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Paper title: **GPS surveys and the internet**

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Abstract (200 words):
ITS has been pioneering the use of GPS to provide more accurate data on where and when people travel, their routes, travel distance, and travel time. GPS provides no information on the number of people travelling together, trip purposes, and travel costs. ITS has pioneered the development of a method of collecting this additional information called the prompted recall survey, designed to be conducted some days after the GPS data are collected, using maps and tabular presentations from the GPS records to prompt the respondent's memory. We describe these surveys and document some of the results. As an improvement on the paper and pencil version, we developed an internet-based survey. This provides animation of each GPS trip, and gives respondents the ability to stop the trip part way through to indicate a trip end that the analysis of the GPS data had not detected, to restart the trip, and to indicate that a stop was only a traffic stop, not a destination. The paper describes the animation, shows the types of data that can be collected, and describes the advantages offered. Some examples are provided of the results of people using the various prompted recall survey versions.

Introduction

Use of GPS technology in transport research is growing rapidly, particularly in conjunction with household travel surveys (HTSs) (Wolf, 2004; Stopher et al., 2002a). The Institute of Transport Studies at the University of Sydney has been pioneering the use of GPS as a means to provide more accurate data on where people go, when they travel, the route they take, and the distance and time taken to travel. GPS is, however, limited in what data it can collect, and provides no information on the number of people travelling together in a vehicle, the purposes of their travel, and the costs associated with that travel. ITS has pioneered the development of a method of collecting this additional information called the prompted recall survey (Stopher et al., 2002b). This survey is designed to be conducted a week or two after the GPS data are collected, and uses maps and tabular presentations developed from the GPS records as the basis of prompting the memory of the traveller. This paper describes the surveys that we have developed of this type, and documents some of the results obtained.

As an improvement on the paper and pencil prompted recall survey, we developed an internet-based survey (which could possibly be run in the future from a CD on a computer that is not connected to the internet). One of the principal goals in developing this internet-based survey was to provide animation of each trip measured in the survey, and to allow the survey respondent to be able to stop the trip part way through, to indicate a trip end that the analysis of the GPS data had not detected, to restart the trip, pause in the trip, slow down or speed up the display of the trip, and to indicate that a stop shown on the screen was only a traffic stop, and not a destination. The paper describes the animation, shows the types of data that can be collected by this system, and describes the advantages that the system can bring, as well as acknowledging some disadvantages. Some examples are also provided of the results of people using this version of the prompted recall survey.

Using GPS with Household Travel Surveys

In the past few years, GPS devices have become significantly smaller, as have the capabilities to store data from a GPS device. Removal in the beginning of this century of Selective Availability increased significantly the potential accuracy of GPS data collection. Over the past few years, GPS has been introduced into Household Travel Surveys, predominantly in the U.S. (Wolf et al., 2003) and as a means to check on the accuracy of the reporting of trip information in more conventional diary surveys. The benefits of GPS, and the reason for it to be used in this manner, are that it provides highly accurate, unambiguous spatial and temporal data on the travel of vehicles and, in a form that can be worn, of people. Specifically, GPS can provide data on:

- Where people go   (spatial data);
- The route they take   (spatial data);
- Distance covered   (spatial data);
- When they travel   (temporal data);
- Time taken   (temporal data); and
- Speed of travel   (temporal data).

Despite a high level of accuracy, GPS data are not perfect. The accuracy of the above data may be compromised by such phenomena as urban canyons, tunnels, and cold starts (Stopher, 2003; Stopher et al., 2003). Holes in the data may be filled manually, but this is time

consuming and error prone. ITS has developed software to undertake a significant portion of the necessary data repair. Despite this, there is still a necessity for a time-consuming manual process to be implemented. Current and imminent advances in GPS technology and affordability will help solve these problems of accuracy for travel researchers, and hence reduce the amount of post processing required.

Among the developments in GPS devices for this type of measurement are the incorporation of the GPS device into a mobile telephone, with the ability to use the position of mobile telephone transmission devices to triangulate a position, when the GPS signal is corrupted in some way. In this form, the GPS device can be very mobile and readily carried by an individual, so as to permit tracking of travel by foot, bicycle, on public transport, and in cars. ITS has used GPS devices that are carried by individuals in its surveys (Stopher et al., 2002b), but the current device is bulky, and has encountered some resistance from survey participants. A mobile phone form factor will both reduce respondent resistance to size and increase the accuracy of the position value. Another direction of development is to include in the GPS device a means to capture odometer information from a vehicle, and also to provide an inertial device of some type to give information on directional changes. Such devices are already available, but very expensive, and require professional installation in a vehicle, thereby making them impractical for general public surveys. Devices of these types can use a filtering algorithm to determine the weight to be placed on the different input signals at any given time, thereby dynamically selecting how much information to draw from the GPS, and how much from the auxiliary positioning devices.

The implications of these advances for transport research and travel surveys is an active area of research. Although GPS data can contain errors, it must be recognized that its use in travel surveys is a significant step forwards from self-reporting.

The GPS device provides a continuous stream of data. However for the household travel survey, we are interested in travel behaviour on a journey-by-journey basis. The GPS data can be analysed to suggest where the journey ends are located (Stopher at al., 2003). This analysis focuses on the length of time for which the GPS device is stationary. Yet any inferences made from this analysis are not completely reliable. A journey end may be falsely detected (a false positive), or a true journey end may not be detected (a false negative). Therefore we need to have a mechanism by which the survey participant can correct erroneous journey start and end points. Journey start and end points represent a form of data that can be derived from the raw GPS data, but has a limited accuracy, and needs to be verified.

The GPS device, while providing very accurate spatial and temporal data, does not provide some types of data, specifically:

- Number of people travelling in the vehicle;
- Purpose of travel; and
- Costs associated with travel.

Although the GPS device does not provide these data, the GPS data are still useful. ITS has developed a prompted recall survey to gather the information not provided by the GPS device, and to validate or correct journey start and end points. The GPS data can be used to build maps and provide tabular presentations to aid the prompted recall survey. This is an even more subtle use of the GPS data. The GPS data are being used as a means to aid the participant's recall of data that cannot possibly be gathered by the GPS device itself. The

highly visual nature of the GPS data, when displayed in a map, greatly increases the effectiveness of the prompted recall survey.

The Prompted Recall Survey

Prior to the research reported in this paper, ITS has been using a prompted recall survey that works in the following manner. After the GPS devices are returned by a household, the data are downloaded and processed both through software developed by ITS and through inspection and manual adjustment of the data. The purposes of these processing steps are to first repair any cold start problems (by linking the position first recorded by the GPS device back to the true origin of the trip), and to remove problems resulting from urban canyons and other interruptions in the GPS signal (by inferring travel through the affected area from the underlying street network).

Once the GPS data have been processed, they are grouped by day of the week, and maps are produced, showing the route of travel, and labelling each origin and destination, and giving each trip a number. The result might appear similar to Figure 1.
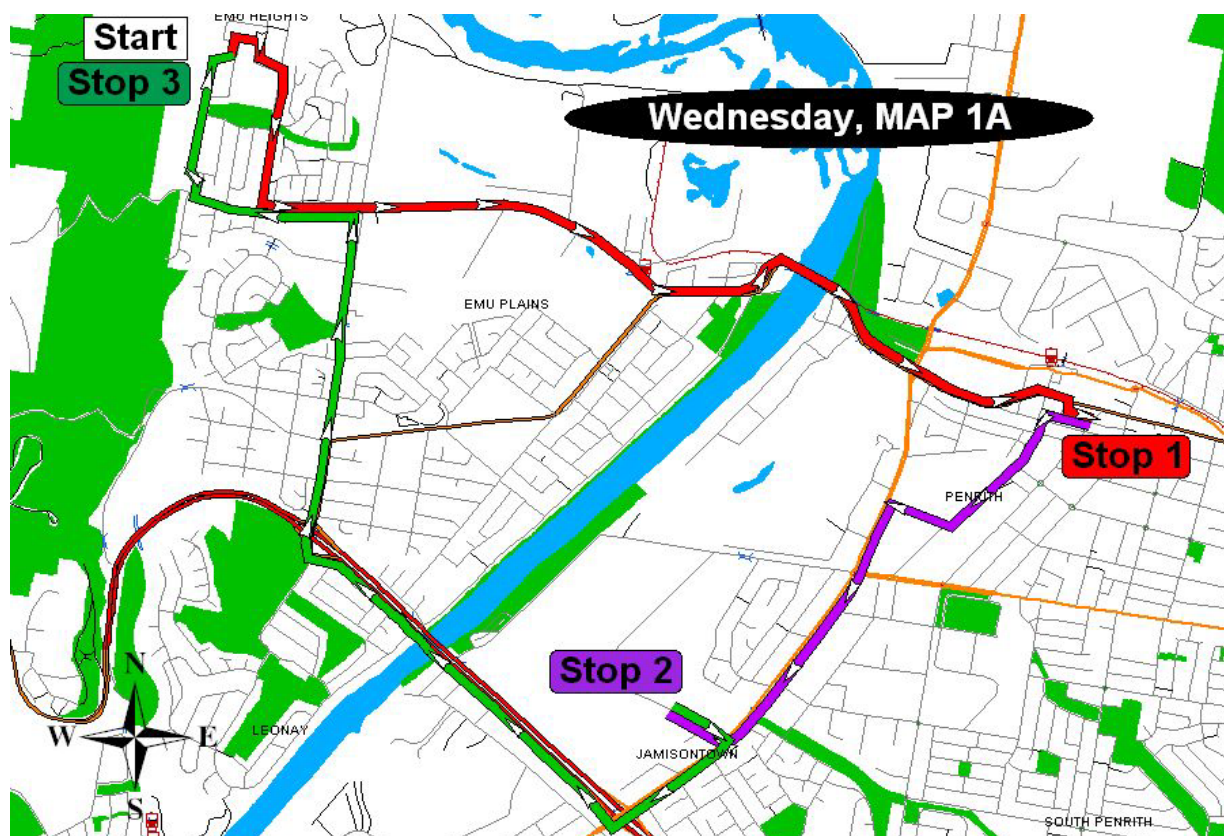

Figure 1: Representation of One Day's Travel

In addition to the map, a tabular presentation of the data is also provided. This is provided for those respondents who are not comfortable in reading maps, and for those who prefer to see the tabulated data. An example of this is shown in Figure 2. These materials are sent to the respondents who elect to complete a paper or telephone survey. The former also receive a self-administered questionnaire; information from those opting for the telephone survey is

gathered over the telephone. All maps and travel data are downloaded over the internet by those respondents who elect to complete the internet survey.

The information that is collected is the purpose of each trip, the number of accompanying people, the purposes of those accompanying the respondent, and any costs paid out of pocket on the trip, such as for parking, etc. Respondents are also asked to confirm that the trips as shown are the full set of trips they undertook, or that there are either missed stops, entire missed trips, or stops portrayed that are not real stops.

2004 Passive GPS Household Travel Survey

Summary of Travel Activity for Peter Stopher
Wednesday 5/5/2004

Location at Start of Day:	Street	Suburb
	PARKWOOD GR	EMU HEIGHTS

STOP NUMBER	TIME OF ARRIVAL AT STOP	TIME SPENT TRAVELLING TO STOP (min)	DISTANCE TRAVELLED TO STOP (km)	LOCATION OF STOP Street	Suburb	MAP	NOTES
1	10:23	14	6.9	ALLEN PL	PENRITH	Map 1A	1
2	10:40	9	3.6	BLAIKIE RD	JAMISONTOWN	Map 1A	2
3	11:54	12	7.3	PARKWOOD GR	EMU HEIGHTS	Map 1A	3
4	16:42	6	3.4	WATER ST	EMU PLAINS	Map 1B	4
5	17:03	6	3.4	PARKWOOD GR	EMU HEIGHTS	Map 1B	5

**Figure 2: Tabular Presentation of GPS Data**

Motivation for an Internet-Based Household Travel Survey Incorporating GPS Data

There are a number of conventional motivations for internet surveys, all of which are certainly relevant to this case. These include:

- No need for data entry, which cuts costs and improves data reliability;
- No need for the respondent to send back the survey manually;
- Automatic data validation, prevention of missing data for reasons other than dropout;
- Complex skip patterns are possible, without ever exposing the participant to the questions to be skipped;
- Internet provides a better mechanism for respondents to be able to choose the time of their response than a telephone or face-to-face survey, and even than a postal survey; and
- Internet is likely to appeal to certain segments of the population that are hard to get to respond to other methods, such as face-to-face, telephone, and postal surveys.

In the context of a household travel survey that uses a GPS device, the internet survey also offers some new capabilities, which focus on the way in which information is shown and gathered. In particular, the decision was made to provide an animated portrayal of the route of each trip on the screen, rather than just offering the paper maps as a snapshot on the screen. Some of the specific capabilities that animation of the route provides to the respondent are that it:

- Allows the map to be zoomed in more than with a paper survey, allowing more detail to be shown on the map, hence providing more clues that might help respondent recall. This is shown in Figure 3.
- Provides richer information on the route taken, as the route unfolds over time. The time corresponding to the current location on the map can be shown to the respondent. By comparison, the paper surveys only show time information for the start and the end of the journey. Similarly, the street and suburb name of the current location can be displayed. This can be particularly useful in assisting the respondent as they indicate the exact location of a missed stop.
- Allows the respondent to pause the animation, thus giving the respondent time to consider what they were doing at that point in the journey, without being overwhelmed by the rest of the route information being shown on the map.
- Provides the opportunity for the respondent to insert stops that occurred along what is displayed as a single journey, where in fact it was two or more journeys.
- Provides the opportunity for the respondent to join two or more journeys into a single journey, where that single journey is incorrectly displayed as multiple journeys.
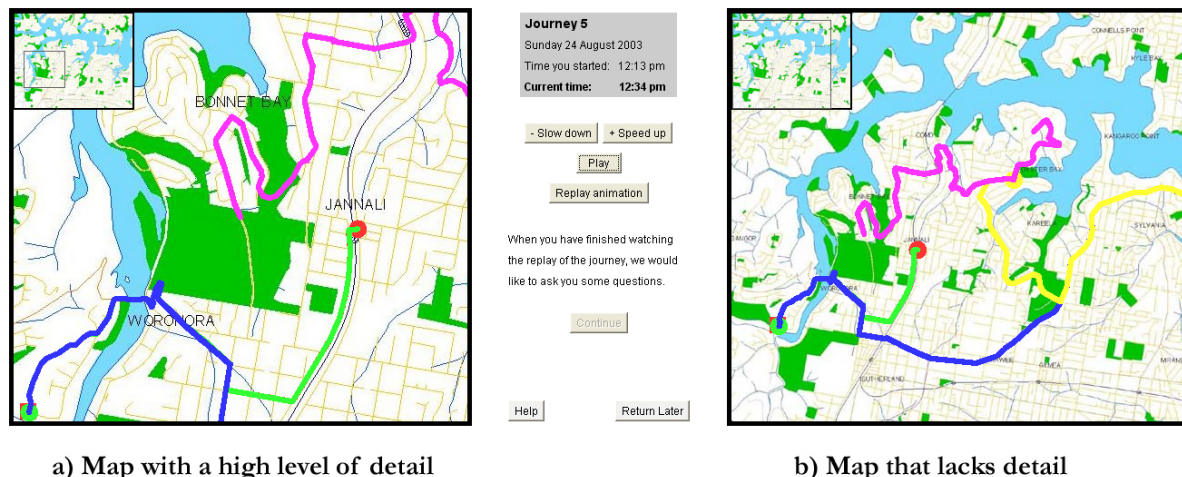
a) Map with a high level of detail   b) Map that lacks detail

Figure 3: Demonstration of Zoom Capability

In each of the last two situations, the respondent then is asked only to provide the additional descriptions after the amendments are made to the display of the journeys. In the paper versions, the paper maps continue to display the incorrect information and add some complexity to how the respondent communicates the correct information.

An internet version of the survey allows very precise spatial data to be gathered, consistent with the purpose of a GPS survey. Specifically with the case of missed journey ends, the location of a missed journey end can be gathered by directing the respondent to mark a point on the map with his or her mouse. This allows the exact longitude and latitude of the missed journey end to be calculated and stored in the database. In a similar way, other geo-referenced data could be gathered precisely and stored.

Description of the Internet Survey

The internet survey screen contains two main areas: the map area on the left of the screen, and the information and question area on the right of the screen (see Figure 4). The map area itself contains two maps: the main map, and an index map. As with the paper versions of the survey, the maps contain information obtained from a GIS dataset, and include street networks, water bodies, parks, railways and suburb names. The main map contains all the above information, as well as the animated path of the journey. In the top left corner, to help orientate the respondent, a smaller, zoomed out index map that shows the entire area which was covered in the travel day is shown. This map also shows the location of the main map with respect to the total area, in the form of a rectangle. Together, the main and index map provide both detailed information and a mechanism to help locate this detailed information in a wider area.
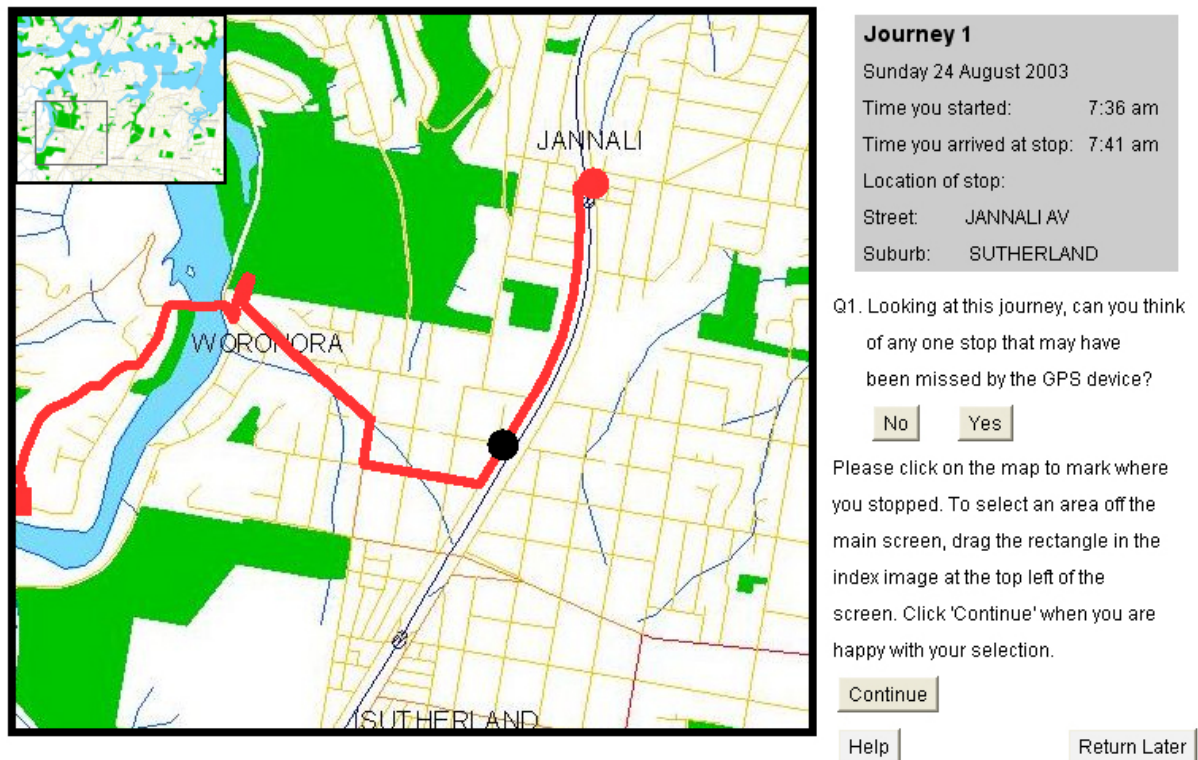

Figure 4: Animation Progress, Showing On-Screen Dialogue

The content of the information and question area varies over the survey, but at all stages it contains at least some information on the current trip. This information includes the journey number and the exact time and street location of the current point in the journey. Often, this current point will be the stop for which we wish to gather information. Whereas the tabular presentation for the paper surveys contains only aggregate information for each trip, the internet version displays the exact spatial and temporal information for every point of the journey as it is animated, potentially boosting recognition of location and recall of trip purpose and other information. This area of the screen also contains controls during the animation, brief instructions, and questions at the appropriate stages of the survey. Note also the help button, which will provide the respondent with detailed help in a separate window at any stage of the survey.

The animation is the first stage of gathering information for each journey. The start point is clearly marked, and then a line is progressively drawn on the screen, tracing out the path of the journey. When the line approaches the edge of the main map, the map pans, so that the current position in the journey is always shown on the screen. In this way, a very detailed map can be shown. Only a part of the entire map is shown at any one time on the main map. The speed of the animation can be controlled, and the animation can be paused or restarted. When the respondent is happy with the animation stage, they can continue to the questions on the journey just animated. During all these questions, it is possible to control which part of the main map is shown by dragging on the rectangle found in the index map. The section of the index map located within the rectangle is shown on the main map. In this way, the respondent can review all parts of their journey to aid in the answering of the questions.

It should be recalled that the demarcations between journeys that we indicate may not be correct. All of the survey media have mechanisms for determining if some journey end points are incorrect or missing. However, the internet survey is better than other survey media at handling route changes that result from the addition and removal of journey ends. The map is immediately altered to display the new route visually, removing confusion and hopefully improving recall. As an improvement over the paper survey, the internet survey can ask questions about the journeys after any possible changes to the journey ends are made. This way, questions are asked about journeys that were missed, and not about journeys that did not happen.

If a journey end was missed, the respondent can indicate exactly where the journey ended. The map immediately removes the rest of the journey, thus showing the exact journey on the screen. Figure 5 shows the initial screen, and also indicates that the respondent has marked a point not far from the currently shown trip end where the initial trip actually ended. The on-screen dialogue is also shown. The respondent would first respond "Yes", at which point on-screen editing is enabled, and the respondent marks the destination point with a click on the main map. The chosen point automatically locks to the journey path, to assist the process. He or she would then select "Continue", at which point, the display would change to Figure 6, which reflects the altered journey.

Figure 5: Initial Question of a Missed Trip End

The questions that would have been asked anyway regarding the trip end are then initiated, as shown in Figure 6. Figure 7 shows the subsequent questions that are asked about each trip. These questions relate to the purpose at the end of the trip, whether or not the respondent was the driver, details about others in the vehicle, and a question on whether parking was paid for. Note from Figure 7 that some of the questions are enabled and disabled based on the current answer to another question. For example, the amount paid for parking is not asked if the respondent has indicated that they did not pay for parking. The software performs data checking, so that missing answers or answers that do not make sense are rejected. A dialog box appear, indicating specifically what was wrong with the answers.

Figure 6: Corrected Trip

Figure 7: Subsequent Questions on Each Trip (Journey)

The missing end point procedure removes any ambiguity about what journey the subsequent questions refer to. In the paper version of the survey, each set of questions about a journey is grouped together under a heading indicating the number of the journey. This journey number corresponds to the journey number marked on the map. If the respondent indicates that a journey end was missed, there are now two journeys where once there was one. Yet the paper survey still only asks questions about the one journey. This is confusing to the respondent: which journey are they being asked about? This ambiguity means that the researcher does not know if the answers refer to the first journey, second journey, or both. By comparison, the

internet survey gathers the information for each of the two journeys that result from a newly marked journey end, but does so in the sequence in which the journeys were made.

Similar advantages are evident in the internet survey if the respondent indicates that a marked journey end did not actually happen. Now there is only one journey where once there were two. In this situation, the paper survey will ask questions about both journeys, and hence one question will be about a journey that did not actually happen. This could confuse the respondent. By contrast, the internet survey will resume the animation, which will continue until the next journey end, and only ask questions about the combined journey. This is shown in Figure 8. Further, when these questions are asked in the internet survey, the map will show both journeys combined, eliminating confusion and hopefully improving recall.

In addition, because of warm up problems, the GPS record may not always start at the first origin in the day, or there may be a gap in the records in the middle of the day, if the vehicle was parked for a significant period of time. These are awkward to pick up in the paper version of the survey, but are quite easily handled by the internet version.

Before   **After**

Figure 8: Before and After Removing an Incorrect Stop

Some Results of the Internet Survey

Table 1 shows the number of households recruited for each type of prompted recall method. The telephone was the method most widely chosen by respondents, followed by the internet. All prompted recall surveys were sent to respondents within two weeks of their travel day with the exception of one household. This was sent only a couple of days over two weeks after the travel day. Households that elected the self administered method were generally slow in returning the completed forms and a number of phone calls had to be made to remind them to post them. One household took two months to return the survey. However, out of the six households that were sent the mail-back forms only one failed to send it back. The telephone method of survey proved to be troublesome for a few cases. It was often quite difficult to contact households during the day to arrange a suitable time for a telephone interview. Messages were left on answering machines but respondents did not return the calls. For a few cases when finally getting through, and completing the interview, respondents were being asked to recollect travel that was over a month ago. However, this was not a major issue because the maps and tables proved to be a good method of jogging people's memory and

even when asked about travel that occurred so long ago, most respondents were able to answer the questions. This is a situation which should be avoided whenever possible, however. One of the drop-outs for the telephone method was found to have their telephone disconnected when attempts were made for an interview. The internet option, while a reasonably new concept, was taken up by almost one third of the recruited households. However, only 50 per cent of such respondents completed the survey. Reminders were also given for these households, and further reminders may increase the response rate. Two cases of technical problems contributed to the low completion rate for the internet survey. Fortunately, these households completed a self-administered survey that was sent to them. The face-to-face option was not taken up by many respondents. Yet it was the most successful method with a 100 percent completion rate. In total there was a 73 per cent completion rate for using the GPS devices or more accurately, a 27 percent drop-out rate. For the prompted recall surveys that were sent out, there was a 71 percent completion rate.

Table 1: Recruitment and Completion Rates for the Various Methods of Recall

Disposition	Prompted Recall Method				
	Internet	*Self-administered*	*Phone*	*Face-to-face*	*Total*
Households Recruited	19	9	30	6	**64**
Drop-outs	6	1	8	2	**17**
Sent Prompted Recall	12	6	20**	3	**41***
No Travel	1	2	2	1	**6**
Completed Prompted Recall	6	5	16	3	**29**
Completion Rate for GPS	68%	89%	73%	67%	**73%**
Completion Rate for Prompted Recall	**50%**	**83%**	**80%**	**100%**	**71%**

* an extra prompted recall was actually sent to one phone household, but their phone was disconnected and has therefore been coded as a drop-out
** 3 still to be sent which have already been counted here

While the samples are rather small, so that differences between methods are probably not very significant, it is interesting to look at some of the statistics from the GPS survey, both including the internet responses and for the internet alone. Table 2 shows some summary results. One of the major differences that contributes to numeric differences between the internet results and the overall results is that a smaller proportion of wearable GPS devices were used by households responding on the internet than to the rest of the methods. For internet respondents, 28.5 percent of the GPS devices were wearable, whereas the non-internet respondents reported for 32 percent wearable devices. The wearable devices capture public transport and walking trips, while the in-vehicle devices capture only car trips. Hence, there will be a decrease in the number of trips for in-vehicle devices, and also a decrease in the average distance. Average travel time will also be lower, if the distances covered in walking tend to be short. The results in Table 2 are all consistent with the almost 5 percent lower use of wearable devices from the internet respondents.

Table 2: Summary Statistics from the Prompted Recall Survey

Statistic	Internet	Overall
Households	6	34
Total Persons	10	53
In-vehicle GPS	7	35
Wearable GPS	2	11
Total Trips	53	302
Trips per person	5.3	5.7
Average travel time per trip (minutes)	15.3	12.7
Average walking time per walk trip (minutes)	11.3	9.4
Average car driver time per car driver trip (minutes)	16.0	12.4
Average car passenger time per car passenger trip (minutes)	11.5	12.6
Average VKT per trip (kms)	11.1	8.4
Average VKT per person per day	55.5	42.3
Average Vehicle Occupancy	1.35	1.45

After taking into account this difference between the internet respondents and the total respondent sample, it appears that the internet has captured the results well. Other differences between the internet responses and the overall responses are not particularly notable.

Disadvantages and Problems with the Internet Survey

A disadvantage to the internet survey is that it requires Java to run. Java is a complete programming language that allows programs to run from within a web browser. The Java technology revolves around the concept of a 'thick client', where an application is downloaded and run on the respondent's computer. Most surveys are run as a 'thin client', where the server receives responses from the respondent's web browser, performs all the logic, and sends the appropriate data to the respondent's web browser in standard HTML code. This allows the survey to be run on any computer with a web browser. However, it is not possible to achieve the desired functionality for this survey using the thin client approach. Java was chosen as it is a widely recognized thick client technology. In the survey, the respondent downloads a web page, which in turn directs Java to download the executable code that contains all the application logic. The Java program loads within the web browser, and the program then downloads the map and a data file that contains all the information on the day of travel. When the download is complete, the survey is ready to start.

Unfortunately, the Java program needs to be installed first, and it can not be assumed that Java will be installed on all respondents computers. To make matters worse, different versions of Java have quite different specifications, and some versions of Java have bugs that can not be avoided. So even if the respondent has Java installed, it might not be an appropriate version. Consequently, it was decided to target only a single version of Java, necessitating all internet respondents to install a specific version of Java to run the survey. This is a huge respondent burden. Java was provided to all internet respondents on a CD, together with installation instructions, to make the installation process as easy as possible. Still, people may not have the time, desire, or access privileges to install Java on their computer.

Even with the successful installation of the required version of Java, there are many external factors that can lead to failure of the survey. For example, one household had a problem

loading the Java CD due to a problem with their CD drive. Another household encountered problems when the Java program was unable to contact our server due to the presence of a computer on their local network called a proxy server. This situation could have been avoided if the program was designed to ask them for several settings, but this would be a frustrating and burdensome experience for the respondent, as the settings are not usually readily known. Both these households had to have a paper survey sent to them. The problems posed by access privileges and proxy servers is indicative of the increased importance placed on computer security by software developers. The focus on security is fuelled by malicious computer activity, such as computer hacking, viruses and fraud. While the increased focus on security is both necessary and laudable, it does present an obstacle to the successful implementation of complex internet surveys.

The download times for the internet survey are acceptable for a broadband connection, but not trivial for a dialup modem connection. The Java program itself is approximately 180KB. The data file that describes the journeys averages 40KB. The map file, which is stored as a JPEG image file, averages 500KB in size, with the largest file being 1MB in size. At a realistic download speed of 28.8kbps on a modem connection, a survey with the average and maximum image size would take 3.5 minutes and 5.5 minutes to download respectively. These times represent a significant burden to the respondent, especially if the time required to install the Java software is also considered. It is suspected that the burden of this waiting time is particularly high, because waiting for data to download is a boring task that is likely to frustrate the respondent. By contrast, actively completing the survey is much more engaging, and for the same period of time is likely to impose less burden on the user than merely waiting for a download.

The development of the internet survey took a substantial period of time, of which a large percentage was spent testing and debugging the software. The small number of respondents who elected to use the internet survey meant that the cost of deployment per respondent was very high. This negative aspect is offset by the relatively reusable nature of the software. Any future internet surveys that use this software will take much less time to develop. Indeed, the original internet survey developed at ITS was modified to create a slightly different survey in quite a short period of time. Costs are likely to rise when more significant changes are required. The cost of changing computer code is much higher than making changes to a paper survey. It is very easy to introduce bugs, and testing and debugging are time consuming and costly.

A risk with using a complex Java program for an internet survey is that despite extensive testing, a bug may still be experienced by the respondent. This is especially likely in an internet environment, because there are many factors that are hard to control. For example, one household installed Java, but had a problem running the program because of a firewall security setting. The experience of a program that crashes is frustrating to all computer users, and the risk is that such an experience in an internet survey will lead to a dropout. In this case, the respondent was able to assist in identifying the cause of the problem, but the respondent is not a software tester. Well designed and tested software should help avoid bugs, but the small scale of GPS surveys means that the resources for testing the software are limited.

Conclusions

The results obtained with the internet survey appear to be very promising. The take-up rate of the internet survey was reasonable, but the potential exists for this to increase. This is likely to happen as internet use becomes more widespread, and especially as more households move to a broadband connection. The greatest challenge the GPS internet survey currently faces is the low response rate, which was the lowest of all the survey methods employed. Technical problems on the users computer contributed to this, but improved vetting of the potential internet respondent's computer is likely to reduce the likelihood of these problems. The small sample size might also be influencing the low response rate, but further investigation into what might be causing a lower response rate is necessary.

An alternative to running the software over the internet is to provide all the software and data on a physical storage medium, such as a CD or USB key (a cheap storage device that is the size of a pen lid, connects to the USB port, and acts like a hard drive). Consequently, download times are no longer an issue, and the survey does not rely on a correctly configured internet connection. Data retrieval is an issue. The results could be stored to a file and returned by email, but this process is rather cumbersome. The results could be written to a USB key which would have to be physically returned, but this negates the advantage of trivial data retrieval provided by an internet survey. Also, the current software would still require the installation of Java, and lead to all the disadvantages associated with this. If the survey software was written in another language and deployed as a standalone program, Java would not need to be installed. Unfortunately, Microsoft is heading in a similar direction to Java with its .NET software development environment. Like Java, it requires a large set of libraries to be installed for programs to run correctly, and so does not facilitate the design of a truly stand alone program.

The traditional advantages to internet surveys were certainly evident in this survey. The ability to handle complex skip patterns improved the flow of the survey, the respondents were able to choose the time of their response, the data went straight to our database, eliminating the need for the respondent to return the survey, and the internet survey is likely to have helped capture responses from people who would not otherwise respond to a survey. Further, unlike with the self-administered surveys, there were no instances of missing data.

The ability of the respondent to edit the trips shown on the screen and then provide appropriate information about those trips is a technique not typically found in internet surveys. This internet survey provides a mechanism to capture this information more accurately and with less respondent confusion than with other survey methods. In combination with the skip patterns, the end result is a survey that only asks relevant questions, hence reducing burden and making the survey more "user friendly".

It is clear that the information contained in the GPS records is more fully utilized and more clearly shown to the respondent in the internet survey than in other survey methods. A comparison of the response values between the internet surveys and all other surveys shows no problems with the response data. Unfortunately, it is difficult to quantitatively verify that improved information led to greater recall and hence more accurate results. In order for us to place more confidence in our theory that the new internet methodology for GPS surveys will improve result accuracy, it might in future be necessary to ask questions about the survey process per se for each of the survey methods, and to run focus groups that provide feedback on a comparison each of the survey methods.

Our current GPS internet survey is only the first generation. We are confident that the marriage of GPS, GIS and internet technologies is the way ahead in household travel surveys. Improvements to the software, advancements in technology, and changes in the way people think about and use the internet will make successive generations of the GPS internet survey increasingly useful to the transport researcher.

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