APPLICATIONS OF NEW TECHNOLOGIES
IN TRAVEL SURVEYS

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Abstract
During the past three years, GPS-based methods for augmenting traditional travel surveys have been implemented in numerous regions and states across the U.S. In these studies, household vehicles have been instrumented with passive GPS loggers to audit reporting accuracy of household vehicle trips; underreporting rates have ranged from 11 to 81 percent, depending on a range of socio-demographic and trip-making characteristics. Pilot studies conducted in London and Sydney to evaluate the usefulness of wearable GPS loggers have showed the great potential for capturing person-based trips for all modes of travel. Now that GPS methods are rapidly being accepted as a method of augmenting and auditing traditional travel survey methods, the next evolutionary step forward is the adoption of GPS-based data collection methods for the replacement of traditional methods (when cost effective or cost justified). It is feasible that GPS-only surveys could be conducted either with prompted recall techniques to collect missing information or with imputation procedures to fill in missing details. Automated GPS data processing and imputation procedures also enable the reuse of large, existing GPS datasets for travel behavior analyses, where the data were originally collected for other purposes (such as in traffic safety studies or road pricing systems). Data collected from similar tracking-capable technologies such as cell phones or RFID tags and readers could also be used (or reused) in this manner. This paper presents an overview of the various location collection technologies, their recent applications in travel behavior surveys, and technology trends for the future.
1. **TRAVEL SURVEY TECHNOLOGY INVENTORY**

Within the past several decades, the first significant technological enhancement in travel survey methodology was the use of computers to collect diary-type survey data in an electronic format. This technology could support complex branching patterns, automated error checking, and sample management. The primary methodologies used for electronic data collection have been computer-assisted telephone interviews (CATI), computer-assisted personal interviews (CAPI), and computer-assisted self-interviews (CASI). CATI has typically been implemented on PCs; CAPI on laptops, PCs, and handheld devices; and CASI via the Internet.

The next major technological enhancement for the collection of travel survey data has been the use of passive location data collection technologies, including Global Positioning System (GPS) data loggers that can collect second-by-second location, position, and speed data. A comprehensive description of GPS and its ability to provide location information for household travel surveys can be found in the Handbook of Transport Geography and Spatial System (Wolfa, 2004; Stopher, 2004). The first passive GPS study conducted as part of a major household travel survey occurred in Austin in 1997 (Casas and Arce, 1999; Pearson, 2001). Since then, numerous other vehicle-based GPS studies have been conducted in the U.S. In these studies, participants are provided with the GPS loggers for the duration of the study and participation is the GPS component is completely voluntary.

Other passive location tracking capable technologies, including personal cell phones and RFID tags / readers used in electronic toll systems, are also capable of providing travel details, although both of these have seen limited travel survey application to date, most likely due to privacy issues in obtaining personal cellular location data from wireless data services and the infrastructure requirements necessary for a regional RFID tag and reader system. In addition, more and more automobile manufacturers are including GPS-based navigation and safety (i.e., OnStar) systems in their vehicles, but again, these systems are designed to assist the driver, not to provide complete tracking details to an unknown public agency.

One variation to passive data collection (or measurement) technologies is active / interactive technologies which include both passive GPS data collection and a computerized user interface to initiate the collection of GPS data and/or to collect additional details about each trip and destination. This methodology for collecting travel data has been around since 1996, when the U.S. Federal Highway Administration (FHWA) conducted the first GPS pilot study (Wagner, 1997) with a vehicle-based system that included a personal digital assistant (PDA) coupled with GPS. Other subsequent studies have further explored the use of PDAs and GPS (Draijer, 2001; Frank et al, 2004). Many PDAs on the market today support GPS attachments or plugins. In addition, Garmin International, a large manufacturer of GPS equipment, recently released the iQue, which is the first fully integrated PDA and GPS device to reach the market.

Both passive and active GPS logging technologies can be designed for vehicle-based logging or for person-based logging, which enables capture of all modes of travel. In-vehicle systems are generally better performers, given the fixed mount position (usually roof, windshield, or trunk mount) and the vehicle power source. Key issues facing person-based loggers (or wearable loggers) include the portable power source and capacity, the form factor (including size, weight, and wearability), and GPS antenna visibility to the sky (required to obtain GPS satellite signals).

Standard GPS positioning accuracy has proven to be in the 5 to 10 meter range, with differential GPS techniques capable of providing accuracy in the 2-5 meter range for moving vehicles or people. In the GPS world, positional accuracy can be defined as the absolute difference (in meters)
between the GPS-calculated location and the true location. The precision of GPS positioning refers to the variability of a specific measured location across time. These two attributes have a significant impact on the ability to confidently identify the travel paths and destinations of study participants based solely on the GPS data and accurate spatial datasets.

Other augmentations are available to fill in locations where GPS signals are not easily captured, such as in urban canyons or underground. These augmentations include dead reckoning (DR) sensors and Assisted GPS (A-GPS). Dead reckoning uses a continuous source of speed (e.g., from an odometer or accelerometer) and heading (from sensors such as magnetic compasses and gyros) to fill in missing GPS points. A-GPS uses a wireless network, with its own GPS receivers, to predict the GPS signal that a given handset will receive and to relay that information to the handset; this technology may also provide sufficient indoor location.

Finally, there are several methods for transferring the GPS and related data from devices deployed in travel surveys. For short duration studies, such as one week or less, it is usually sufficient to download the collected data when the devices are retrieved from study participants. However, for longer-term studies, it is desirable to have remote transfer capabilities, which can be provided through a cellular (or digital wireless) connection or through an in-home modem-based solution. The ongoing convergence of cell phone, PDA, and GPS technologies make the feasibility of long-term travel surveys attainable in the near future.

The next section covers what has become the ‘traditional’ use of GPS in household travel surveys. Following this, emerging uses of GPS are presented, followed by a brief review of similar technology trends.

2. ‘TRADITIONAL’ GPS STUDIES

It has long been suspected that people tend to underreport their travel in diary-based surveys (more so in diary only surveys, but to a lesser extent using CATI retrieval methods). Quantifying this level of underreporting has been a desire of transportation planners everywhere who use these trip rates in their travel demand models. GPS offers a completely passive method for capturing all trips made, and by deploying passive GPS loggers in tandem with CATI-based household travel surveys, it has proven possible to collect both reported and measured travel from study participants without increasing respondent burden. By instrumenting a subsample of households with in-vehicle GPS loggers, GPS studies conducted to date have performed comparisons of reported and measured vehicle trips. These comparisons have resulted in the identified of unreported trips, whose characteristics along with the characteristics of the reporting household and persons have been analyzed to identify the correlates of underreporting. Using these correlates, customized trip rate correction factors can be developed and applied to the appropriate households in the larger sample.

The first regional travel survey to use this approach was conducted in Austin, Texas in 1997. In this study, 117 households were instrumented with GPS data loggers and reported their travel via CATI retrieval. A total of 186 vehicles were instrumented. Although this study proved that the approach was feasible, analysis of the GPS data proved challenging since the data were collected while Selective Availability (the intentional degradation of GPS signal accuracy) was active (Casas and Arce, 1999; Pearson, 2001).

After the Austin GPS study, the next wave of GPS studies began in the U.S. in 2001, following the 2000 census. Table 1 below shows the vehicle-based GPS studies conducted in the past three years, along with the GPS study descriptions.
Table 1: Traditional GPS Studies Conducted To Date

<table>
<thead>
<tr>
<th>Study name</th>
<th>Date of study</th>
<th>Unit of analysis</th>
<th># Travel days</th>
<th>Total days in study</th>
<th># Deployed (households)</th>
</tr>
</thead>
<tbody>
<tr>
<td>California Statewide HTS</td>
<td>Feb - Oct 2001</td>
<td>Vehicle</td>
<td>1 day</td>
<td>79</td>
<td>517</td>
</tr>
<tr>
<td>SCAG (Los Angeles) HTS*</td>
<td>Sep - Dec 2001</td>
<td>Vehicle</td>
<td>1 day</td>
<td>NA</td>
<td>820</td>
</tr>
<tr>
<td>Pittsburgh HTS</td>
<td>Sep - Dec 2001</td>
<td>Vehicle</td>
<td>1 day</td>
<td>38</td>
<td>74</td>
</tr>
<tr>
<td>Ohio Statewide HTS*</td>
<td>2001 - 2002</td>
<td>Vehicle</td>
<td>1 day</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Laredo (Texas) HTS</td>
<td>Mar - May 2002</td>
<td>Vehicle</td>
<td>1 day</td>
<td>45</td>
<td>187</td>
</tr>
<tr>
<td>St. Louis HTS</td>
<td>Sep - Nov 2002</td>
<td>Vehicle</td>
<td>1 day</td>
<td>44</td>
<td>313</td>
</tr>
<tr>
<td>Tyler / Longview (Texas) HTS</td>
<td>Sep - Nov 2003</td>
<td>Vehicle</td>
<td>1 day</td>
<td>61</td>
<td>367</td>
</tr>
<tr>
<td>Kansas City HTS</td>
<td>Feb - Apr 2004</td>
<td>Vehicle</td>
<td>1 day</td>
<td>62</td>
<td>294</td>
</tr>
</tbody>
</table>

* These studies were conducted by Battelle; information was obtained from NuStats and Battelle, 2004, and Pierce et al, 2003. All other studies were performed by GeoStats. The full analysis of the California Statewide Travel Survey GPS Study are covered in Wolf et al, 2003, and Zmud and Wolf, 2003).

Table 2 shows the deployment, completion, and percent missed trips statistics found in these passive, in-vehicle studies. In addition, the percent missed trips is a study average and is based on total GPS trip counts compared to total CATI trip counts for the same vehicles. These have not been adjusted for missing GPS trips, which would cause the rates to be higher. Finally, these rates are not to be used for the entire sample; regression analyses are required to determine the appropriate correction factors based on the significant correlates for underreporting. Analyses and results of the California Statewide GPS Study and the Ohio Statewide GPS Study are available in papers by Wolf et al (2003), Zmud and Wolf (2003), and Pierce et al (2003).

Table 2: Deployment, Completion, and Missing Trip Statistics

<table>
<thead>
<tr>
<th>Study Name</th>
<th># Deployed (households)</th>
<th># Deployed (all vehicles)</th>
<th>GPS Completes (Per/Veh)</th>
<th>GPS &amp; CATI Completes (all vehs)</th>
<th>% Missed Trips (overall)</th>
</tr>
</thead>
<tbody>
<tr>
<td>California Statewide HTS</td>
<td>517</td>
<td>920</td>
<td>NA</td>
<td>292</td>
<td>23%</td>
</tr>
<tr>
<td>SCAG (Los Angeles) HTS*</td>
<td>820</td>
<td>1217</td>
<td>631</td>
<td>293</td>
<td>35%</td>
</tr>
<tr>
<td>Pittsburgh HTS</td>
<td>74</td>
<td>149</td>
<td>101</td>
<td>46</td>
<td>31%</td>
</tr>
<tr>
<td>Ohio Statewide HTS*</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Laredo (Texas) HTS</td>
<td>187</td>
<td>348</td>
<td>234</td>
<td>87</td>
<td>81%</td>
</tr>
<tr>
<td>St. Louis HTS</td>
<td>313</td>
<td>666</td>
<td>428</td>
<td>150</td>
<td>11%</td>
</tr>
<tr>
<td>Tyler / Longview (Texas) HTS</td>
<td>367</td>
<td>646</td>
<td>350</td>
<td>197</td>
<td>NA</td>
</tr>
<tr>
<td>Kansas City HTS</td>
<td>294</td>
<td>548</td>
<td>462</td>
<td>228</td>
<td>11%</td>
</tr>
</tbody>
</table>

These GPS studies and their corresponding methodologies have been evolving with each study performed. Given the newness of GPS in travel surveys, each study reveals new insights about appropriate methodologies and what needs improved in subsequent studies. As such, the methodology for generating trip rate correction factors is considered experimental.

3. Wearable GPS Studies

As mentioned earlier, all ‘traditional’ GPS studies have taken a vehicle-based approach, primarily because 1) the vehicle’s power system can be used to power the GPS loggers; 2) GPS signal reception is better if the antenna is mounted on a vehicle roof or windshield as compared to being
worn somewhere on the body; and 3) once installed, all vehicle trips are sure to be captured, as compared to a wearable device that may be forgotten by the participant when traveling. In addition, a vehicle-based approach has been acceptable to modelers who are focused on vehicle trips, especially in the vehicle-dependent U.S.A. However, it has been recognized that if wearable GPS loggers were available that met project needs, these would be the preferred tool for personal mobility data collection.

Research trends for wearable GPS logging devices have split into two distinct paths – those that include a user interface (typically a PDA) and those that are completely passive.

3.1 PDA / GPS Applications
Early research on the use of wearable GPS logging devices for travel survey data collection included a PDA component for collecting additional travel details. The first study of this type occurred in the Netherlands in 1997, with a custom-built PDA, a GPS receiver and antenna, and a DGPS antenna (Draijer, 2000). This study deployed the wearable equipment package to 151 participants to compare GPS performance across different travel modes and to assess GPS system usage by survey respondents. Although the researchers concluded that it was possible to use GPS to monitor trips with various modes of travel, the equipment package (which weighed approximately 2 kg) was considered heavy by study participants and was consequently reported to be left behind on a significant number of walk, cycling, and public transport trips.

The next study to use a wearable PDA / GPS combination was the SMARTRAQ Non-Motorized Travel / Physical Activity Study, which was a subcomponent of the Atlanta Regional Household Travel Survey. The primary purpose of the GPS-based physical activity study was the development and testing of a person-based methodology to objectively collect the spatial and temporal aspects of urban travel, especially non-motorized travel. Of the 8069 households participating in the regional travel survey between spring 2001 and spring 2002, 542 participants received an electronic travel diary implemented on a Palm PDA that included a GPS component. The total weight of this wearable package was approximately 1 kg. Results of this study were recently presented (Frank et al, 2004, Georgia Tech and GeoStats, 2004) and will be released this spring in a project report for the Georgia Department of Transportation.

One variation of a PDA/GPS tool for collecting travel survey data can be found in the ongoing evolution of CHASE (Computerized Household Activity Scheduling Elicitor), a computerized tool for capturing the activity scheduling process of study participants (Doherty 2002). Early versions of CHASE were implemented on laptop PCs, without a geographic component. As CHASE evolved, it was enhanced to support some GIS (Kreitz and Doherty 2002) and even GPS capabilities (Doherty et al. 2001). Most recently, it appears the implementation of the CHASE approach will be broken down into discrete segments that include an initial, limited amount of preplanning / scheduling, followed by passive GPS data collection, and then finishing with additional prompting for scheduling decisions that were not detected (Doherty and Papinski, 2004). Plans for implementation of this latest approach include the use of a PDA / cellular phone connected to a BlueTooth GPS, combined with a hand-held web-based survey interface to be tested in the fall 2004.

3.2 Passive GPS Applications
In 2002, the London Department for Transport sponsored a research study investigating the use of GPS in travel surveys (Steer Davies Gleave and GeoStats, 2003), with a specific focus on evaluating how GPS could enhance the London Area Transport Survey (LATS). Wearable GPS data loggers (the Wearable GeoLogger™ by GeoStats) were selected for this study, which consisted of a three-day data collection effort for 154 study participants. For the first two days of data collection, participants were asked to carry the loggers with them throughout the day. On the third
day, they were asked to carry the loggers and to fill out a simple trip log. When the equipment was collected on the fourth day, a short recall survey was conducted using the trip log as a basis.

This study found that even in London’s demanding environment with many trips made by bus, train, and underground subway, GPS loggers performed effectively in collecting data across all modes of travel. When the person traveled out of view of the GPS satellites, the data collected could still identify where the signal was lost and where it was regained, thus confirming an underground trip segment occurred. Of all possible days for data collection, 82% of the days yielded usable GPS data. The remaining 18% were not usable primary due to either a lack of use (ie, the participant did not carry it) or misuse (there were some communication problems regarding the proper way to carry or wear the device). This study also found that London participants were receptive to the technology, and although a few comments were made about the size and weight of the GeoLoggers, concerns about security and privacy were less than expected.

4. **CELLULAR POSITIONING STUDIES**

At the 2001 Conference on Transport Survey Quality and Innovation: How to Recognise It and How to Achieve It, Wermuth, Carsten, and Krietz presented a paper entitled “Impact of new Technologies in Travel Surveys (Wermuth et al, 2003). In this paper, studies involving two GSM-based travel activity collection systems (TeleTravel System and personal Handy-phone System) were presented. The TeleTravel System was implemented in Germany on a commercial mobile phone that included an electronic questionnaire to collect trip details and utilized GSM (a mobile radio network) for both periodic data transmission as well as location identification to within 100 meters on average. The Personal Handy-phone System was developed and tested in Japan; it consisted of a mobile communications system was developed that provided position accuracy levels within 60 meters on average. This system was tested in tandem with a simple activity diary survey.

Since these studies, there has not been much research in the use of cellular-based positioning as a sole means of collecting travel survey data – most likely due to the lower accuracy levels available compared to GPS accuracy levels (five to seven meters typical) as well as the ongoing delay of full E911 implementation in the U.S (which has driven the enhancement of cell phones to provide location within 100 meters for emergency calls). It is much more likely that as cellular phones with GPS chips become more commonplace, A-GPS will prove to be the best cellular solution for providing accurate location outdoors with a much greater coverage area than GPS alone – and that indoor traces will also be available. However, there are several key issues with the use of this technology for collecting travel behaviour; these include privacy concerns about collecting data without traveler consent and the challenge of working with a variety of cellular network standards and providers (especially in the U.S.). Of course, the benefits of this promising cellular / GPS solution, including both enhanced location determination and remote data transfer that enables long-term data collection efforts, should lead to more studies leveraging this technology in the near future.

5. **EMERGING GPS STUDIES**

It is likely that the use of GPS in travel surveys to audit reported travel behaviour is merely the first step in accepting the technology for collection of highly accurate travel data. Now that this acceptance seems to have arrived, recent trends indicate that someday GPS may be used to replace some or all components of traditional travel survey data collection methods. Of course, the costs of GPS studies are still much higher than traditional methods. However, there have been discussions lately within the travel behaviour survey community that smaller sample sizes with longer survey periods for each participant may provide greater value than large-scale 24-hour surveys (Murakami
et al., 2003). In addition, the generation and use of synthetic datasets may also offer a method to augment smaller GPS studies.

There are two emerging areas for GPS in travel surveys: 1) GPS-based prompted recall and 2) GPS-only data collection.

5.1 GPS-based Prompted Recall

In GPS-based Prompted Recall studies, households are recruited into the travel survey through traditional means (e.g., an advanced mailing followed by telephone recruit call). During this recruit call, basic household socio-demographic data, travel modes, and habitual destination address information (e.g., home work, school, daycare, grocery shopping) for each person in the household is collected. GPS loggers are then provided for all household vehicles or household members (over a given age) for the duration of the assigned travel period. The GPS data is then processed leveraging the recruit call information and presented back to the respondents for confirmation and/or correction of derived trip details and the completion of other traditional elements that cannot be derived from GPS data, such as number of travel companions and destination activities.

The implementation of prompted (or assisted) recall can occur through a combination of methodologies and technologies, including mail out / mail back letters with trip tables and maps, CATI personnel using a computer application that presents prompted recall details and collects responses, and computer assisted self interviews (CASI) implemented via the Internet, personal digital assistants (PDAs) with GPS, or GPS-enabled PDA cellphones. Evaluation of GPS-based prompted recall techniques for travel survey data collection was first reported by Louisiana State University (Bachu et al., 2001). Since then, other projects have tested GPS-based prompted recall methods as well. Currently, GPS-based prompted recall is being used in the Kansas City Household Travel Survey to collect details on unreported trips, and the 2004 Sydney Household Travel Survey plans to provide GPS devices to 100-150 households and to collect additional trip details via prompted recall. If the methodology and technology supports periodic GPS data processing throughout the data collection period (such as what can be supported through wireless data transfer and/or CASI solutions), it is very feasible to have participants in the study for long periods of time with the prompted recall occurring throughout the data collection period.

5.2 GPS-only Data Collection

GPS-only data collection consists of passive GPS data collection (in-vehicle or wearable) with full trip detail derivation / imputation occurring during data processing. This methodology requires no further contact with the study participants, which could greatly reduce costs as well as participant burden. In addition, the entirely passive nature of this method makes long-term data collection periods practical.

Significant research has occurred over the past four years to develop algorithms that automate the identification of trip details once considered difficult, if not impossible, to determine from GPS data, including trip purpose and travel mode (Wolf, 2000; Wolf et al., 2001; de Jong and Mensionides, 2003; Wolf et al 2004b; Chung 2004, Chung et al., 2004). Initially, algorithm development was slow as researchers worked through the feasibility of deriving various trip variables. More recent algorithm development has been driven by projects that have accumulated GPS data for hundreds of participants for an extended period of time, resulting in trip counts in the 50,000 to 500,000 range. When dealing with historical datasets of this size and duration, it is simply infeasible to go back to the participants to ask for missing details. The next section presents several of these studies in more detail.
6. DATA COLLECTED IN OTHER STUDIES

The implementation of GPS technology in other transportation-related studies is generating incredibly large datasets of high-resolution GPS details collected from personal automobiles in travel survey study areas. Safety and road pricing studies have been the leading applications for long-term GPS data collection. Here are a few recent examples:

- **Sweden Speed Adaptation Study.** The recent Swedish Intelligent Speed Adaptation (ISA) study was concerned with the traffic safety effects of in-car speed information systems (Hultkrantz and Lindberg, 2003). The three systems, a different one installed in each city (Borlänge, Lund and Lidköping), informed the driver in real-time about violating the posted speed limits by a blinking light, by a sound, by increasing the resistance of the gas pedal, or by combinations thereof. In each case, an in-vehicle unit measured the location and speed of the vehicle by GPS, looked up the posted speed limit from a suitably enriched network database, and informed the driver of speed violations when they occurred. These vehicles were observed for up to two years, and in the Borlänge component, the speed and location data of each vehicle were transmitted at regular intervals to a central server and stored for later analysis. Researchers at the Swiss Federal Institute of Technology in Zurich and Lausanne, along with GeoStats, have been processing and analyzing this dataset for trip-making details, including trip end identification, trip purpose imputation, and route choice behaviours (Wolf et al, 2004b; Frejinger, 2004).

- **Copenhagen Road Pricing Experiment.** Four hundred vehicles were instrumented with GPS-based devices for 8 to 10 week control and experimental periods in this AKTA road pricing experiment conducted in Copenhagen. Pricing schemes included zonal and cordon based rates, which varied by peak and non-peak hours; these prices were displayed back to the participants in real-time as an accumulated cost for each trip as it was underway. The GPS data were collected and analyzed to determine the behavioural impacts of the different pricing schemes, (Nielsen and Jovicic, 2003). The research team recognizes the richness of the dataset with respect to opportunities for evaluating route choice, trip patterns, and speed. Research efforts currently are focused on estimating route choice under the various tolling models.

- **Commute Atlanta.** In 2001, Georgia Tech was awarded a FHWA Value Pricing Pilot Program project grant for a study to evaluate the impact of mileage-based insurance rates on commuter behavior. In the past year, more than 250 households in the Atlanta region have been recruited into this study. Event data recorders (EDR) have been installed in the household vehicles; these EDRs collect second-by-second GPS data and speed, and transmit these data on a daily basis. Researchers at Georgia Tech have begun the exploration of these data to improve understandings about travel behavior (Li et al, 2004).

There are also numerous other applications for GPS-instrumented vehicles, including fleet tracking and vehicle theft prevention and/or recovery. Perhaps one of the more interesting non-transportation applications for GPS-instrumented vehicles was a city-wide art project conducted in Amsterdam; Amsterdam RealTime attempted to visualize the mental maps of city residents by examining their travel behaviour (www.waag.org/realtime/Amsterdam). This two-month project invited all city residents to carry a PDA / cellphone connected to a GPS receiver and antenna. GPS data was transmitted in real-time to a central location where the data was projected into the exhibition space.
If these datasets are made available, travel behaviour researchers and modelers will have enough data to keep themselves busy for years. Of course, there will always be some data elements missing, so it is desirable for secondary users of such datasets could be involved in the study design. The tradeoff for this involvement is typically more requirements, higher costs, and longer implementation schedules. Privacy issues may also arise. Cost sharing and data sharing agreements are beneficial for establishing relationships between primary and secondary user groups.

David Forkenbrock, Director of the Public Policy Center at the University of Iowa, is an expert in road pricing policies and implementation. In a recent publication on assessing road user charges (Forkenbrock and Kuhl, 2002), he acknowledges the numerous benefits for transportation planning if road user fee systems gathered additional information to support technical travel demand analyses. Given that the implementation of a system that enables the assessment of road user charges is the primary objective, and that there are significant privacy issues with the collection of the additional elements required by planners (such as trip origin and destination locations, as well as travel routes), Forkenbrock recommends that only user charge data should be collected in the initial implementations.

7. CONCLUSIONS

It is clear that GPS technologies have much to offer in the passive collection (or measurement) of detailed travel behaviour data. When enhanced with cellular positioning (such as in A-GPS) and transmission capabilities, GPS logging devices are a powerful tool for collecting multi-day and multi-period survey data with little or no respondent burden. At the last Transport Survey Quality Conference at Kruger Park, Murkami et al. (2003) reported on the benefits, barriers to use, data issues, and utility of technologies for travel surveys. Since then, the expanding use and exploration of technology applications, specifically GPS-based technologies, in travel surveys have furthered the understanding of the issues as well as resolutions. For example, the high costs of GPS studies are driven by equipment and deployment costs. These can be reduced significantly by using smaller sample sizes over longer time periods. The use of wireless or modem-based data transfer methods will also enable participation for extended periods of time.

Although it seems unlikely that GPS methods will replace traditional methods anytime soon, it seems equally likely that applications of GPS will progress from the traditional use as an auditing tool for reported behaviours to a supplement (e.g., prompted recall) or replacement (e.g., GPS-only) for traditional diary and CATI survey methods – at least on a small scale. In addition, the proliferation and adoption of consumer devices with GPS, cellular, and/or PDA capabilities offers the opportunity to leverage existing hardware already in the hands of study participants for collecting detailed travel behaviour information. The availability of massive vehicle-based GPS datasets collected for other purposes facilitates algorithm development, testing, and implementation for all types of GPS-based travel surveys. As these data processing and imputation routines are proven to be accurate, this reuse or repurpose of data may, in itself, lead to very cost-effective solutions for generating (vehicle) travel behaviour datasets without ever deploying a single GPS device for a travel survey.

Of course, travel behaviour researchers are interested in all modes of travel, and therefore, wearable GPS devices are desirable over vehicle-based solutions. There is much promise in this area, as consumer-driven services such as child, elderly, and parolee tracking are bringing technology improvements that include reductions in size, power demand, and price in wearable devices. Other form factor improvements have focused on the wearability of these devices, and can be seen in products such as GPS watches and Bluetooth (wireless) GPS receivers. These improvements
should help to address concerns about participants either forgetting to carry or deciding not to carry wearable loggers. For a more interactive solution, the integration of GPS with PDAs and PDA / cell phones offers the ability to collect additional trip details either in real-time or immediately after travel occurs; size, performance, and power demand are all areas of continuing technology improvement for these devices.

To incent travel survey study participation beyond offers of cash or gifts, the latest efforts have focused on making participation easier or more convenient, such as what can be offered in Internet-based solutions. GPS technology is passive by nature, which does make participation easier than traditional methods. Other ideas to increase response rates include making participation more like a game, which can be implemented through a combination of GPS and user interface (Internet, PDA, PC) tools, perhaps the basis of which could be GPS-based prompted recall. Another interesting game-like approach has been tested by researchers in The Netherlands, who are exploring the use of virtual reality systems as a means of collecting travel data (Tan and Timmermans, 2004).

Other technologies not covered in this paper deserve acknowledgement for their potential roles in collecting travel survey data; these include Internet surveys and PDA / laptop / Tablet PC technologies for use in face-to-face or self-administered surveys. As travel survey researchers move forward in their quest to collect more and better data, it seems obvious that there will not be one solution, but rather a combination of high, low, and no technology solutions that can be implemented singularly or in tandem (i.e., mixed mode surveys) to collect accurate and representative datasets. It is also clear that GPS and cellular technologies belong in this toolset.
8. REFERENCES


Zmud, J. and J. Wolf (2003), “Identifying the Correlates of Trip Misreporting - Results from the California Statewide Household Travel Survey GPS Study,” Presented at the 10th International Conference on Travel Behaviour Research, Lucerne, August.