6, consistent with national statistics.

Distributions of Lexington sample population travel time and trip length were also compared to 1990 NPTS statistics. These comparisons show that, in general, the Lexington sample population had shorter travel times and shorter trip lengths than the national distribution, for both person trips and person miles of travel (PMT).

Comparison of Machine-recorded and Recall Data. The in-vehicle data collection units were in operation for 5 or 6 days in each vehicle. A "recall" telephone interview with the respondent was conducted on one day during the data collection period. This telephone interview was similar to the travel day portion of the 1995 Nationwide Personal Transportation Survey[3], where information on trips for a 24-hour period is collected.

The comparison of trip start time data is revealing. It is well known that trip start times reported in interviews are often rounded to nearest quarter-hour or half-hour[4]—people simply do not report an accurate trip start time. The Lexington field test equipment recorded these times automatically for each trip initiated by the respondent. Figure 5 shows the frequency distributions of trip start times for the 1995 NPTS 6-month interim dataset, the Lexington data collected automatically during the field test, and the Lexington self-reported (interview) data. The NPTS and self-reported data clearly show peaks at every quarter hour and lesser peaks at every five minute interval. The Lexington data have no such peaks. Trip start times are almost evenly distributed over the entire hour.

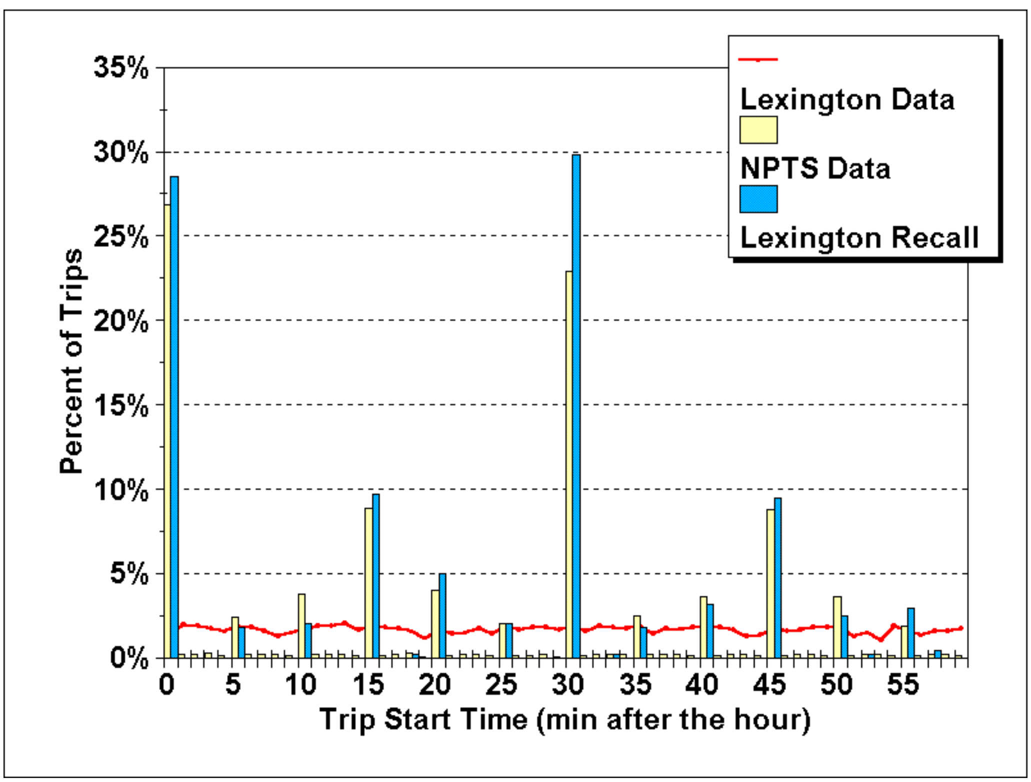

Figure 5: Distributions of trip start times

Conclusions

Combining GPS technology with small hand-held computers is a functional reality, particularly for use in private vehicle surveys. The technology has progressed to the point that small, relatively light-weight, and relatively inexpensive equipment can be delivered to respondents for self-installation and use. Using GPS without additional equipment (gyroscopes, dead-reckoning) is sufficient to plot most trips on the roadway network, even without the availability of differential correction. In addition, matching to the roadway network could be done sufficiently without a positionally accurate geographic base file. That is, map matching is possible, using only the TIGER/Line files available from the U.S. Census Bureau, although errors in some roads would be more likely in areas with parallel roads in close proximity. However, GPS technology alone will not be sufficient to track vehicles in urban canyons and in dense tree cover where the GPS signals may be reflected or obscured.

The touch screen interface was easy to use, even for people over age 65. The general public is responsive to this technology and is willing to participate in multi-day surveys, given a financial incentive.

This proof-of-concept project has shown that computer-assisted self-interviewing (CASI) combined with GPS technology can improve the quality of data from household travel surveys. Because the machine is tracking the start and end times, and the actual routes traveled, the respondent is no longer responsible for reporting similar items. In particular, the reporting of destination addresses is long and time consuming, and often frustrating for the respondent. The frustration may be because the respondent does not know an actual address and may get to their destination using landmarks, or because the telephone interviewer cannot correctly spell or type in the street name.

In addition, the time taken for the respondent to begin each trip using this technology takes about one minute. This is not perceived to be as burdensome as spending 20 minutes on the telephone in one session to report travel of one day.

This CASI approach not only improves the quality of data that is traditionally collected using self-reported methods with paper diaries and telephone or mail-back retrieval, but information which was previously nearly impossible to collect can be collected (Table 1). For example, in the 1990 NPTS conducted on the telephone, one trip of each respondent was selected, and the respondent was asked to estimate how many miles were traveled on what type of roadway (i.e., Interstate, major arterial, collector, local road). Previous efforts to collect this type of information have asked respondents to draw their selected routes on paper maps. Neither of these two methods captures accurate departure time or travel speed. Not only is route choice information easily available by including a GPS component, but because the survey period covers 6 days, variability by day, by day of week, and departure time can be analyzed.

Another objective of this project was reducing missing (unreported) trips. In this project, the respondent was required to turn the equipment on each time they made a trip. If the respondent failed to turn the equipment on (either deliberately or inadvertently), then no trip was recorded, and the data record would contain a gap in the positional information that was recorded. However, when the equipment was on and the respondent made an intermediate stop, the time and positional record will reflect those stops although there is no trip purpose assigned to the activity. Thus the attempt to reduce unreported trips is incomplete. The equipment is currently being modified for a

Table 1: Comparison of traditional telephone survey with GPS/PTS survey

Data Item	Traditional Telephone Survey	GPS/PTS Survey
Trip start and end times	Estimated	Machine recorded
Trip distance	Estimated	Calculable from GPS trace Link distances from GIS
Route choice	Modeled “shortest path”	Actual path from GPS trace
Origin/destination	Recalled street address or intersection	GPS point Address/link match from GIS
Travel speed	Not available	Available from GPS Speed by link from GIS
Functional class	Not available	Available by link from GIS

truck activity survey so that the equipment will turn on automatically when the engine is operating, thus the machine can be designed to collect time and position data, even if the respondent does not actively communicate with the machine.

Acknowledgments

The successful conclusion of this project is a direct result of the active and enthusiastic support of the field test by Mr. Robert Kennedy, Manager of the Lexington Area MPO, the entire MPO staff, and of course, the cooperation and active participation of the citizens of Fayette and Jessamine counties, Kentucky.

User interface software development was performed by FASTLINE, Inc. Key elements of GPS and GIS post-processing and data analysis performed by TransCore (formerly JHK & Associates). Cambridge Systematics, Inc. and Etak, Inc. participated in research planning and the early phases of this research program.

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