National Travel Survey GPS Feasibility Study

Preliminary phase

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P2803

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1 BACKGROUND

The National Travel Survey (NTS) is the Department for Transport's primary source of personal travel data. The survey collects information on travel behaviour including detailed information on trips made during a seven day period. This is achieved via face-to-face interviews and the completion of a travel diary.

Whilst the survey provides detailed trip information (such as purpose, time, duration, mode of transport, distance), consideration has been given to enhancing and improving the data collected. A GPS enhanced NTS could deliver:

- more accurate trip data (time, duration, distance) allowing diary data to be validated/adjusted and NTS trip estimates to be improved
- precise origin-destination data for each trip which would enable us to look in more detail at particular types of travel (e.g. in the urban environment)
- data on all walking trips (currently only measured on day 7 of the diary)
- data on the routes types and on speed of travel

A review was carried out in 2006 to explore the possible use of 'new technologies' on the NTS, including GPS monitors[1]. GPS provides accurate second-by-second data on the position, route, speed and time of journeys. The review found that GPS is increasingly being used to enhance travel surveys and may also be appropriate to use with the NTS. In particular, the use of personal handheld GPS devices was recommended for the NTS, as these are able to monitor all journeys made by the individual, regardless of the mode of transport (as opposed to in-car systems which will only monitor trips by car).

1.1 Aims and objectives

The purpose of this study is to test the feasibility of using personal GPS monitors to collect travel data on the NTS. The specific objectives are listed below:

- **To collect, clean and analyse GPS data from a sample of households**
  The data recorded by a GPS monitor is very different to that collected via a written diary. This study will investigate how best to clean, aggregate and analyse the data from GPS monitors, in a way that is compatible with the Department for Transport's information needs.

- **To link GPS data with the data collected from a travel diary**
  Combining the GPS data with the diary data will provide a detailed picture of personal travel based on different sources. Furthermore, linking the data will allow any differences between the diary and GPS data to be identified and examined.

[1] See Review of the potential role of new technologies in NTS (2006), P, Bonsall, J, Wolf, S, Holroyd on DfT's website

- **To examine the practical issues of equipping individuals with personal GPS monitors and recommend**

  A key objective of this study will be to provide recommendations on the feasibility of using GPS monitors on the NTS in the future. In particular it will provide recommendations on how monitors could be most effectively incorporated into current NTS procedures, looking at issues such as take-up rates and overcoming any practical issues encountered.

1.2 Overview of the study

The study consists of three main phases: the preliminary phase, the data collection phase and the data cleaning and analysis phase.

The preliminary phase consisted of a number of activities to inform how best to approach the collection of GPS data within the context of the National Travel Survey and, indeed, whether progressing to the data collection phase is worthwhile. The key elements of this phase are as follows:

- A telephone survey of recent NTS respondents to establish the acceptability of GPS monitoring
- A review of the available GPS devices on the market
- A small scale pilot of the selected devices and the final selection of the most appropriate
- Finalising the feasibility study design and ethical review
- Developing and finalising the survey materials and instruments

This report focuses upon the preliminary phase of the project. Chapter 2 focuses on the telephone survey of recent NTS respondents. Chapter 3 describes the methods and findings of the device review. The results of the pre-fieldwork testing of the shortlisted devices is presented in Chapter 4 and, finally in Chapter 5, the recommendations for the main fieldwork are set out.

A separate report (NTS GPS Feasibility Study – Final Report) covers the latter two phases, providing an overview of the data collection and processing. It also presents analysis of the diary and GPS data, examining the similarities and differences between the two.

2 TELEPHONE SURVEY OF RECENT NTS RESPONDENTS

2.1 Introduction

Prior to going into the field with GPS devices, it is important to understand the likely acceptability of GPS monitoring among NTS respondents – specifically whether a sufficient proportion would be willing to use a GPS device while completing a travel diary and, if not, why not. Such knowledge is important in informing the survey design in terms of how the topic of GPS monitoring is introduced and explained. To achieve this, a small-scale telephone survey was conducted to assess the acceptability of GPS monitors among recent NTS respondents.

2.2 Sample

The issued sample for the telephone survey consisted of 300 recent NTS respondents. The selected respondents:

- were originally interviewed in February/early March 2008 for the NTS
- had fully completed a travel diary
- had given permission to be recontacted
- had provided one or more telephone numbers on which to be contacted.

The sample was drawn from NTS respondents who had completed their travel diaries within 4-6 weeks of the start of the telephone survey fieldwork. This was done to improve the likelihood of respondents being able to recall the content of the survey and the requirements of the travel diary.

The sample was stratified by age and gender to ensure all sub-groups were represented. In an attempt to ensure that all age groups would be represented in similar proportions to the NTS, the proportion of the sample aged 16-29 was boosted, taking into account their typically lower response rates on previous NTS follow-up surveys. Recent respondents who had been selected for quality check call-backs were removed from the sampling frame of eligible respondents before selection.

All selected respondents were sent an advance letter on NatCen headed paper informing them of the follow-up study (Appendix A), prior to being contacted by a telephone interviewer.

2.3 Fieldwork

The fieldwork took place between 25 March and 21 April 2008. In total 218 interviews were achieved, giving a response rate of 73 per cent.

Table 2.1: Breakdown of outcome from telephone survey

	n	% of issued
Interviewed	218	73
Refusal	20	7
Non-contact[2]	45	15
Other unproductive	17	6
Total	*300*	*100*

As on previous NTS telephone follow-up surveys, the response rate varied across age groups, with the lowest response rate among 16-29 year olds.

Table 2.2: Response rate by gender and age

	Issued	Achieved interviews	Telephone survey response rate
	n	*n*	*% of issued*
Male	129	95	74
Female	171	123	72
Aged 16-29	53	32	60
Aged 30-39	49	42	86
Aged 40-49	56	42	75
Aged 50-59	45	32	71
Aged 60-69	41	32	78
Aged 70 or older	56	38	68
Total	*300*	*218*	*73*

Comparison with NTS respondents

In terms of gender, the profile of the telephone survey respondents is identical to that of NTS respondents interviewed in person (i.e. excluding those interviewed by proxy). The age profile is also very similar, although there is a slightly higher proportion of 30-39 year olds and a lower proportion of 50-59 year olds.

[2] The non-contacts include 6 cases where the telephone number provided was unobtainable and attempts to look-up telephone numbers had been unsuccessful.

Table 2.3: Gender and age profile of respondents

	All non-proxy respondents aged 16 or older (NTS 2006)	All non-proxy respondents aged 16 or older (NTS 2007)	Telephone survey respondents
	% of achieved	*% of achieved*	*% of achieved*
Male	44	44	44
Female	56	56	56
Aged 16-29	15	15	15
Aged 30-39	17	16	19
Aged 40-49	19	18	19
Aged 50-59	18	17	15
Aged 60-69	15	17	15
Aged 70 or older	17	17	17
Total	*100*	*100*	*100*

2.4 Questionnaire

The interview covered the following areas, and lasted less than 10 minutes in most cases (only eight interviews exceeded 10 minutes in duration):

- Recent travel behaviour
- Experience of completing the NTS travel diary
- Willingness to use electronic diaries
- Willingness to carry a GPS monitor
- Concerns about carrying a GPS monitor
- Access to technology (mobile phones, personal computer/laptop, palmtop/PDA, internet)
- Access to and use of SatNav

The full questionnaire can be found in Appendix B.

2.5 Findings

2.5.1 Willingness to use GPS technology

Two thirds (66%) of the respondents said that they would have been very or fairly willing to carry a GPS device alongside using a diary; 29 per cent said they would have been very willing. While seventy two per cent said that they would be very or fairly willing to carry a GPS device instead of completing a diary (44 per cent said very willing).

Of those very or fairly willing to carry GPS device alongside completing a diary, 94 per cent said they were willing to carry the device for 7 days or more (others said 3 to 5 days)

Only 14-15 per cent said that they would not be willing at all to carry a GPS device, with or without a diary.

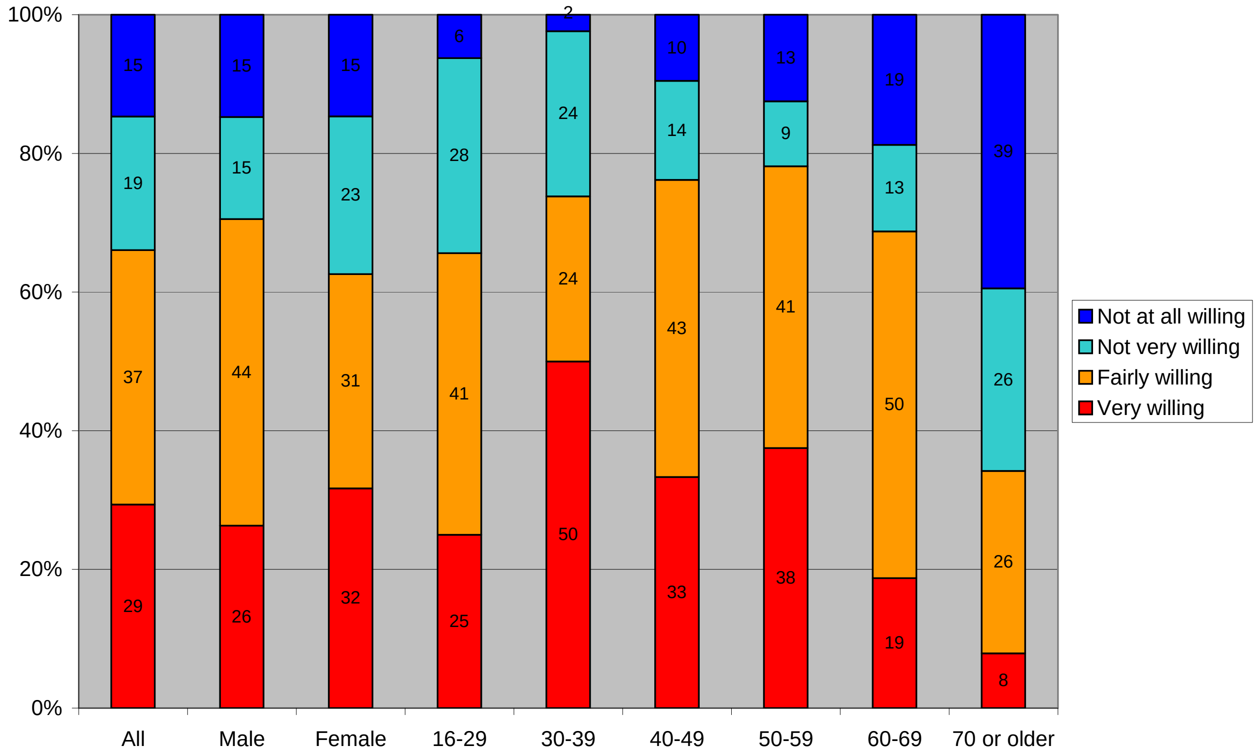
2.5.2 Factors associated with willingness

Being very or fairly willing to carry a GPS device alongside completing a diary was somewhat higher amongst men (70 per cent compared with 63 per cent amongst women), although not significantly so, and lower amongst those aged 70 or older (34 per cent compared with 66-76 percent in other age groups). A similar pattern was seen in terms of willingness to carry a GPS device instead of completing a diary.

Older respondents may feel less comfortable and/or confident in their ability to use/cope with new technologies (as noted below, older respondents tend to have lower levels of access to technology) :

'Really I'm partly disabled (and) in my mid 70s when it comes to it, things like computers, my children have to switch them on. (It's the) fear of the unknown'

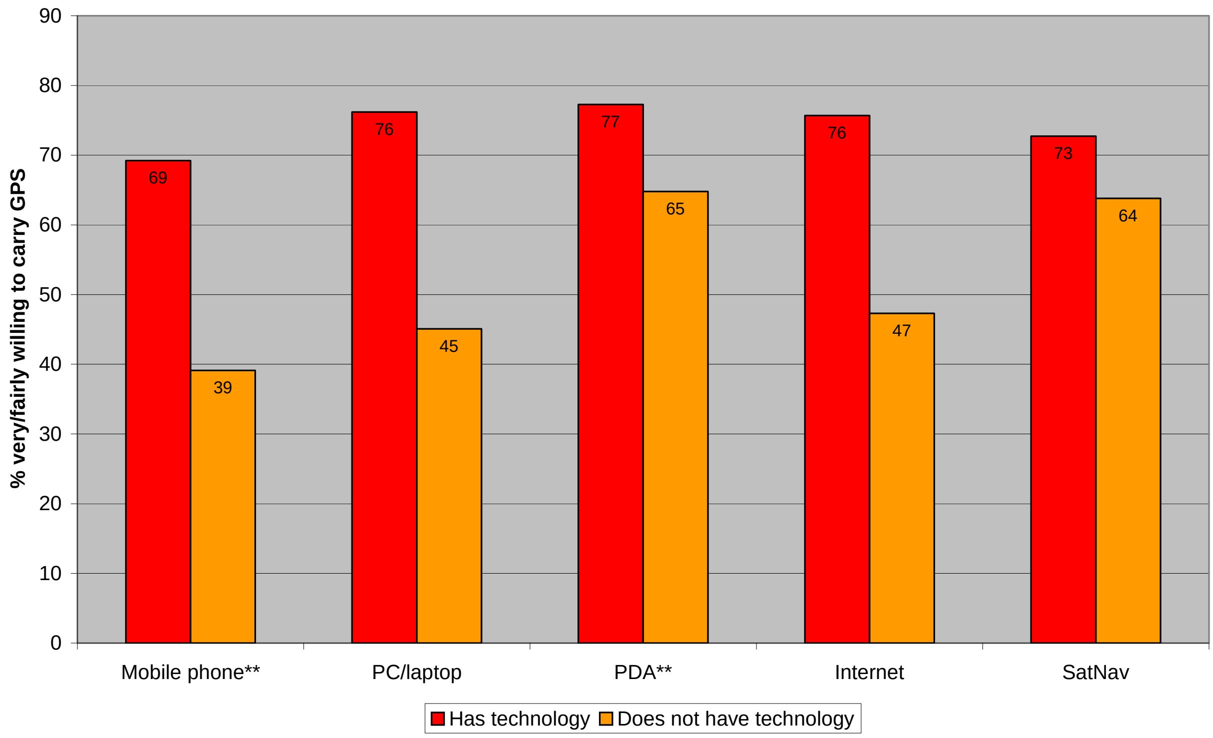
Figure 2.1: Willingness to use GPS device alongside a diary by age and gender



Willingness was also higher amongst those within households with a car (72 per cent compared with 42 per cent) and those who drive once or more per week (73 per cent compared with 53 per cent among those who drive less than once a week or never[3]). Those respondents familiar with other technologies were also more likely to say that they were very/fairly willing to use a GPS device.

[3] Or 52 per cent of those respondents with a driving licence who drive less than once a week.

Figure 2.2: Willinness to use GPS device alongside a diary by access to technology



** indicates categories with small bases of 20-25 cases

2.5.3 Access to technology

Among the respondents, 89 per cent have a mobile phone and 67 per cent have a PC/laptop. Furthermore, 66 per cent of the telephone survey respondents have internet access, 91 per cent of whom have broadband. Ten per cent of respondents have a PDA or palmtop and 24 per cent of respondents have SatNav in their car/van (that is 38 per cent of respondents who drive and have a car). Of those respondents who drive at least once a month and have SatNav (18 per cent of respondents), only 48 per cent used the SatNav at least once a month.[4] Access to the different technologies varied by age with older respondents, particularly those aged 60 or older, being less likely to have any of the technologies asked about.

Official figures suggest that in 2006, 80 per cent of households had a mobile phone and 67 per cent had a PC/laptop.[5] In 2007 61 per cent of households had the internet, 84 per cent of whom had broadband.[6] Some of these levels are lower than those found amongst the telephone survey respondents. This may be due to NTS respondents generally (and/or the telephone survey respondents specifically) having a slightly different profile to the general population; although it should be noted that levels of ownership can increase rapidly and these statistics are not current. If this sub-group of NTS respondents are atypical, this may mean that the willingness to

[4] Only one quarter of those who used SatNav at least yearly reported having changed the route they took on a regular journey as a result of SatNav.
[5] http://www.statistics.gov.uk/cci/nugget_print.asp?ID=868
[6] http://www.statistics.gov.uk/cci/nugget.asp?id=8

carry a GPS device amongst the general population may be lower than suggested here.

2.5.4 Comparing the profile of the willing and the unwilling

The following tables show the profiles of those willing to carry a GPS device compared with those who were not. As anticipated in light of the previous analysis, those who are not very/not at all willing to use a GPS device alongside completing a diary were more likely than the very/fairly willing to be aged 70 or older and less likely to have access to various technologies, particularly PC/laptops and the internet.

There was no clear difference between the groups in terms of whether they had needed help with completing the diary. Those who were not very/not at all willing were less likely to have found the diary task very easy, although not significantly so. The same pattern was also found with regard to willingness to carry a GPS device instead of completing a diary.

Table 2.4: Profile of the willing and the unwilling: gender, age & access to technology

	Very/ fairly willing	Not very/ not at all willing	Very willing	Fairly willing	Not very willing	Not at all willing
	%	%	%	%	%	%
Gender						
Male	47	38	39	53	33	44
Female	53	62	61	48	67	56
Age						
16-29	15	15	13	16	21	6
30-39	22	15	33	13	24	3
40-49	22	14	22	23	14	13
50-59	17	9	19	16	7	13
60-69	15	14	9	20	10	19
70 or older	9	34	5	13	24	47
Access to technology						
Mobile phone	94	81	95	93	83	78
PC/laptop	78	47	84	73	57	34
PDA	12	7	14	10	10	3
Internet	76	47	81	71	60	31
SatNav	28	20	33	24	29	9
N	*144*	*74*	*64*	*80*	*42*	*32*

Table 2.5: Profile of the willing and the unwilling: diary experience

	Very/ fairly willing	Not very/ not at all willing	Very willing	Fairly willing	Not very willing	Not at all willing
	%	%	%	%	%	%
Completed diary						
Without help	84	85	88	81	86	84
With help	16	14	13	19	14	13
Can't remember	0	1	0	0	0	3
Ease of completion						
Very easy	42	34	50	36	29	41
Fairly easy	53	61	45	59	64	56
Fairly difficult	4	4	5	4	7	0
Don't know	1	1	0	1	0	3
N	*144*	*74*	*64*	*80*	*42*	*32*

Looking more specifically at differences in travel behaviour, it can be seen that those who were less willing to use a GPS monitor were less likely to have a household car, drive at least once a week but more likely to use a bus at least once a week, compared with those who were very or fairly willing.

Table 2.6: Profile of the willing and the unwilling: travel behaviour

	Very/ fairly willing	Not very/ not at all willing	Very willing	Fairly willing	Not very willing	Not at all willing
	%	%	%	%	%	%
Number of cars in hhld						
None	13	34	6	18	29	41
1	51	43	50	53	40	47
2 or more	36	23	44	30	31	13
Drives a car/van						
At least once a week	72	51	75	70	55	47
Less than once a week but at least once a year	1	1	0	1	2	0
Less than once a year or Never	27	47	25	29	43	53
Uses a bus						
At least once a week	21	39	17	24	45	31
Less than once a week but at least once a year	33	28	33	34	26	31
Less than once a year or Never	46	32	50	43	29	38
Cycles						
At least once a week	12	8	16	9	10	6
Less than once a week but at least once a year	17	12	16	18	14	9
Less than once a year or Never	72	80	69	74	76	84
Walks more than 20mins						
At least once a week	60	61	59	60	74	44
Less than once a week but at least once a year	17	11	19	15	12	9
Less than once a year or Never	24	28	22	25	14	47
N	*144*	*74*	*64*	*80*	*42*	*32*

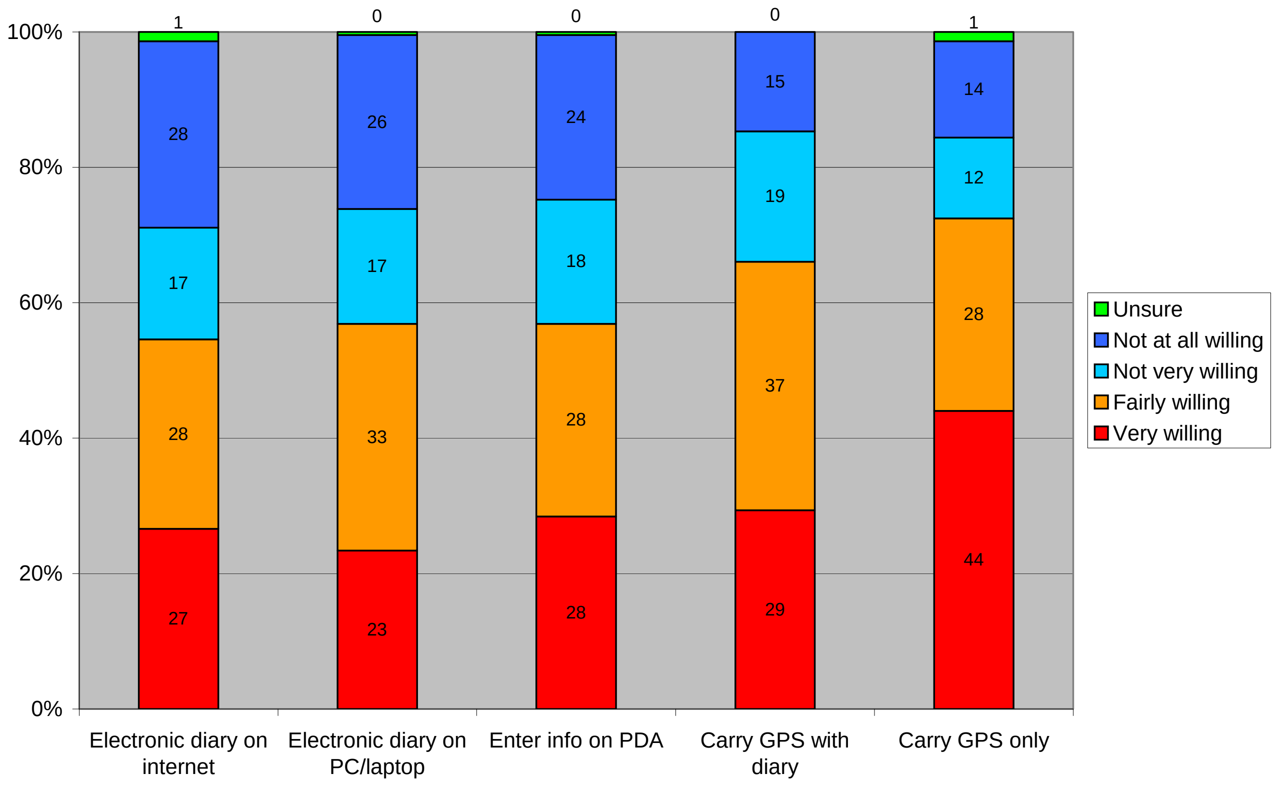
2.5.5 Willingness to use alternative methods of collecting diary data

Respondents willingness to use GPS compared favourably with their willingness to use alternative methods of collecting diary data.

Just over half were very or fairly willing to complete an electronic diary on a secure internet site (55 per cent), an electronic diary on a PC or laptop (57 per cent) or enter information on a PDA (57 per cent). Around one quarter of respondents (24-28 per cent) were not willing at all to use such methods.

Just looking at the proportion who were very willing to use the various methods of data collection, it can be seen that carrying a GPS device without a diary was perceived to be the most favourable option, with the proportion increasing to 44 per cent compared with 23-29 per cent for the alternatives.

Figure 2.3: Willingness to use alternative methods of data collection



2.5.6 Respondents concerns

Of those who were very/fairly willing to carry a GPS device alongside a diary, only 17 per cent said that they would have concerns. The predominant concern was about losing the GPS device or it being stolen (68 per cent). Other concerns were about being able to use the GPS device, having to carry the device, breaking the device, what would be done with data and the data being lost/stolen. Respondents said that they would like assurances that they would not be held financially responsible if the device was broken, lost or stolen. A few also thought that assurances about the security of the data and detailed instructions on how to use the GPS device would be helpful.

> *"You need to make information available to me how the data would be kept secure as I would be telling you where I am when I'm in & out of the house"*

Of those who were not very or not at all willing to carry a GPS device, the most common reasons were the invasion of privacy (19 per cent) and a lack of confidence using the technology (18 per cent).

> *"It would feel like I'm under surveillance"*

> *"The term big brother springs to mind"*

> *"I'm passed all that, I get mixed up and would want to give up the idea altogether"*

"I'd have to step into the 21st century. I'm not Mr 2008."

Other common reasons for their unwillingness were:
- Having to carry the device all the time (12 per cent)
- Having to complete a diary as well (12 per cent)
- Concern about the device being lost/stolen (8 per cent)
- Not needing to use as rarely go out (7 per cent)
- Finding it easier to complete a diary (5 per cent)

Concern over how the data would be used, breaking the device and potential loss of the data were also mentioned.

Of those who were not very or not at all willing to carry a GPS device, 66 per cent said that there was nothing that could be done to persuade them to carry a GPS device. Some felt that they could be persuaded but were unable to say how. Others said that they may be persuaded by:
- The size of the device and ease of use
- Assurances about the data being secure and how it was going to be used
- Some financial reward
- If they did not have to complete the diary as well

Discounting those who said they would be persuaded if they did not have to complete the diary as well, this leaves 28 per cent of those less willing who may be persuaded.

2.6 Implications for the mainstage

The findings from the telephone survey suggest that around 66 per cent of NTS non-proxy respondents may be willing to use a GPS device, alongside completing a diary (assuming that the telephone sample are not atypical in terms of their access to technology as previously noted). In addition to this, around 28 per cent of those less willing may be persuaded to do so. Together this suggests that up to 76 per cent of all NTS non-proxy respondents could be persuaded to complete a diary and use a GPS monitor.

To achieve this, the materials developed for the mainstage must take the concerns raised by the telephone survey respondents into account, as must the interviewer briefings, so that interviewers can clearly explain (and respondents understand):
- how the data will be used and securely stored
- how to use GPS monitor, instilling confidence in the respondent
- that they will not be held personally responsible for damage, theft or loss of the GPS device.

In addition to this it will be important for the respondent to feel supported throughout the process, knowing that they can contact their interviewer or the NatCen office should they have any queries or encounter difficulties.

The careful handling of respondent questions and the provision of support may help to encourage some of those less willing respondents to consent to using the GPS device. It may also be a factor in preventing 'partial' outcomes where respondents give up on using the GPS monitor part way through the travel week.

Based on the findings of the telephone survey and the NTS main response rate (around 60 per cent of households), a fully productive response rate (i.e. completing the diary and using the GPS device) of up to 46 per cent may be anticipated on the feasibility study fieldwork. However, there are a number of additional factors which should be considered and may influence the response rate achieved.

2.6.1 Reduced household burden

NTS currently requires the participation of all household members regardless of age. The feasibility study will include only those household members aged 16 or older. This will reduce the total interview length and the amount of effort required at household level to complete the diaries, and may have a positive impact on response.

2.6.2 Increased incentive voucher

It is likely that a £10 voucher per fully participating respondent will be offered for the feasibility study fieldwork. This is double the amount currently paid to NTS respondents and may also have a positive influence on the response rate.

2.6.3 Approaching households who have not already participated

The sample for the telephone survey consisted of people who had already taken part in the NTS, fully completing a diary. Although the telephone survey gives us an indication of GPS acceptability, theoretically giving consent in hindsight is not the same as giving consent at the time of the survey. It may overestimate acceptability if it is proves more difficult for interviewers to simultaneously persuade respondents to complete the diary and use the GPS device. On the other hand, it could be argued that recent respondents who are fully aware of the effort required for the diary may be less willing to look favourably upon an additional task compared with new respondents who are yet to start their diary. In addition to this, it may be that the novelty of using a GPS monitor is sufficient to encourage full participation amongst a few respondents who would normally be less amenable to completing a diary.

2.6.4 Inclusion of respondents interviewed by proxy

Because the telephone survey was restricted to NTS respondents who had given permission to be recontacted, the sample was restricted to respondents who were interviewed in person. Those whose interview data were collected by proxy are not asked for permission to recontact. In the main fieldwork, it is intended that respondents interviewed by proxy are also asked to use a GPS device. In many cases this will require the interviewer to leave the necessary instructions and rely on another household member to explain what is required and convince them to take part. This is likely to be less effective than the interviewer doing so him/herself[7] and therefore could have a negative influence on overall response.

[7] on the 2007 NTS, fully completed diaries were received for 86 per cent of respondents aged 16 or more who were interviewed by proxy compared with 93 per cent of respondents interviewed face to face

3 DEVICE REVIEW

3.1 Introduction

Since the review of ‘new technologies’ for use on the NTS, carried out in 2006, there has been substantial developments in the GPS market. In order to establish the GPS device most suitable for the project, GeoStats undertook a review and shortlisting exercise of appropriate GPS devices. This task involved the identification of portable (i.e. wearable) GPS data logging devices available on the market and the assessment of suitability of these devices based on the project requirements, which were defined to include:

- Form, size and weight – the devices should be relatively unobtrusive or else respondents may be reluctant to carry them around
- Battery life – the battery should support data collection for at least one day of travel activity without recharging to avoid data loss
- Ease of recharging (if applicable)
- Memory capacity – the memory must be capable of storing the data for the full period
- Cost – including any additional costs for chargers, cases etc.
- Ease of use
- Ease of downloading data
- Data elements captured – latitude, longitude, time, date, and speed are required
- Data quality – output data should be of high quality with regard to coverage area and horizontal positional accuracy

3.2 Available devices

After an extensive internet and vendor-based search conducted in March/April 2008, 32 wearable GPS logging devices were identified as available on the market. During the initial evaluation, all GPS data logging devices whose specifications did not meet a minimum memory capacity of 50,000 points, battery life of 14 hours, and the ability to download data via a USB connection were eliminated. This elimination process resulted in the selection of nine devices for further evaluation, Table 3.1.

Table 3.1: Nine GPS devices selected for further testing

Product	Battery life	Point capacity
Atmel BTT08 Data Logger	48-72 hours with vibration sensor	512,000
EverMore BT-900	Up to 24 hours	120,000
GiSTEQ PhotoTrackr	Up to 32 hours with vibration sensor	250,000
GlobalSat DG-100 Data Logger	24 hours	60,000
i-Blue 747 Data Logger	20 hours	100,000
i-Blue 821 Slim Trip Recorder	18 hours	150,000
Pharos Trips & Pics with GPS	24 hours	100,000
Qstarz BT-Q1000P	32 hours	100,000
Wintec WBT-201 Data Logger	15 hours w/o Bluetooth	131,072

These devices varied in size and weight but all weighed less than 68 grams[8] and were smaller than 80 by 70 by 23 millimetres (these are the largest values in each dimension). This represents a huge reduction in size and weight from previous generation devices and offers great promise for improved participant acceptance and usage. The purchase cost of the devices varied from £36 to £126 (at the time of the review).

The ability for a user to control the functionality of a device is critical to optimizing the storage capacity and the battery life of a device between recharges, as well as the usability of the device from both the participant and project coordinator perspectives. Speed screen and distance screen enable the devices to be set to limit the GPS points logged based on a speed or distance threshold (e.g., do not log points with a speed less than 1 mile per hour). This is critical for storage capacity reasons. The presence of a vibration sensor can extend the battery life between recharges up to several days by going into a low power mode whenever the device is not is use. Table 3.2 shows the configuration options available on the device selected for testing.

Table 3.2: Configuration options

Product	*Speed screen*	*Distance screen*	*Select output units*	*Vibration sensor*	*Blue-tooth option*	*Voice option*
Atmel BTT08	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
EverMore BT-900	*Yes*	*Yes*	*No*	*No*	*No*	*No*
GiSTEQ PhotoTrackr	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
GlobalSat DG-100	*Yes*	*Yes*	*Yes*	*No*	*No*	*No*
i-Blue 747	*Yes*	*Yes*	*Yes*	*No*	*Yes*	*No*
i-Blue 821	*Yes*	*Yes*	*Yes*	*No*	*Yes*	*No*
Pharos Trips & Pics	*Yes*	*Yes*	*Yes*	*No*	*No*	*No*
Qstarz BT-Q1000P	*Yes*	*Yes*	*Yes*	*No*	*Yes*	*No*
Wintec WBT-201	*Yes*	*Yes*	*Yes*	*No*	*Yes*	*No*

3.3 The testing process

To evaluate the performance and suitability of the nine devices selected, twelve tests were undertaken, broken into three test phases. At the end of each phase, some devices were eliminated based on that phase's results. Those devices remaining after a given phase of testing were then tested in the next phase.

Phase 1

- TEST ONE: Document data fields captured by each GPS device
- TEST TWO: Evaluate ease of use, form factor, and durability

Phase 2

- TEST THREE: Evaluate cold start acquisition time
- TEST FOUR: Compare GPS traces versus accuracy of road network
- TEST FIVE: Compare GPS traces between different manufacturers
- TEST SIX: Compare GPS traces between the same manufacturers (when possible)

[8] Based on information provided by the manufacturers. This may not always include the weight of the battery.

- TEST SEVEN: Evaluate GPS performance in urban canyon environment (i.e. a built up area containing numerous tall buildings)

Phase 3

- TEST EIGHT: Test battery life
- TEST NINE: Test memory capacity
- TEST TEN: Test volatile or non-volatile memory
- TEST ELEVEN: Check vibrations sensor effectiveness – *if applicable*
- TEST TWELVE: Check speed screen accuracy

3.3.1 Phase 1 Methods and Results

TEST ONE: Data fields captured by each GPS device

The data fields captured by each device, as seen in Table 3.3, can be deciding factors in determining whether a particular device can be used as a GPS data logger in household travel surveys. The output fields required are Latitude, Longitude, Date, Time and Speed. If these fields are captured, bearing (or heading) can be programmatically derived. It is not necessary to capture altitude for household travel surveys.

Horizontal Dilution of Precision (HDOP) and the Number of Satellites are primarily used for assessing the quality of the GPS data collected. These fields are not necessary, but can be useful in identifying bad or potentially bad data points.

Table 3.3: Captured data fields

Product	*Lat/ Long*	*Time/ Date*	*Speed*	*Bearing*	*Altitude*	*HDOP*	*Number of satellites*
Atmel BTT08	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
EverMore BT-900	*Yes*	*Yes*	*No*	*No*	*No*	*No*	*No*
GiSTEQ PhotoTrackr	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
GlobalSat DG-100	*Yes*	*Yes*	*Yes*	*No*	*Yes*	*No*	*No*
i-Blue 747	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*No*	*No*
i-Blue 821	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*No*	*No*
Pharos Trips & Pics	*Yes*	*Yes*	*Yes*	*Yes*	*No*	*No*	*No*
Qstarz BT-Q1000P	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*No*	*No*
Wintec WBT-201	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

TEST TWO: Evaluating ease of use, form factor, and durability

GeoStats asked staff members to carry GPS devices for a five-day period, to answer some basic questions, and to comment on issues related to ease of use, form factor and durability. Additional comments related to the device configuration and data download were documented by project team members. The qualitative assessments provided for each device were then aggregated into positive and negative categories and summarized in Table 3.4.

Table 3.4 Ease of use, form factor and durability review

Product	Positives	Negatives
Atmel BTT08 Data Logger	*• Battery life • Storage capacity • Vibration sensor • Data output format*	*• Multiple buttons on device • Voice feature • Lanyard carry option • Back detaches easily*
EverMore BT-900	*• One button on / off • Durability*	*• Bluetooth configuration • Data output*
GiSTEQ PhotoTrackr	*• Battery life • Storage capacity • Vibration sensor • Data output format*	*• Multiple buttons on device • Voice feature • Software • Back detaches easily*
GlobalSat DG-100 Data Logger	*• Single button on / off • Clip for carrying • Software • Durability*	*• Storage capacity • Does not capture HDOP or number of satellites*
i-Blue 747 Data Logger	*• Simple to use • Easy to configure/download • Appears to be durable*	*• Logging could be disabled using power switch • No carrying case / option*
i-Blue 821 Slim Trip Recorder	*• Light weight and sleek looking • Storage capacity*	*• Difficult to tell if the device is in logging mode • Lights are difficult to see*
Pharos Trips & Pics with GPS	*• Light weight and sleek looking*	*• Memory can be accidentally dislodged / likely lost. • Software*
Qstarz BT-Q1000P	*• Simple to use • Easy to configure / download • Appears to be durable*	*• Logging could be disabled using power switch • No carrying case / option*
Wintec WBT-201 Data Logger	*• Single on / off button • Small and lightweight*	*• Battery life • Other buttons easily pushed to further reduce battery life*

As a result of the first two tests, the Evermore BT-900 and Pharos Trips & Pics were eliminated from further evaluation. The Evermore was eliminated for two reasons: first, the device can only be configured via Bluetooth (downloaded via USB), which causes significant issues when multiple devices are being configured on the same computer; and second, the data output is extremely difficult to interpret. This would require software to be written to standardize the content and format of the data output. The Pharos was eliminated because the memory component easily pops off of the device and is likely to be lost or misplaced. The other seven devices moved into the next phase of testing, even though there were concerns regarding the power switch and / or the ability to verify data logging on several of these devices. These remaining issues were evaluated in tandem with the spatial accuracy tests that followed in Phase 2.

3.3.2 Phase 2 Methods and Results

The second phase of testing focused on the quality of the data captured by each device. For these rounds of testing, all devices were assigned a number. This allowed the positional data accuracy analysis to be carried out in a blind or unbiased manner.

TEST THREE: Evaluating cold start acquisition time

How quickly a device acquires a satellite fix (i.e. receives signals from at least four of the 24 GPS satellites orbiting the earth) after moving from indoors to outdoors is important to the capture of complete trip information, especially trip start details. To test this, each GPS device was fully charged indoors (and out of sky view for at least four hours) and then taken outdoors into an open area with a clear sky view (this represents optimal conditions). Table 3.5 shows the number of seconds that passed until each device obtained a location fix. (Devices 10, 11, 12 and 13 were eliminated from testing before the third cold start test, which was conducted later in the testing process.)

Table 3.5 Satellite acquisition test results (in seconds)

ID	Product	Cold Start 1	Cold Start 2	Cold Start 3	Average Cold Start
1	GlobalSat DG-100	32	22	36	30
2	GlobalSat DG-100	38	34	25	32
4	GiSTEQ PhotoTrackr	42	40	95	59
5	GiSTEQ PhotoTrackr	142	38	96	59
6	i-Blue 747	136	46	43	75
7	i-Blue 747	34	41	54	43
8	Atmel BTT08	20	22	-	21
9	Atmel BTT08	28	58	55	47
10	i-Blue 821	28	39	-	34
11	i-Blue 821	36	66	-	51
12	Wintec WBT-201	40	35	-	38
13	Wintec WBT-201	29	42	-	36
14	Qstarz BT-Q1000P	55	48	92	65
15	Qstarz BT-Q1000P	41	38	52	44

TESTS FOUR to SEVEN: Comparing GPS traces for accuracy and evaluating performance in urban canyon environment

Analysis was undertaken to identify the spatial errors in the data collected by the devices with respect to predefined network test routes located in Atlanta, Georgia. This procedure included matching the GPS points to GIS datasets and statistical analyses of the distances between the collected points and the reference route. (Appendix C provides greater details on the processing and analysis undertaken). These analyses provide the results of tests four through seven.[9]

The GPS data collected were viewed together with the corresponding road network and aerial photography of the area. Visual inspection of the GPS traces revealed that all of the GPS data loggers seemed to perform very well throughout the test routes, including the urban canyon areas of downtown Atlanta. At one-second logging frequencies, there was no doubt regarding the travel path taken. Less frequent logging intervals, such as three to five seconds, would also produce route traces that could easily be processed for household travel survey needs.

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[9] In a separate but related testing effort, a GeoStats employee travelled to New York City for a weekend trip. During this time, GPS data were collected using the Atmel BTT08 and the GlobalSat DG-100 along three routes in New York City to evaluate how well each device performs in a dense urban environment. The results of these tests are available in Appendix C of this report.

Examination of the GPS data files revealed that all devices did indeed record one point per second during the test runs, even during the more challenging urban canyon portion of the routes.

An automated process was used to analyze the spatial errors observed between the tested GPS loggers and the developed test routes. This procedure included matching the GPS points to a GIS dataset and computing the distances between the collected points and the reference route based on the closest route link. **Error! Reference source not found.** shows summary statistics of the computed distances by device. When looking at the average distances, it can be seen that most devices performed remarkably well with average distance of 12 meters or less. The standard deviation values for the devices were in the same order of magnitude as the averages, showing small distance variability which is an indicator of good spatial stability of the reported points.

Table 3.6: Average distance to route reference segments (in metres)

ID	*Product*	*Average distance*	*Standard Deviation*
1	*GlobalSat DG-100*	*9.1*	*9.2*
2	*GlobalSat DG-100*	*7.7*	*9.1*
4	*GiSTEQ PhotoTrackr*	*7.7*	*9.5*
5	*GiSTEQ PhotoTrackr*	*6.9*	*6.6*
6	*i-Blue 747*	*5.7*	*4.5*
7	*i-Blue 747*	*7.6*	*7.3*
9	*Atmel BTT08*	*10.2*	*11.2*
10	*i-Blue 821*	*11.0*	*11.3*
11	*i-Blue 821*	*11.7*	*12.3*
13	*Wintec WBT-201*	*7.2*	*7.6*
15	*Qstarz BT-Q1000P*	*6.3*	*7.8*

As expected, higher urban density areas (reflecting urban canyon conditions) caused performance to degrade, with higher average errors and variability observed. Performance in lower urban densities is very close for the tested devices, with the majority of points falling within 15 meters of the route's centreline. On the other hand, there was a wider distribution for the 'distance to route' variable under urban canyon conditions.

Overall, the devices demonstrated very similar performance. This is an expected result as the GPS receiver industry has become heavily commoditized in the recent years, with most of manufacturers using the same GPS chipsets. After these tests were completed, the i-Blue 821 was removed from consideration because it is difficult to verify that it is logging properly, and it is relatively easy to accidentally turn the device off because of the location of the power switch. The Wintec-201 was also eliminated at this point due to limited battery life and the ease of accidentally turning on the Bluetooth functionality, further reducing the battery life.

3.3.3 Phase 3 methods and results

The final testing phase was designed to verify the vendor-provided or published specifications for battery life, point capacity, memory type and data screens (vibration sensor / speed screen) for the remaining five devices.

TEST EIGHT: Testing battery life

The batteries on the five remaining devices were fully charged. They were then disconnected from the chargers and carried in a manner similar to that if used in a household travel survey.

All devices without a vibration sensor performed similarly in the 24 to 32 hour range. The units with the vibration sensor, when the vibration sensor was turned off, performed identically to the non-vibration sensor devices. As expected, the best-performing units were those equipped with a vibration sensor when the sensor activated, with the Atmel lasting 60 hours and the GisTEQ PhotoTrackr lasting 72 hours.

TEST NINE: Test memory capacity

All of the final five devices were found to have a memory capacity that met or exceeded that listed by the manufacturer. Furthermore, the point capacity for all devices is sufficient to cover a 7-day deployment period with the logging parameters properly set for each device.

TEST TEN: Test volatile or non-volatile memory

It is particularly important that the GPS memory on any devices deployed into the field have non-volatile memory, meaning that if the device completely loses power at any time, all data collected on the device remains on the device. Data were collected on each of the five devices tested in Phase 3. The devices were then run until no power capacity remained and were left without power for several days after which they were powered and data downloaded. This confirmed that the memory on the five remaining devices was not volatile.

TEST ELEVEN: Check vibration sensor effectiveness

The vibration sensors on the Atmel BTT08 and GisTEQ work well for preserving battery life. The devices go into “sleep mode” when they have not been moved for 15 or more minutes and “wake up” when moved. For a 7-day deployment period, however, all devices would need to be recharged several times during the deployment period to provide sufficient power throughout the week. Consequently, it is recommended that participants are instructed to recharge devices nightly. This will make it easier for participants to understand and comply with study procedures, rather than asking them to recharge the device every few days. If participants do forget to recharge for one or two nights during the week, then the vibration sensor feature should provide adequate power during the following days. For the devices without the vibration sensor, this may not be the case.

TEST TWELVE: Check speed screen accuracy

Initial tests indicated that the speed screen functionality on the five remaining devices operate as expected when the GPS is in motion. All devices maintain at least a low-level “fix” inside some structures. In these instances, a false speed greater than one mph is often reported. These “phantom points” are considered normal “noise” given the performance of the latest GPS chipsets and are eliminated before delivery during the data processing step.

3.4 Shortlisted devices

After the final set of tests, the GisTEQ and the Qstarz were eliminated from further consideration. The GisTEQ is essentially the same device as the Atmel, only with half the point capacity. The QStarz is identical to the iBlue 747 – with the iBlue 747 having a slightly preferable style with respect to buttons and LEDs.

Consequently, it was recommended that the Atmel BTT08, the GlobalSat DG-100 and iBlue 747 continue on into the pre-test phase of the study. All three devices tested well and the Atmel and GlobalSat have been successfully deployed in numerous wearable GPS studies with reported success. When properly configured, the point capacity, battery life and positional accuracy of these devices exceeded the requirements for this study, although there were some concerns that the “LOG” / “NAV” switch on the iBlue 747 will result in accidental data loss.

4 PRE-FIELDWORK TESTING OF THE SHORTLISTED DEVICES

4.1 Aims and method

Once the most appropriate GPS units had been identified, pre-fieldwork testing was conducted to trial the three shortlisted GPS devices and identify any potential problems with using them for the study.

Specifically this pre-fieldwork testing aimed to explore:

- Whether the devices are easy to use
- Whether the respondent instructions are understood by participants and provide all of the necessary information
- Whether participants remember to use the devices and use them as instructed
- Whether the devices meet manufacturers claims in terms of battery life and reliability
- Whether there are any problems experienced when downloading GPS data
- Whether there are any instances of data loss and the reasons for this

The participants for the trial consisted of volunteers from the DfT and NatCen research team. Participants were provided with a GPS unit and an information sheet providing instructions on how to use the device. Participants were asked to use the GPS device for a period of time (5-7 days) and to complete a daily feedback form, recording any problems experienced. They were also asked to complete a travel diary over the same period.

Initially it was envisaged that there would only be one round of pre-fieldwork testing. However, a number of issues were encountered in the first round, outlined below. In light of this, a second round of testing was considered prudent.

4.2 Participant experiences

4.2.1 Charging devices

On the whole, the testers did remember to charge the devices overnight – although on the odd occasion people either forgot, or did not charge the device as they had hardly used it the previous day.

However, problems were experienced in terms of knowing when the device was fully charged. Some of the GlobalSat devices did not appear to be fully charged from day one, the other devices of this type developed the same problem a day or two later. All six devices failed to work after two or three days. It appears that the batteries stopped charging/holding charge. This problem had not been previously encountered by GeoStats who have successfully used this device in hundreds of deployments within the United States. The same problem was encountered even when a different adaptor plug was used. One GlobalSat tester, whose device had stopped holding charge, charged the batteries in a separate battery charger overnight rather than through the GPS device. The battery stayed charged for the whole of the next day. This suggested that there is a problem with the power adaptor or device itself rather than the battery.

For the second round of testing the problem with the GlobalSat devices not charging was remedied by using new chargers which provided higher level charging. One person using the GlobalSat reported concerns that their device appeared to turn off for no reason when charging and so would have to switch it on again. It was unclear whether this meant that the device was fully charged or not. As the lights did not change, even when the device is fully charged, testers were unable to tell for certain when the device was fully charged.

One tester using the Atmel reported that the solid green light (fully charged) sometimes showed before the light started flashing (charging). Furthermore sometimes the light would not start flashing until the plug was 'jiggled'. One tester using the Atmel reported, that at times, the device looked like it was logging while it was charging. Another tester of the same device thought that the device was fully charged one day, however the battery ran out before the day was over. One tester using the iBlue device found that part way through the week they were unable to charge from the mains but were still able to charge the device via a PC USB connection, suggesting a problem with the adaptor plug rather than the device.

4.2.2 Carrying the devices

The testers usually remembered to carry the device with them, although a couple forgot on odd occasions. Some testers reported concerns regarding carrying the device. The GlobalSat device is more bulky than the others and only has a clip for carrying. Some reported not feeling confident that the device would remain attached when clipped onto clothes, although thought it felt secure when clipped onto a bag, and found it unsuitable to clip onto some outfits. One Globalsat tester reported that the screws on the back of the clip loosened as they moved around and occasionally came off; they felt that it would have been easier to carry a device worn around the neck.

The iBlue and Atmel are similarly sized and have a strap to be worn around the neck. In addition, these devices can be unclipped from the strap and clipped onto a belt-loop or bag, which some testers found more convenient. However, some thought that a bigger clip would be helpful to make it easier to do this – one tester attached their own clip to enable them to easily clip it onto their bag.

Testers who tried to run with the GPS device did encounter difficulties as they could not run with the device round their necks and had nothing to clip it on to – on occasions it was put in a pocket where available, on others it was left at home. Concern was also raised about how easy it is to knock the devices against things when they are attached to your bag. Generally testers were unwilling to wear the devices around their neck because they were either too big and conspicuous or they felt uncomfortable wearing it in this fashion. At times, some testers also preferred, to carry the device in their bags or in a pocket. The impact of this of the data collected will need to be examined.

Testers of the GlobalSat and Atmel reported of being very aware of having the device on show due to the size of the former and the multiple flashing lights on the latter, and sometimes felt safer concealing the device in a bag when out in public and/or at night. One of the testers of the iBlue device also said that they felt conscious of the flashing lights at night.

Concern was raised by some testers about the fact that the instructions stated the devices should not be worn under a coat or in a bag. This raised practical issues regarding ease of use and concerns about safety/theft. Further thought should be given as to how respondents are asked to carry the devices. It may be that while keeping the device in a bag may increase the risk of losing the satellite signal, being able to do this means respondents are less likely to forget to carry the device.

The testers had a couple of queries regarding what they should do with the device when it rains, whether the device is waterproof and what they should do if visiting a hospital (i.e. should they switch it off). The instructions for round two were amended to address these issues.

4.2.3 Ease of use

All the devices were easy to switch on and off. However, the testers using the Atmel and iBlue reported difficulties understanding the lights on the device. The Atmel device sometimes had all lights flashing or flashed amber and the testers were unclear as to what this meant and whether they needed to take action. Another Atmel tester reported that the brightness of the lights, and the fact each light spread over both display windows, made it difficult to tell which was on and whether they were flashing. One tester also found it counter-intuitive that the flashing red light meant that everything was fine in that the device had a satellite signal.

Some Atmel testers found that the device did not always show a red light when they were outside as they would have expected, the instructions did not make it clear what this meant or whether they need to do anything. Some testers also noted how the Atmel's lights would turn off if there had been no movement for a while, which could cause some confusion as to whether it was working or not. The Atmel testers all experienced the device 'talking' and managed (eventually) to switch this off, although the instructions could be clearer as to how this is done.

Some testers using the GlobalSat queried which position the switch on the side should be set at. The position of this switch does not have any impact as all modes are set the same but this should be made clear in any future instructions. One tester using a GlobalSat device noted how it seemed to periodically turn off, although this could have been because it was not fully charged or was being turned off accidentally.

The instruction sheets were amended for the second round of testing to ensure that respondents were clear as to what action, if any, they should take when the lights changed (or a voice is heard) or whether they could ignore this.

Testers using the iBlue device reported that towards the end of the week the device showed a blue light. The instruction sheet made no reference to the blue light so they were unsure whether this indicated a problem. In the second round of testing the cause of this was identified, this was because the device was running out of memory as it had not retained it configuration settings and so was logging every 1 second (see section on processing for further detail). For this reason the iBlue was eliminated from any further consideration.

One iBlue device did not record any GPS data during the first round. This may have been because the switch on the side of the device had been knocked from the log position. The instruction sheets needs to make clear the position any switches should be in and request that the respondents periodically check this.

For the mainstage, most respondents will not be as reliant on reading the instructions as the testers were as the interviewer will explain to them how to use the device. Interviewers will be given clear instructions on the key things to cover with respondents.

4.2.4 Impact on completion of the diary

Testers felt that using the GPS device had some impact on their diary completion. Some felt that they needed to ensure that all the info recorded in the diary was exact as the GPS device would highlight their errors. Others felt that they could worry less about the detail in the diary as the GPS data would provide exact time, distance etc. Concern was also raised about whether respondents who forgot to take their GPS device on a journey may choose not to enter the journey in their diaries, rather than admit to having forgotten. Similarly if a respondent chose not to take the device with them (e.g. because it was difficult to carry when they were running), they may also decide not to 'own up' to doing this by not recording the journey in their diary. The impact of using the GPS device on diary completion will need to be considered in interpreting the mainstage findings.

4.3 Ease of download

The iBlue download took substantially longer than the other downloads and the file was seven times bigger than the Atmel download, in spite of the devices being set to only take a reading every 3 seconds compared with every second with the Atmel. Furthermore the iBlue data file is in a format that cannot be viewed to enable easy checking of the data downloaded. The GlobalSat and Atmel data files are saved in .csv format and therefore can be easily viewed to verify.

In the second round the iBlue devices continued to take a particularly long time to download. It transpired that the devices did not hold their configuration settings and so had been logging every second rather than every 3 seconds and therefore created very large data files. The flashing blue light encountered during the testing period was due to the memory being nearly full. As mentioned above, the iBlue was eliminated from any further consideration.

The GlobalSat and iBlue download procedure allows you to specify where the file is saved and the name of the data file. The Atmel download automatically names and save the file in a subfolder which then needs to be moved and renamed. This may increase the risk of data being confused and mislabelled.

The GlobalSat device was the most straightforward and quickest device to download followed by the Atmel.

4.4 Data processing

The processing of the GPS data was undertaken by GeoStats using their Trip Identification and Analysis System (TIAS). Multimodal trips, trips that used more than one mode of transport, were left as a single trip for the first round with an associated comment recorded (i.e. MMT: bike, train, bike). For the second round multimodal trips were broken into individual stages to make them more comparable to the travel record methodology.

4.4.1 Device settings

For the first round of testing, GeoStats defined the logging frequency and configuration settings for each device based on knowledge gained from previous experience with the equipment and the point capacity available for each device. For the second round of testing, the logging frequency and configuration was adjusted to the likely settings to be used in the data collection phase, based on the lessons learned during the first round. Table 4.1 shows the logging frequencies recommended for each device at each round of testing.

Table 4.1: Recommended device setting for rounds 1 and 2

	Round 1			Round 2		
Product	Logging freq	Speed screen	Vibration Sensor	Logging freq	Speed screen	Vibration Sensor
Atmel Btt08	1 second	ON, 1 mph	ON	4 seconds	ON, 1 mph	ON
GlobalSat DG-100	5 seconds	ON, 1 mph	N/A	4 seconds	ON, 1 mph	N/A
iBlue 747	3 seconds	ON, 1 mph	N/A	4 seconds	ON, 1 mph	N/A

During the first round a number of the devices had varying configuration settings to that recommended, this was largely rectified in the second round. For the second round of testing, the instructions for configuring the devices were amended to ensure that all steps were made clear and that the configuration was checked by a second researcher prior to the testing.

4.4.2 Round 1 : Data Processing

Atmel processing

For the first round, processing the Atmel data files proved challenging, as three of the four devices had been configured to record data at 100 metre distance intervals rather than the recommended one-second time interval. Consequently, due to the spacing between points, it was difficult to determine accurate trip end points in these data files. It also appears that the origins and destinations for these trips may be slightly inaccurate (the first and last points were sometimes captured 100 metres or more from the actual destination) due to the speed screen and distance interval being used in conjunction.

The one Atmel device that did record at the recommended one-second time interval was also difficult to process due to the large number of points collected and the messy / wavy GPS trace (which swayed back and forth 200 or more feet from the travel path centreline). One explanation for the wavy path could be that the GPS device was not worn with a clear sky view, such as inside a purse or backpack.

A more wavy/messy trace results in somewhat longer distance estimates. The average speed of travel could also be affected by a wavy trace as this is calculated using the total distance. Direct comparisons of Atmel and GlobalSat distances for matched trips collected during the pre-test resulted in inconclusive results due to the range of testing variables experienced in the pre-test. These include different GPS satellite signal dropouts experienced by each device at different times, one device being turned off/battery dead and devices being carried/worn in different manners (such as one on the body and the other in a bag). Furthermore, the majority of stages collected in the pre-test were short walking trips where the trip distances were primarily less than one mile. When comparing trips of short distances such as these, the differences were found to be quite small. Just looking at the relatively small number of stages where the duration identified by the Atmel and GlobalSat for the same journey differed by no more than a minute (27 stages), the average absolute difference in the distance record was 0.06 miles – although in the majority of these cases (19 cases) the difference was less than 0.05 miles.

GlobalStat processing

The GlobalSat files were the cleanest and most efficient files to process. Three of the four files recorded at the recommended 5-second interval. This interval seemed to be appropriate to record walking trips and high-speed train trips without additional noise which can increase difficulty in processing GPS files (see Appendix D, figure 2 for further details).

iBlue Processing

The iBlue GPS files required additional pre-processing cleaning before they could be processed due to the fact that the speed screen was either not enabled or did not work for any of the three files. When the speed screen is not enabled, the GPS collects a point at the specified recording interval regardless of whether the participant is moving (often resulting in many, many points being captured near home and work that should have been filtered; these ‘Phantom’ trips can then obscure valid short walks trips) (See Appendix D, figure 3 for further details). In longer GPS studies, enabling the speed screen (and/or vibration sensor) is essential to ensure that that the GPS device does not fill to capacity before the end of the deployment period.

All GPS points with a speed less than 1 mph before processing were eliminated (i.e. those points the speed screen would have eliminated). This eliminated approximately 60 per cent of the captured GPS points. In longer GPS studies, enabling the speed screen (and/or vibration sensor) is essential to ensure that that the GPS device does not fill to capacity before the end of the deployment period.

In addition to the omission of the speed screen settings, the iBlue GPS data were captured at a one-second frequency, rather than the recommended three-second logging frequency. This resulted in many more captured points than were necessary to identify trip ends and mode, and slowed the processing considerably (see Appendix D, figure 4 for further details).

Recommendations from data processing: round 1

Three to six second logging frequencies were found to be suitable for collecting sufficient GPS point data to reconstruct travel patterns. One second frequencies tended to produce too much data, sometimes making data handling and processing more difficult.

Due to the varying GPS logging configurations used in the first round and challenges experienced with the GlobalSat charger in the UK, which caused some of the units to stop working, a second round of testing using standardised GPS configuration settings was conducted.

4.4.3 Round 2: Data Processing

For the second round, all devices were configured to record at a 4-second time interval with the speed screen activated at 1 mph. Standardising the configuration settings made data download and processing much quicker by reducing the number of points captured without compromising analysis capabilities. This interval seemed to be appropriate for recording walking trips and high-speed train trips without the additional noise found in 1-second frequency GPS data that can increase difficulty in processing GPS files.

Atmel Processing

Processing the Atmel files was easier than in round one of the pretests since the logging rules were set at a 4-second interval, rather than the 1-second interval recommended (or the 100-meter interval actually implemented) in the first round of testing. All six files recorded at the recommended 4-second interval. Both the speed screen and vibration sensor configuration setting worked properly, with the vibration sensor screening out additional points collected by the other two devices during idle times. This reduction in points logged allows for slightly quicker data download and transfer times. However, even with these settings, there were still many instances where the GPS trace was quite messy or wavy.

GlobalSat Processing

From a data processing standpoint, the GlobalSat files were once again the cleanest (and therefore easiest) files to process, with a minimum number of trips containing a wavy trace or lost data due to signal loss. All six files were recorded at the recommended 4-second interval, and the 1 mph speed screen worked properly.

iBlue Processing

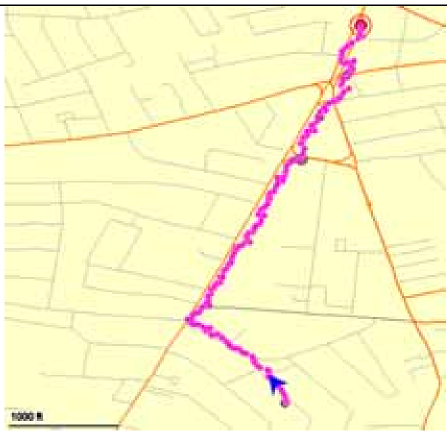
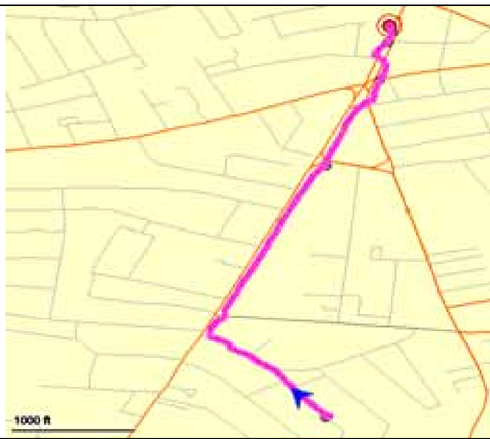
Once again, the iBlue GPS files required additional post-processing before they could be processed due to the fact that the 4-second recording interval with the speed screen enabled did not work properly for any of the five tests. Since the speed screen was not enabled, the GPS collected a point every second (which was the default logging interval) regardless of whether the participant was moving. GeoStats eliminated all GPS points with a speed less than 1 mph before processing (again, deleting the points that would not have been logged had the speed screen been working properly).

In addition to the omission of the speed screen settings, the iBlue GPS data were captured at a 1-second frequency, rather than the recommended 4-second logging frequency. This resulted in many more captured points than were necessary to identify trip ends and mode, and slowed the processing considerably.

Head-to-Head Evaluation: the Atmel and GlobalSat

During the second round of testing, some participants carried two devices simultaneously for comparison purposes. When maps of the Atmel and GlobalSat GPS traces for the same trips were compared, the GlobalSat GPS points showed a clearer route than the more 'wavy' Atmel trace. Figure 4.1 shows examples of GPS traces collected during the pre-test on each device.

Figure 4.1: Example traces

	Atmel Traces	GlobalSat Traces
Example One		
Example Two		

4.4.4 Recommendations from data processing

Processing the GPS data collected by the various devices proved to be much more challenging than originally anticipated. For the first round of testing, considerable time was spent trying to identify the data issues and anomalies that were encountered due to the logging frequencies and rules that were used. In fact, handling these issues took much more time than actually processing the files.

The efficiency improved dramatically during the second round, with all participants returning valid data and the configuration settings working properly on all of the Atmel and GlobalSat devices. Four-second logging frequencies were found to work well for collecting sufficient GPS point data to reconstruct travel patterns using wearable GPS devices. One-second frequencies in person-based GPS studies tend to produce too much data, sometimes making data handling and processing more difficult.

The speed screen is also a huge aid in reducing the number of unnecessary points logged on a wearable, self-powered device, making the download and processing time significantly faster. This feature also assists with storage capacity management, allowing lower capacity devices to collect data for longer periods without any storage issues. The vibration sensor present in the Atmel device also assists with reducing the number of unnecessary points collected.

The iBlue 747 was unable to maintain the configuration settings for logging frequency and speed screen. Even when the device is configured with the speed screen enabled, the iBlue 747 continues to collect GPS points when stationary or moving very slowly. This device also seemed to have issues maintaining the configuration setting for logging frequency, indicating that the speed screen issue, is representative of a more widespread configuration problem with this device.

The Atmel BTT08 and the GlobalSat DG-100 remain viable options, with the Atmel device causing some additional processing challenges due to the messy / wavy point traces seen in the pretest. The source or cause of this variation was unclear.

4.4.5 Data quality: GPS data comparison to travel records

Once the GPS files had been processed, trip level data could then be compared to the travel records. On the whole, all the devices performed similarly, recording most of the journeys and capturing some that were not reported in the travel record. However, each device did fail to record some journeys which had been referenced in the travel records. In some of these missing GPS trip cases, the participant forgot to carry the device or accidentally turned the device off while carrying it in a bag. One tester using both the Atmel and GlobalSat reported that they forgot to recharge the devices nightly, which resulted in GPS data loss on the GlobalSat device. In this instance, the Atmel did continue to capture data since its battery life between recharges is extended due to the vibration sensor. However all of the devices also fail to record some trips recorded in the diary, including walking trips, for unknown reasons.[10] (See Appendix D for an example.)

Just including those journeys when testers were known to be carrying their GPS devices and the device to be working, 25 per cent of journey stages that were recorded in the travel record by the testers were missing in the Atmel data and 20 per cent in the GlobalSat data. This is similar to the proportion of missing stages found in a previous GPS study conducted in London.[11]

[10] For instance the tester feedback indicated that the device was charged, they had taken the device with them, and had worn/carried it in the recommended manner.

[11] Steer Davies Gleave and GeoStats (2003), The Use of GPS to Improve Travel Data: Use of GPS in Travel Surveys, Study report prepares for DTLR New Horizons Programme.

Table 4.2: Data comparison against diaries based on round 2 of testing

	Atmel	*GlobalSat*
Number of stages in diary	*161*	*169*
% lost due to respondent forgetting device or forgetting to switch on	*15%*	*11%*
% lost due battery running out, device switching off etc	*2%*	*11%*
Number of stages where GPS thought to be switched on and working	*133*	*132*
% not recorded by GPS (although device thought to be working)	*25%*	*20%*
% with potentially matching GPS data	*70%*	*74%*
% with partial GPS data	*5%*	*5%*

In addition, and as expected, the devices struggled to maintain/find a signal on the Underground and on other forms of public transport. Of those journey stages missed, 46 per cent were on the Underground, 18 per cent on an over-ground train and 10 per cent on a bus. One quarter of the missed journey stages were walks. Some of the difficulties encountered may reflect that many of the testers were based in London which is more densely built-up making it more difficult to establish a satellite signal. This is likely to be less of a problem in other areas of the country.

Both the GlobalSat and the Atmel devices were carried by different testers in their bags and this did not appear to affect the signal in a consistently negative fashion. One tester who carried their GlobalSat device in their bag did have a number of missing journeys. This may have been because the device was at the bottom of their bag and was perhaps getting turned off accidentally.

The route maps tended to be more accurate if the GPS device was worn on the outside of peoples' clothing rather than in a bag. If the device was carried in a bag the route mapped sometimes jumped about the actual route taken, although the route was still often discernible.

Where testers carried two devices at the same time, and where a journey appeared to be recorded by both, there could be slight differences in the timings of journeys, the duration of a journey and the distance recorded. Usually such differences were relatively small (i.e. less than one mile and around 1-2 minutes) but on occasions they were larger than this, most probably because one of the device took longer to acquire a signal or lost the signal before the end of the journey. However, it is difficult to discern which was the most accurate, even with a completed diary.

4.5 Summary

The Atmel and GlobalSat devices appeared to be suitable for use on the National Travel Survey. Both have advantages over the other. The GlobalSat device is simple to use and the data most easily downloaded and processed. The Atmel device is smaller, easier to carry/wear and benefits from a longer battery life should respondents forget to charge the device.

The two key concerns for a study of this nature are whether the device will be acceptable to respondents and whether the data will be sufficiently accurate and usable. The GlobalSat is the easiest to operate but was considered bulky and difficult to carry/wear by the testers. This could make it off-putting for respondents particularly for a seven day study unless they are able to carry it inside a bag. However this would sometimes disrupt the signal received. The Atmel is easier to carry but the data can be more problematic, although still usable.

For the Atmel, the instructions would need to be reviewed to draw attention to what the respondent should do if the device starts talking. For the mainstage survey, interviewers should also be briefed to cover this in their explanations. In addition to this, the device should be issued with a larger clip to aid easy carrying/wearing.

The following table summarises the issues for each device tested.

Table 4.3: Summary from round 1 and 2 testing

	GlobalSat DG-100	Atmel BTT308	iBlue 747
Battery life	*24 hours*	*48-72 hours with vibration sensor*	*20 hours*
Functions	*Has speed/distance screen but no vibration sensor*	*Has speed/distance screen and vibration sensor*	*Has speed/distance screen but no vibration sensor*
Data recorded	*Latitude, longitude, time, date, speed, altitude*	*Latitude, longitude, time, date, speed, altitude, bearing, HDOP/number of satellites*	*Latitude, longitude, time, date, speed, altitude, bearing*
Settings	*Settings maintained throughout testing*	*Settings maintained throughout testing*	*Settings not maintained for speed screen and logging frequency*
Charging	*Problems initially encountered, but remedied with new chargers.* *Cannot tell when device is fully charged*	*Sometimes the cable needed to be jiggled before charging would start.* *Device can sometimes look like it is logging whilst charging* *Benefits from a long battery life when used with vibration sensor .*	*Encountered some charging problems with one device but able to charge using USB*
Carrying/ wearing	*Bulky and not always suitable to clip onto clothes. Bulkiness could deter respondents from taking it out on certain trips including jogging and social trips to pub etc. It would be more convenient to carry in bag.*	*Small and relatively easy to carry but would benefit from larger clip*	*Small and relatively easy to carry but would benefit from larger clip*
Safety issues	*Some conscious of it being on display due to size*	*Some conscious of it being on display when all the lights are flashing and when the device starts speaking.*	*Some conscious of it being on display when lights are flashing.*
Ease of use	*Simple to use*	*Lights can be confusing and it is surprising when it starts talking. Although the instructions did explain how to turn the volume down, testers did not always read them before using the device.* *The lights on the device sometimes seem to go off if there was no movement for a while.*	*Lights could be confusing. Instructions which explained how to turn the blue light off did not work – this was because the device did not retain its configuration so the blue light indicated that the memory was nearly full.* *Risk of switch being in wrong position and data not recorded.*
Data format	*.csv format*	*.csv format*	*.nmea format*
Download	*Straightforward*	*Straightforward but need to rename file*	*Takes a relatively long time, data file is much larger due to logging every second.*
Trace accuracy		*Route tends to be more 'wavy' than the GlobalSat*	
Processed data compared to travel record	*Collects most journeys, though some missed trips. Route can be difficult to make out if carried inside a bag.*	*Collects most journeys, though some missed trips. Route can be difficult to make out if carried inside a bag.*	*Collects most journeys, though some missed trips. Route can be difficult to make out if carried inside a bag.*

5 RECOMMENDATIONS

The findings of the preliminary phase are promising. The telephone survey has shown that a reasonable level of acceptability of GPS devices exists among NTS respondents. The device review and pre-fieldwork testing have identified devices which are fit for the purpose of this study. This final chapter outlines the recommendations for the data collection phase of the feasibility study; highlighting the issues, based upon these findings, which require particular attention in order to move forward.

5.1 The device

One of the main purposes of this study is to investigate the acceptability of GPS devices to respondents over a seven day data collection period; if respondents cannot be persuaded to use the devices then it will not be possible to examine the accuracy of diary estimates. One of key considerations for respondents is likely to be the form and size of the device they are being asked to use. On this basis, the DfT and NatCen decided that the Atmel device should be used for the main fieldwork. This device is smaller than the GlobalSat and has the potential to be worn/carried in different ways, reducing the likelihood of respondents carrying the device inside a bag. (For the main fieldwork, the device will be issued with a larger clip, in addition to the neck strap, to enable respondents to clip it to their bag or clothing.) As technology develops, one would anticipate that GPS loggers will continue to become less bulky. Consequently, using a more bulky device for the fieldwork of this study may limit the relevance of the resulting estimates of acceptability and recommendations regarding implementation on a future large scale survey.

Additionally, the use of the Atmel, with its longer battery life, means that data should still be collected even when a respondent has forgotten or been unable to charge the device overnight.

The device instructions issued to respondents will make clear what respondents should do if the device starts ‘talking’ – this was the most common complaint from testers. Interviewers will also be briefed to explain this to respondents.

While it is recognised that the trace from the Atmel device can be slightly more wavy, and will have some impact on the accuracy of estimates, this is not believed to be a significant problem.

5.2 Interviewer training

In the main fieldwork, in addition to following normal National Travel Survey procedures, interviewer will need to be able to explain to respondents:

- What GPS data is
- How the data is stored (i.e. on the device)
- What the data will be used for
- Who will have access to the data
- How to use the GPS device

It is likely that interviewers may encounter some suspicion about the purpose of collecting GPS data and the implications for respondent confidentiality. Interviewers will need to be fully briefed on these issues, in addition to the procedural and administrative elements of the fieldwork.

In order to aid interviewers in doing this, it is recommended that interviewers are asked to carry the devices themselves for a few days prior to the briefing so that they familiarise themselves with the process and issues that respondents may encounter.

5.3 Informed consent

Gaining informed consent from respondents is a vital part of the research process as it is essential to ensure that those who participate in the study understand exactly what it involves. In order to give truly informed consent, interviewers will have to explain and make sure respondents understand what GPS data is, how it will be used and who will have access to it.

In order to do this, interviewers will be briefed on all the issues outlined above and be equipped with materials that can help them explain and ensure respondents understand exactly what they are being asked to do. **The GPS study leaflet** (see Appendix E) which interviewers will refer to when introducing the GPS device will clearly outline what GPS data is and what it will be used for. The interviewer will also be able to clarify anything that the respondent finds unclear. A copy of the leaflet will be left with each respondent, who agrees to carry a device, for reference.

5.3.1 Inclusion of proxy respondents

Household members for whom interview data is collected by proxy will also be asked to use a GPS device as well as complete a travel record. It is important to ensure that such individuals, who will not benefit from meeting with an interviewer, fully understand what the GPS device is recording and what the data will be used for, in order to ensure that informed consent is given.

This will require the interviewer to leave a **proxy GPS consent form** (see Appendix F), together with a GPS leaflet, and request that another household member explain and ask them to take part. Should the respondent have any queries, the consent form will provide a number for the respondent to call.

At the pick-up interview it will be necessary for interviewers to make sure that they collect this consent form. If a signed consent is not collected, it cannot be assumed that the respondent gave informed consent and the data will be deleted.

5.4 Maximising acceptability

As the telephone survey of recent NTS respondents highlighted, there are a number of reservations that interviewers will need to overcome in order to persuade people to use the GPS devices, including ease of use, data security, confidentiality and, not least, what will happen if they lose or damage the device.

It will be important for the literature and interviewers to make clear that:

- The device is straightforward to use and requires no prior knowledge.
- The data will be treated as confidential.

- The data will only be used for research purposes and by the research team.
- The data will be stored on the device rather than transmitted back in real time.
- That they will not be held liable in cases of loss or damage.

5.4.1 Support and advice on using the GPS device

Interviewers will be able to refer to the **GPS device instructions** (see appendix G) as well as showing the actual device in order to explain to respondents :

- How and when to charge the device
- How and when to carry the device
- How to turn the device on and off

Interviewers will also explain how to deal with the device if it starts to talk and not to worry if the lights go off after a period of non-movement.

The instructions and interviewer will also make clear when the respondent should carry the device. It will also be important for respondents to feel that they are supported throughout the process by being able to contact the interviewer or the Operations department with any questions or device queries. The instructions, and interviewer, will make this clear.

5.4.2 Incentives

On NTS, respondents are given a £5 high street voucher per household member if the CAPI interview is completed and all household members provide a fully completed travel diary.

For this study respondents will be expected to undertake more than regular NTS respondents, including recharging the GPS device. Furthermore, some respondents in the telephone survey did express the opinion that a larger incentive would be required to persuade them to use a GPS device. As such the payment of a £10 incentive per person completing a diary and using a GPS device seems appropriate, regardless of the participation of other household members. (A larger incentive may also reduce the likelihood of non-return of the GPS devices.)

Respondents would be told that payment of the incentive is dependent upon use of the GPS device in addition to full completion of the diary and the return of the GPS device. Unfortunately there is no way of the interviewer checking whether the GPS device has been used when collecting it and even if, on processing, no data was found to be stored it would be difficult to establish whether this was due to the respondent not using the device at all, equipment failure or the respondent misunderstanding how to use the GPS device. It is therefore recommended that the incentive payment is agreed if the respondent fully completes the diary, claims to have used the GPS device and returns the device to the interviewer.

5.4.3 Completing the travel record or the GPS element only

The findings of the telephone survey suggested that some respondents may only be willing to complete a travel record or use a GPS monitor, but not willing to do both. In such cases, where an interviewer is unable to persuade the respondent to complete both elements (in spite of their best efforts) the respondent will be asked to undertake whichever element they prefer. This may aid our understanding of the reasons for people wishing to only do one or the other, and whether use of GPS is attractive to groups that are less willing to complete a paper travel record.

In such cases, respondent will receive a £5 high street voucher after the travel week. Interviewers will be briefed not to offer this alternative until they have exhausted all options in terms of persuading the respondent to complete a travel record and use the GPS device.

5.5 Monitoring use of GPS devices

The experience of processing the GPS test data has highlighted the importance on knowing whether respondents have carried and/or charged the GPS device on each day of the travel week. Having some appreciation of this can aid data interpretation and identify the potential causes of missing trips.

Respondents will be asked to complete the NTS travel record for seven days, starting the day after the placement interview, and carry the GPS device. Each day during this same period they will also be asked to indicate on a **GPS use document** (see Appendix H) whether they have carried the device and whether they have charged it that day.

APPENDIX A ADVANCE LETTER FOR TELEPHONE SURVEY

Dear

National Travel Survey

You recently took part in the National Travel Survey, for which we and the Department for Transport would like to express our thanks.

> *At that time, you kindly said you would be willing to be recontacted for a follow-up survey. We are currently considering ways of improving the National Travel Survey and would like to ask for your opinion as someone who recently took part.*
>
> *We are arranging for one of our interviewers to phone you. They will either conduct the interview with you by phone there and then, or, if you would rather, they will make an appointment to phone back at a time which is more convenient for you. The interview will last a maximum of 15 minutes.*
>
> *If you have any queries, please call me on 01277 235200 .*

Many thanks for your help.

Yours sincerely

V. Tanner

Vicky Tanner
Project Supervisor

APPENDIX B TELEPHONE SURVEY QUESTIONNAIRE

(% of respondents who gave response are given in brackets after response categories, based on the number of respondents who were asked each question)

{Ask all}
Intro
Hello my name is XXXX from the National Centre for Social Research. May I speak with *respondent name*?
INTERVIEWER ADD IF NECESSARY: He/she was recently interviewed as part of the National Travel Survey. We're contacting a number of people who took part to see how they found the survey and how we might improve it in the future.

1. Named respondent available
2. Named respondent unavailable - Try and make appointment to call back
3. Named respondent no longer resident

{Ask all}
Perm
You recently took part in the National Travel Survey and kindly said that you would be willing to be contacted again.
We are considering things we could do to improve the National Travel Survey and would like to ask for your opinion as someone who recently took part. Would this be ok?
INTERVIEWER IF ASKED: The interview should take no more than 15 minutes.
INTERVIEWER IF ASKED ABOUT INCENTIVE, EXPLAIN THAT THE INCENTIVE WAS A GESTURE OF THANKS FOR COMPLETING THE DIARY LAST TIME.

1. Respondent agreed
2. Respondent declined

Travel behaviour

{Ask all}
Intro1
Before asking you about the National Travel Survey I just need to ask a few questions about your travel behaviour.

{Ask all}
TrChg
First, have your travel patterns changed since we interviewed you for the National Travel Survey?
INTERVIEWER IF YES: Is that a lot or a little?

1. Yes - a lot (6%)
2. Yes - a little (4%)
3. No (90%)

{Ask if travel behaviour has changed: TrChg=Lot or little}
HowCh
In what way have your travel patterns changed?
OPEN

{Ask all}
NCar
And can I just check how many cars or vans does your household own or have continuous use of at present?
INCLUDE COMPANY CARS/VANS IF THEY ARE AVAILABLE FOR PRIVATE USE.
INTERVIEWER: ENTER NUMBER.
:0..95 (0 – 20%, 1 – 47%, 2 – 26%, 3 – 4%, 4 – 1%, 5 – 1%)

{Ask if respondent is aged 17 or older: Dvage>=17 (fed forward from NTS CAPI)}
Drive
And how often do you usually drive a car or van?
INTERVIEWER: PROBE USING CODE FRAME IF NECESSARY:
1. 3 or more times a week (58%)
2. Once or twice a week (8%)
3. Less than that but more than twice a month (<0.5%)
4. Once or twice a month (0%)
5. Less than that but more than twice a year (<0.5%)
6. Once or twice a year (0%)
7. Less than that or never (33%)

Completing NTS diary

{Ask all}
Intro2
Now I would like you to think back to when you took part in the National Travel Survey.
You may remember that you were asked to complete a paper diary for seven days recording the trips you made during that period.

{Ask all}
Diary
Can I just check did you complete the travel diary entirely by yourself or did someone else help you complete it?
1. Entirely by self (84%)
2. Someone else (15%)
3. Can't remember (<0.5%)

{Ask if someone else helped with diary: Diary=someone else}
WhoHlp
Who was it who helped you complete the diary?
INTERVIEWER: CODE ALL THAT APPLY:
1. Another household (82%)
2. Interviewer (18%)
3. Someone else (6%)

{Ask if someone else helped with diary: Diary=someone else}
MchHlp
And how much help did you have to complete the diary?
Did you get… READ OUT…
1. a lot of help (33%)

2. quite a bit of help, or (15%)
3. just little bit of help? (52%)

{Ask all}
DEase
And how easy or hard did you personally find it to complete the diary?
Did you find it.. READ OUT…
1. very easy (39%)
2. fairly easy (56%)
3. fairly difficult or (4%)
4. very difficult? (0%)
5. Don't know (1%)

Other ways of collecting diary information

{Ask all}
Intro3
We are continually looking for ways to improve the survey and make it easier for people to take part so we want to know whether you think there are better ways of collecting the diary information.
I am going to read out a list of different methods and would like you to tell me how willing you would have been to use them.

{Ask all}
IntNet
Thinking about the travel diary, how willing would you have been to complete an electronic diary on a secure internet site? Would you have been… READ OUT…
1. very willing (27%)
2. fairly willing (28%)
3. not very willing, or (17%)
4. not at all willing? (28%)
5. Don't know (1%)

{Ask all}
LapTop
And how about completing an electronic diary stored on a personal computer or laptop?
Would you have been… READ OUT…
1. very willing (23%)
2. fairly willing (33%)
3. not very willing, or (17%)
4. not at all willing? (26%)
5. Don't know (<0.5%)

{Ask all}
PDA
And how about entering the information in a small hand-held computer or PDA (personal
digital assistant) that you could have carried with you at all times?
Would you have been… READ OUT…

1. very willing (28%)
2. fairly willing (28%)
3. not very willing, or (18%)
4. not at all willing? (24%)
5. Don't know (<0.5%)

{Ask all}
GPSInt
In addition to completing the diary we could have also given you a personal GPS monitor, about the size of a mobile phone, to carry with you.
This would have automatically recorded accurate information on the trips you had made, including start/finish times and distance travelled.
As with the diary, the GPS data would be treated in strict confidence in accordance with the Data Protection Act, and the information would only be used for statistical purposes.
INTERVIEWER - ADD IF NECESSARY:
GPS stands for global positioning system. A GPS monitor would log your position every few seconds.
From this information, it would be possible to identify the start and finish locations and times of journeys that you made, how fast you were travelling and the route you had taken from one place to another.
You would have to carry the monitor for every trip you make and ensure that the monitor was regularly charged.

{Ask all}
GPS
How willing would you have been to carry such a device, alongside completing the diary?
Would you have been… READ OUT…
1. very willing (29%)
2. fairly willing (37%)
3. not very willing, or (19%)
4. not at all willing? (15%)

{Ask if very/fairly willing to use GPS: GPS=very willing or fairly willing}
MaxDay
And what would be the maximum number of days that you would consider carrying such a device for?
INTERVIEWER NOTE: ENTER 0 FOR LESS THAN ONE DAY. IF THE RESPONDENT SAYS MORE THAN 20 DAYS, ENTER 20.
: 0..20 (3 – 1%, 4 – 1%, 5 – 4%, 7 – 56%, 10 – 1%, 12 – 1%, 14 – 15%, 20 – 21%)

{Ask if very/fairly willing to use GPS: GPS=very willing or fairly willing}
Concrn
And would you have had any concerns about carrying such a device?
1. Yes (17%)
2. No (82%)
3. Don't know (1%)

{Ask if have concerns: ConCrn=yes}
WhtCon

What would be your concerns?
INTERVIEWER: PROBE - GET AS MUCH DETAIL AS POSSIBLE.
:OPEN
Coded to:
1. Concern - Invasion of privacy (4%)
2. Concern - what would be done with data (8%)
3. Concern - using the device properly (4%)
4. Concern - breaking device (8%)
5. Concern - device not working properly (0%)
6. Concern - having to carry the device everywhere (4%)
7. Concern - device being stolen/lost (68%)
8. Concern - data being stolen/lost (12%)
9. Other (4%)

{Ask if have concerns: ConCrn=yes}
OvCon
"What could be done to overcome these concerns, if anything?
INTERVIEWER: RECORD AS MUCH DETAIL AS POSSIBLE.
: OPEN (Nothing – 12%, Insurance - 48%, Something else – 20%, Don’t know – 20%)

{Ask if not very/not at all willing to use GPS: GPS=not very willing or not at all willing}
WhyNot
Why do you say you would be unwilling to carry a GPS device?
INTERVIEWER: PROBE - GET AS MUCH DETAIL AS POSSIBLE.
: OPEN
Coded to:
1. Invasion of privacy (19%)
2. Concerns about what would be done with data (4%)
3. Lack confidence in using technology (18%)
4. Worried about breaking device (1%)
5. Worried about device not working properly (0%)
6. Awkward having to carry the device everywhere (12%)
7. Worried about device being stolen/lost (8%)
8. Worried about the data being stolen/lost (1%)
9. No need to if already completing a diary (12%)
10. Find it easier to complete a diary (5%)
11. Doesn't go out/travel much so not needed (7%)
12. Other (28%)
13. Don’t know (4%)

{Ask if not very/not at all willing to use GPS: GPS=not very willing or not at all willing}
NotPer
What could be done to persuade you to carry a device, if anything?
INTERVIEWER: RECORD AS MUCH DETAIL AS POSSIBLE.
: OPEN (Nothing – 66%, Something – 24%, Don’t know - 9%)

{Ask all}
NoDry
And can I check, how willing would you have been to carry such a device instead of completing a diary? Would you have been… READ OUT…

INTERVIEWER NOTE: IF ASKED EXPLAIN THAT A GPS DEVICE CANNOT PROVIDE ALL THE INFORMATION WE COLLECT IN THE DIARY (E.G. TRIP PURPOSE) BUT IT WOULD PROVIDE SOME OF IT

1. very willing (44%)
2. fairly willing (28%)
3. not very willing, or (12%)
4. not at all willing? (14%)
5. Don't know (1%)

Access to technology

{Ask all}
Intro4
Finally I would like to ask a few questions about the types of technology you have access to.

{Ask all}
Tech1
Do you have access to any of the following devices for your own personal use?...
A mobile phone?

1. Yes (89%)
2. No (11%)

{Ask all}
Tech2
(Do you have access to any of the following devices for your own personal use?...)
A personal computer or laptop?

1. Yes (67%)
2. No (33%)

{Ask all}
Tech3
(Do you have access to any of the following devices for your own personal use?...)
A palmtop, handheld or PDA (personal digital assistant)?

1. Yes (10%)
2. No (90%)

{Ask all}
Tech4
(Do you have access to any of the following devices for your own personal use?...)
The internet?

1. Yes (66%)
2. No (34%)

{Ask if have internet access: Tech4=yes}
BBand
And, can I check, is your internet access through broadband?

1. Yes (91%)
2. No (7%)
3. Don't know (2%)

{Ask if household has a car/vam: Ncar>0}

SatNav

And do any of your household cars/vans have a SatNav system?

This could be integral to the car/van or a separate portable device that can be placed in the car/van.

INTERVIEWER PROBE IF YES: Is that an integrated system or a separate portable device?

INTERVIEWER INFO: MAKES OF SATELLITE NAVIGATION TECHNOLOGY INCLUDE TOM-TOM, GARMIN AND NAVMAN. SEPARATE DEVICES INCLUDE HAND-HELD PLUG AND GO SYSTEMS OR TELEPHONE/PDA SYSTEMS WITH GPS FEATURES.":

1. Yes - an integrated system (6%)
2. Yes - a hand-held/plug and go system (32%)
3. No (62%)

{Ask if have SatNav and drive at least once a month: SatNav=yes AND Drive=1...4}

SNvOft

And how often would you say you personally use a SatNav system when driving?

INTERVIEWER: PROBE USING CODE FRAME IF NECESSARY

1. 3 or more times a week (10%)
2. Once or twice a week (10%)
3. Less than that but more than twice a month (8%)
4. Once or twice a month (20%)
5. Less than that but more than twice a year (33%)
6. Once or twice a year (8%)
7. Less than that or never (13%)
8. Don't drive anymore (spontaneous) (0%)

{Ask if use SatNav at least once a year: SnvOft<=6}

SNvCh

And has the use of SatNav while driving resulted in you changing the route you take for any of your regular journeys?

1. Yes (26%)
2. No (74%)

{Ask all}

OthSN

(Apart from when driving) do you use a SatNav device for any other purpose, for example when walking or jogging?

1. Yes (4%)
2. No (96%)

{Ask all}

Thank

Thank you for taking part in this survey. Your answers will help us to improve the National Travel Survey and benefit future respondents.

APPENDIX C TECHNICAL RESULTS FROM THE DEVICE REVIEW: DATA PROCESSING AND ANALYSIS FOR PHASE TWO TESTING

Data Processing

A spatial layer for the defined Atlanta test routes was created in a GIS using a high-accuracy line feature dataset for the Atlanta metropolitan area (ARC, 2006). Using aerial imagery, each line segment was identified as belonging to either a low/medium density area or to a high density area.

Once all of the collected GPS point data were consolidated in a single database, an automated link matching procedure was applied to the collected GPS points. This procedure associated each point with a line feature along the test routes and computed the shortest distance between the point and the route. Distances were calculated in meters, with the GPS points and line features projected to the WGS84 World Mercator Projection (EPSG: 3395). The resulting dataset was then imported into the statistical package R (ARC, 2006) for further analysis.

Data Exploration

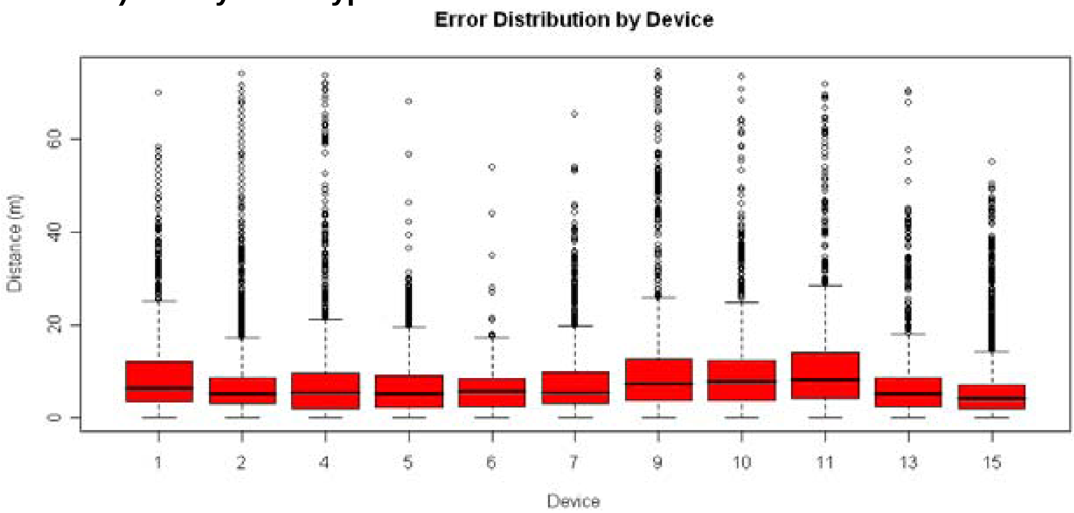
Prior to conducting the statistical analysis, all GPS data collected were loaded into ArcView along with the corresponding road network and aerial photography of the area. Visual inspection of the GPS traces revealed that all of the GPS data loggers seemed to perform very well throughout the test routes, including the urban canyon areas of downtown Atlanta.

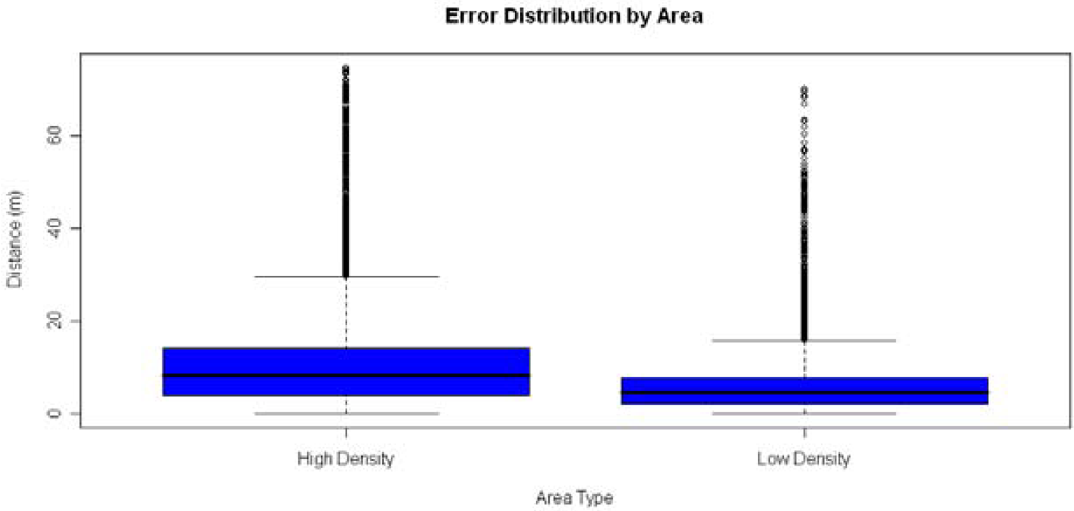
After examining the data visually, the analysis moved on to more quantitative methods. Examination of the logged files revealed that all devices did indeed record one point per second during the test runs, even during the more challenging urban canyon portion of the routes.

When looking at average shortest distances to the reference segments of the route, it could be seen that most devices performed remarkably well with average distances of 12 meters or less. Figure A1 displays box and whisker plots of these distance values and provides a better representation of their dispersion for each of the tested devices. The solid ‘box’ represents 50% (two quartiles) of the data points collected, with the line in the middle of the box representing the median of all points collected. The ‘whiskers’ are the solid lines outside the box, and represent approximately 95% of the data collected. The data above the outer-most whisker (remaining 5% of data) are the outlier points collected. The table below shows device types tested.

Device ID	*Product*
1	*GlobalSat DG-100*
2	*GlobalSat DG-100*
4	*GiSTEQ PhotoTrackr*
5	*GiSTEQ PhotoTrackr*
6	*i-Blue 747*
7	*i-Blue 747*
9	*Atmel BTT08*
10	*i-Blue 821*
11	*i-Blue 821*
13	*Wintec WBT-201*
15	*Qstarz BT-Q1000P*

Figure A1: Box Whisker Plots Showing Overall Performance by Device (Across all areas) and by Area Type





As expected, higher urban density areas (reflecting urban canyon conditions) caused performance to degrade, with higher average errors and variability observed as seen in the lower plot.

Figure A2 and Figure A3 show histograms of the shortest distances between each device's points and the route segments for the two urban density categories. Figure A2 illustrates that performance in lower urban densities is very close for the tested devices, with the majority of points falling within 15 meters of the route's centreline. On the other hand, Figure A3 reveals a wider distribution (and error) for the 'distance to route' variable under urban canyon conditions.

Figure A2: Distance (m) to Route Error Histograms for the Low Density Areas

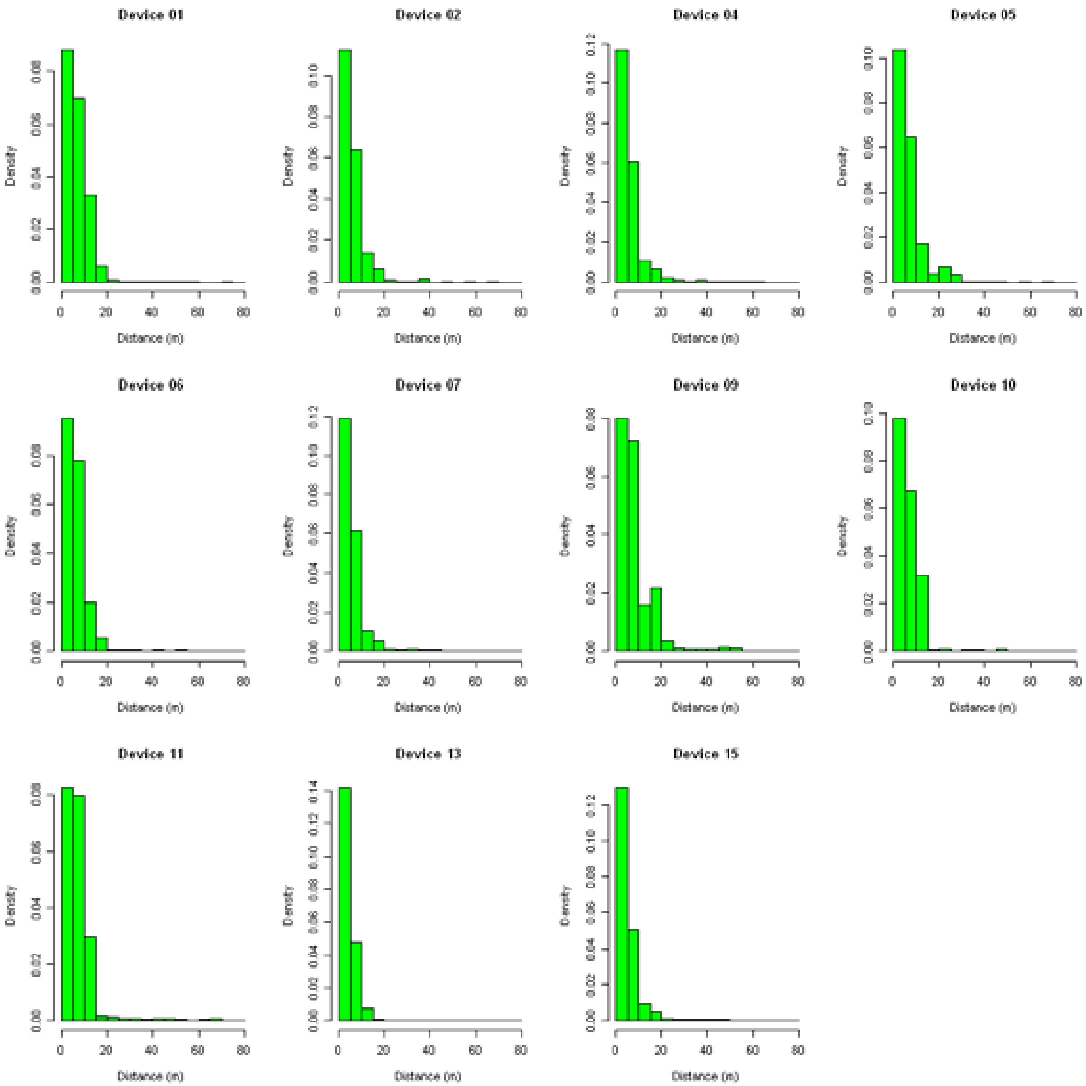
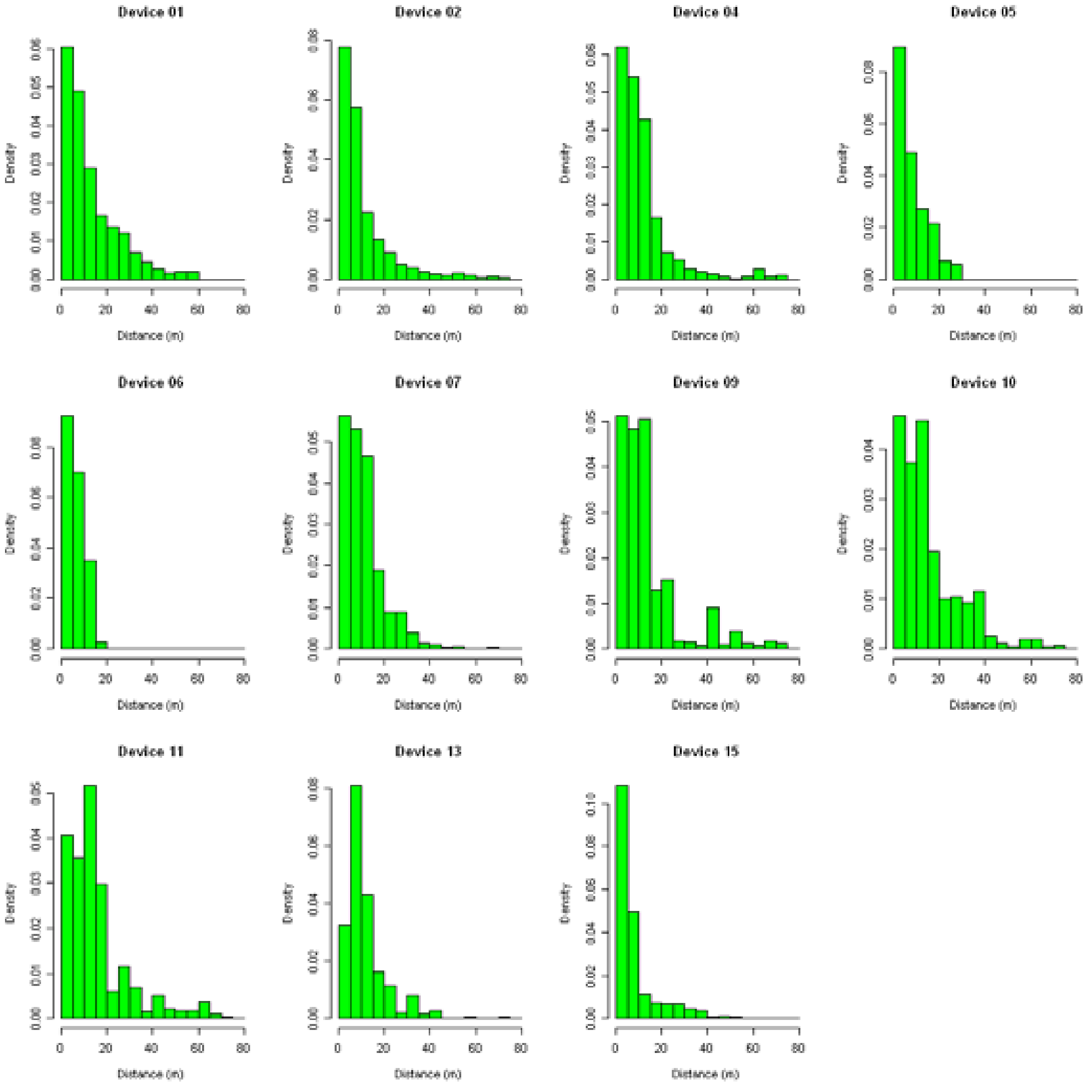


Figure A3: Distance (m) to Route Error Histograms for High Density (Urban Canyon) Areas



Analysis of Variance

Analysis of variance (ANOVA) tests were conducted on the match error results by fitting a linear model of the distance to the route (response) as a function of the device through the use of dummy variables, with device 01 being used as the base level on the models fitted in these analyses. One analysis was conducted for each of the two area types. Initial fitting of both models indicated lack of homogeneity in the residuals, which was remedied by applying a log transformation of the response variable (distance to route). Table A1 shows the results for the high density portions of the route; it indicates that the differences between the performances of the devices are significant at the aggregate level.

Table A1: ANOVA Results for High Density

Residual standard error: 1.151 on 8618 degrees of freedom
Multiple R-squared: 0.05686, Adjusted R-squared: 0.05576
F-statistic: 51.96 on 10 and 8618 DF, p-value: $< 2.2e-16$

However, Table A1 indicates that the device type had a small explanatory power on the error level ($R^2 = 0.06$). To facilitate their interpretation the exponentials of the coefficients are displayed in parentheses. To further examine pair-wise significance of these differences, the Tukey's Honest Significant Difference (HSD) intervals were built around each device's error estimate and are shown in Table A1 (Faraway, 2002).

Table A2: HSD Differences for High Density

	1	2	4	5	6	7	9	10	11	13	15
1											
2	0										
4	1	1									
5	0	0	0								
6	0	0	0	1							
7	1	1	1	0	0						
9	1	1	1	0	0	1					
10	0	0	0	0	0	0	0				
11	0	0	0	0	0	0	0	1			
13	1	0	0	0	0	1	0	1	1		
15	0	0	0	1	1	0	0	0	0	0	

Table A3 shows that the differences between the devices were significant at the 95% confidence level for the low density segments of the route. However, it also indicates that the device type had an even smaller explanatory power on the error level (R^2 = 0.03).

Table A3: ANOVA Results for Low Density

Residual standard error: 1.086 on 13032 degrees of freedom
Multiple R-squared: 0.03429, Adjusted R-squared: 0.03354
F-statistic: 46.27 on 10 and 13032 DF, p-value: < 2.2e-16

To further examine pair-wise significance of these differences, HSD intervals were built around each device's error estimate and are shown in Table A4.

Table A4: HSD Differences for Low Density

	1	2	4	5	6	7	9	10	11	13	15
1											
2	0										
4	0	0									
5	0	1	0								
6	0	1	0	1							
7	0	1	0	1	1						
9	1	0	0	0	0	0					
10	1	1	0	1	1	1	1				
11	1	1	0	0	0	0	1	1			
13	0	0	1	0	0	0	0	0	0		
15	0	0	1	0	0	0	0	0	0	1	

Results – Statistical Analysis of GPS Route Positional Quality

Even though the ANOVA and HSD results indicate the presence of statistically significant differences between devices, it worth noting that the models have very weak explanatory power and that the absolute values of the differences were rather small (< 10 meters). This weak power combined with the large size of the sample (thousands of points) can often generate artificially different results.

Further testing New York City

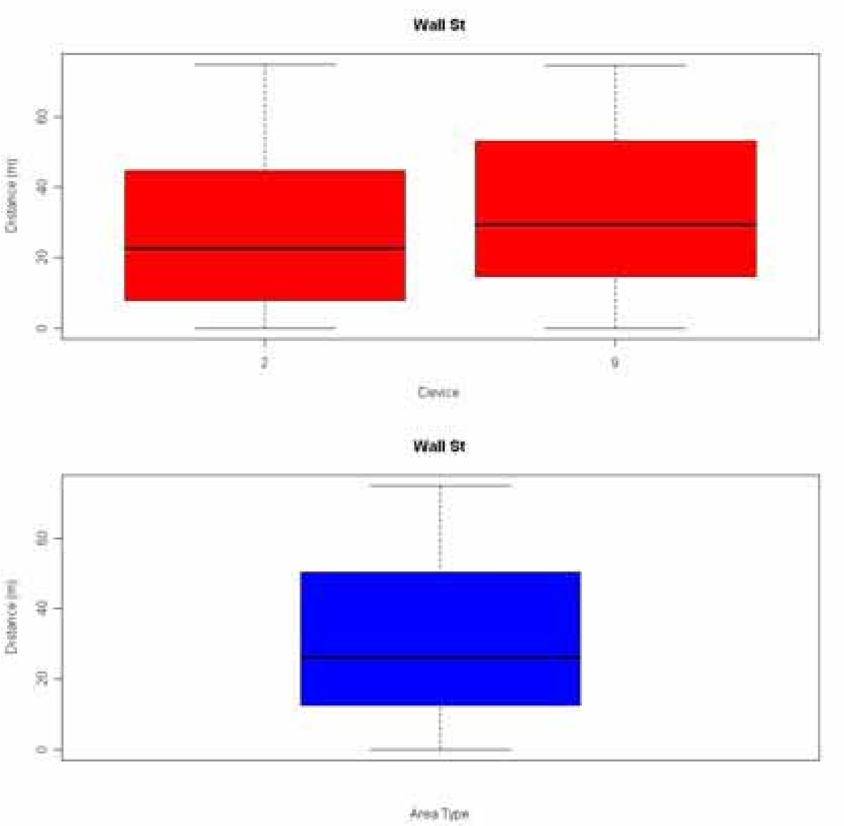
Additional tests were performed between the Atmel BTT08 and the GlobalSat DG-100 in New York City to evaluate how the two devices perform in a dense urban environment. Three routes were defined in Manhattan, one near Central Park along

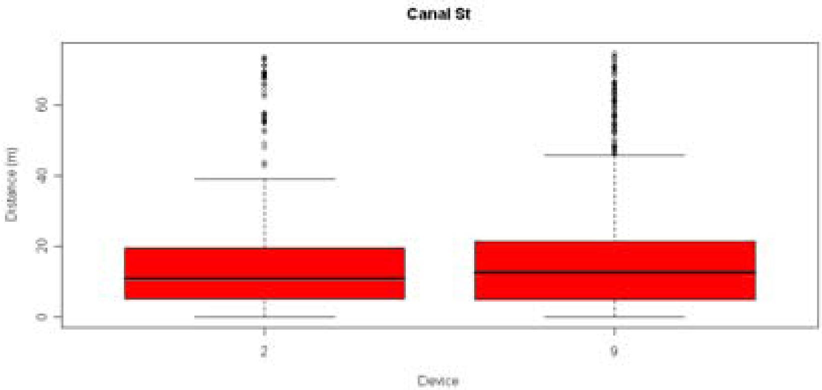
82nd Street, one in Central Manhattan near Canal Street, and a third in an extreme urban canyon environment located in the Financial District near Wall Street.
The same procedures were used in the New York City testing as were used during the Atlanta testing. Prior to conducting the statistical analysis, all GPS data collected were loaded into ArcView along with the corresponding road network. Visual inspection of the GPS traces revealed that in non-urban canyon environments both GPS data loggers seemed to perform reasonably well. In the extreme urban canyon areas of financial district along Wall Street in Manhattan, both devices had difficulty, but the GlobalSat performed better (followed the route more closely) than did the Atmel.

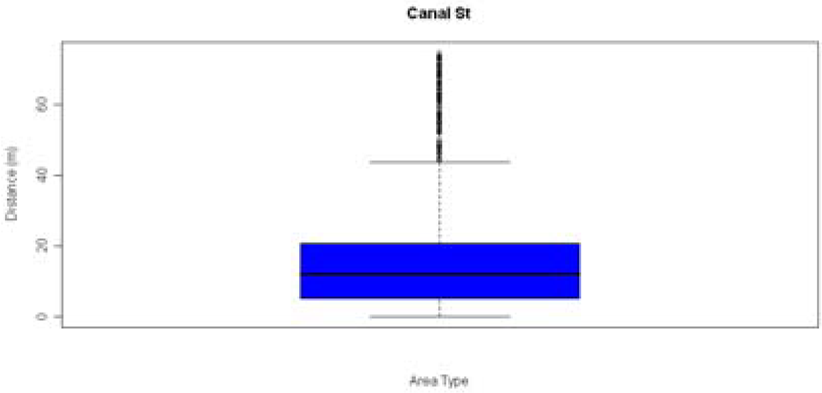
After examining the data visually, the analysis moved on to more quantitative methods. Figure A4 displays box and whisker plots of these distance values and provides a better representation of their dispersion for each of the tested devices. The solid ‘box’ represents 50% (two quartiles) of the data points collected, with the line in the middle of the box representing the median of all points collected. The ‘whiskers’ are the solid lines outside the box, and represent approximately 98% of the data collected. The data above the outer-most whisker (remaining 2% of data) are the outlier points collected.

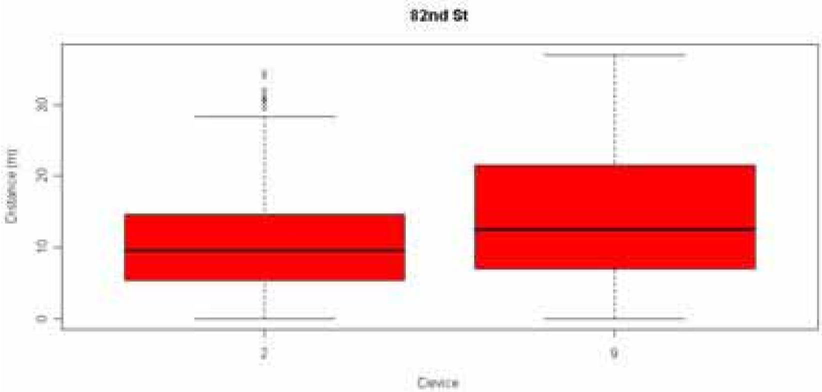
As expected, higher urban density areas (reflecting urban canyon conditions) caused performance to degrade, with higher average errors and variability observed for the Wall Street Route.

Figure A4: Box Whisker Plots Showing Atmel and GlobalSat Performance by Route Surveyed




Canal St
Distance (m)
0
20
40
60
2
9
Device


Canal St
Distance (m)
0
20
40
60
Area Type


82nd St
Distance (m)
0
10
20
30
2
9
Device

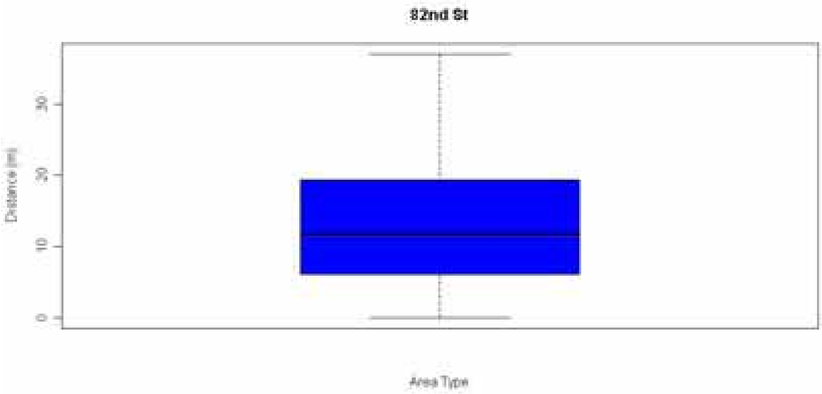
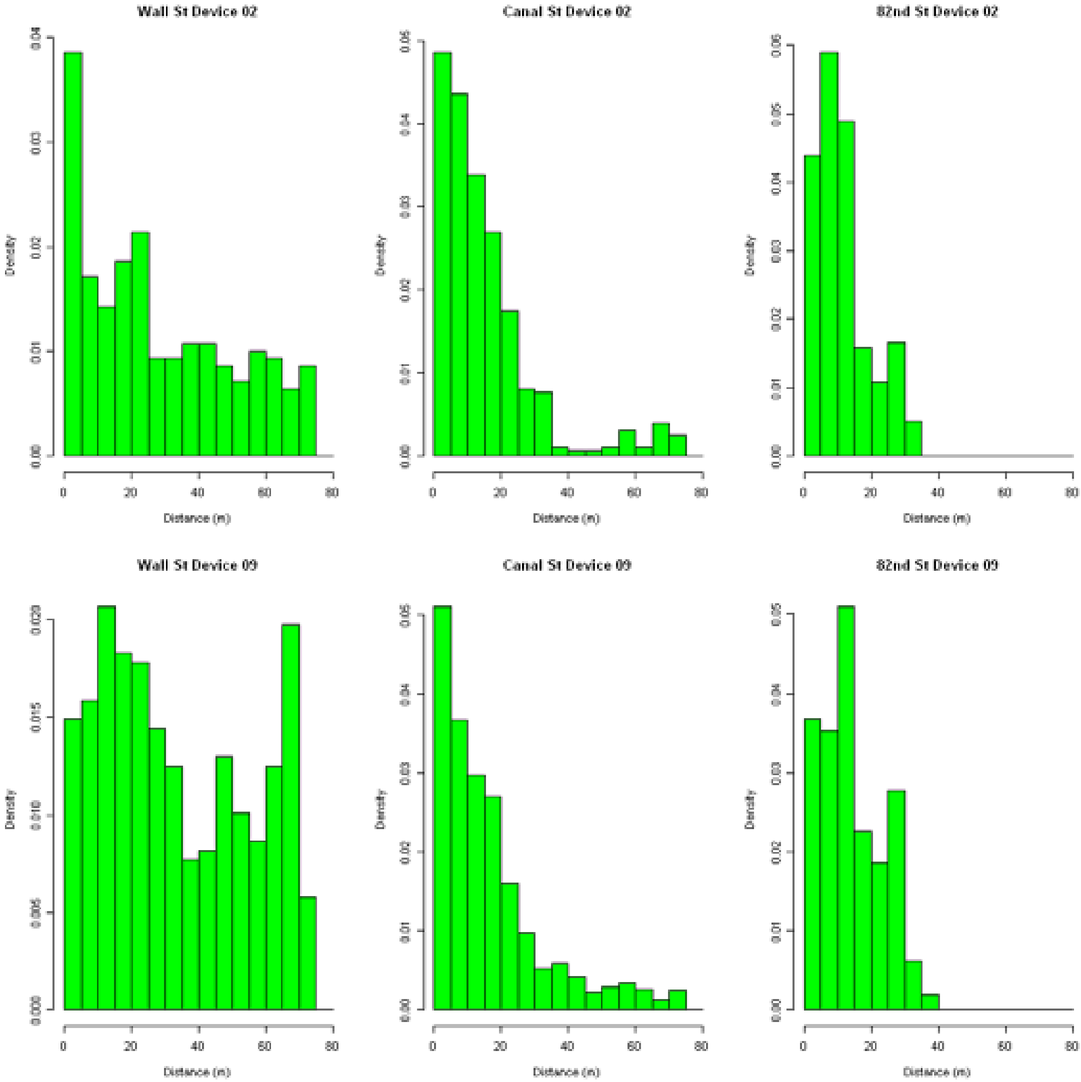

82nd St
Distance (m)
0
10
20
30
Area Type

Figure A5 shows histograms of the shortest distances between each device's points and the route segments for the three routes tested.

Figure A5: Distance (m) to Route Error Histograms for New York City (Manhattan) Areas



References

ARC (2006), Atlanta Regional Commission Street Network for Metro Atlanta, Atlanta, GA.

Faraway, J. (2002), Practical Regression and Anova using R, July 2002, http://cran.rproject.org/doc/contrib/Faraway-PRA.pdf, accessed on 16 April 2008

APPENDIX D DATA PROCESSING

GPS data comparison to travel records

The table below shows a trip-level comparison between the trips reported in the travel diary and the trips detected within the GPS data collected by the Atmel and the GlobalSat. These results indicate that the participant made a total of 25 trips over the course of seven days. The participant neglected to report five trips in their travel diary that were captured by one or both of the GPS devices. There were also occasions where they reported a trip in the diary that was not captured on one or both GPS devices. In some of these missing GPS trip cases, the participant forgot to carry the device or accidentally turned the device off while carrying it in a bag.

Overall		Travel Diary					Atmel BTT-08					GlobalSat DG-100				
Trip #	Trip Sgmt	Start Date	Start Time	End Time	Mode	Comment	GPS Trip ID	Start Time	End Time	Worn	Comment	GPS Trip ID	Start Time	End Time	Worn	Comment
1	1	2008-07-11	8:40 AM	9:10 AM	Bus	Home to Work	1	8:32 AM	8:37 AM	Outside	Walk to Bus? from Home	1	8:32 AM	8:37 AM	Outside	Walk to Bus? from Home
1	2						2	8:38 AM	9:11 AM		Bus?	2	8:38 AM	9:10 AM		Bus?
1	3						3	9:11 AM	9:17 AM		Walk to Destination	3	9:10 AM	9:16 AM		Walk to Destination
2	4											4	10:17 AM	10:19 AM	Outside	Short Walking Trip
2	5	Not Reported					4	10:26 AM	10:28 AM		Short Walking Trip	5	10:26 AM	10:27 AM		Short walking trip
2	6						5	10:51 AM	10:59 AM		Short Walking Trip	6	10:51 AM	10:55 AM		Short Walking Trip
3	7	Not Reported					6	6:09 PM	6:17 PM		Walk Trip					
3	8						7	6:40 PM	6:42 PM		Walk Trip					
4	9	2008-07-11	8:55 PM	9:20 PM	Bus	Work to Dinner	8	8:55 PM	8:59 PM	In Bag	Walk Trip? Speed Spike.				Outside	
5	10	Not Reported					9	9:08 PM	9:20 PM		Bus Trip					
5	11						10	9:21 PM	9:25 PM		Walk to Destination					
6	12	2008-07-11	11:55 PM	12:20 AM	Bus	Dinner to Home				Outside						
7	13	2008-7-12	1:00 PM	1:20 PM	Walk	Home to Shopping				In Bag						FORGOT DEVICE
8	14	2008-7-12	2:00 PM	2:15 PM	Bus	Shopping to Home				In Bag						FORGOT DEVICE
9	15	2008-7-12	7:00 PM	7:35 PM	Bus	Home to Dinner				Outside		7	12:00 AM	6:54 PM	Outside	Walk to Bus from Home Missing trip(s) above
9	16											8	7:01 PM	7:32 PM		Bus Trip
9	17											9	7:32 PM	7:45 PM		Walk to Destination

Overall		Travel Diary					Atmel BTT-08					GlobalSat DG-100				
Trip #	**Trip Sgmt**	**Start Date**	**Start Time**	**End Time**	**Mode**	**Comment**	**GPS Trip ID**	**Start Time**	**End Time**	**Worn**	**Comment**	**GPS Trip ID**	**Start Time**	**End Time**	**Worn**	**Comment**
10	18	2008-7-12	11:30 PM	12:05 AM	Bus	Dinner to Home	11	11:35 PM	12:02 AM	Outside	Bus Trip? Gap in trace over bridge. Missing trip(s) on previous day.	10	11:37 PM	12:02 AM	Outside	Vehicle Trip Cold start - missing previous trip, or first part of this trip.
10	19						12	12:02 AM	12:07 AM	Outside	Walk Trip to Home	11	12:02 AM	12:08 AM		Walk Trip to Home
11	20	2008-7-13	1:30 PM	1:50 PM	Walk	Home to Shopping	13	1:21 PM	1:34 PM	Outside	Walk Trip	12	1:22 PM	1:35 PM	Outside	Walk Trip - Speed Spike
12	21	2008-7-13	2:15 PM	2:35 PM	Walk	Shopping to Home	14	2:12 PM	2:28 PM	Outside	Walk Trip	13	2:13 PM	2:27 PM	Outside	Walk Trip
13	22	Not Reported					15	3:19 PM	3:29 PM		Walk Trip	14	3:20 PM	3:30 PM		Walk Trip
14	23	Not Reported					16	7:21 PM	7:34 PM		Walk Trip	15	7:22 PM	7:33 PM		Walk Trip
15	24	2008-7-14	8:40 AM	8:50 AM	Underground	Home to Work	17	8:28 AM	8:43 AM	Outside	Walk to Train Station	16	8:28 AM	8:43 AM	Outside	Walk to Train Station
15	25						18	8:56 AM	9:05 AM		Walk Trip - Missing trip above - most likely due to the Underground	17	8:56 AM	9:07 AM		Walk Trip - Missing trip above - most likely due to the Underground
16	26	2008-7-14	6:00 PM	6:35 PM	Bus	Work to Home	19	6:02 PM	6:31 PM	Outside	Bus Trip - Small cold start				Outside	
16	27						20	6:31 PM	6:37 PM		Walk Trip Home					
17	28	2008-7-15	8:50 AM	9:10 AM	Underground	Home to Work	21	8:34 AM	8:50 AM	Outside	Walk to Train Station					ACCIDENTALLY TURNED OFF (OR NOT ON) ACCORDING TO LOG
17	29						22	9:06 AM	9:14 AM		Walk Trip - Missing trip above - most likely due to the Underground					
18	30	2008-7-15	12:05 PM	12:45 PM	Bus-Bus	Work to Meeting	23	12:07 PM	12:30 PM	Outside	Bus Trip	18	12:19 PM	12:30 PM	Outside	Bus Trip - Long Cold Start
18	31						24	12:30 PM	12:45 PM		Walk Trip	19	12:30 PM	12:45 PM		Walk Trip

Overall		Travel Diary					Atmel BTT-08					GlobalSat DG-100				
Trip #	Trip Sgmt	Start Date	Start Time	End Time	Mode	Comment	GPS Trip ID	Start Time	End Time	Worn	Comment	GPS Trip ID	Start Time	End Time	Worn	Comment
19	32	2008-7-15	3:30 PM	4:15 PM	Bus-Bus	Meeting to Work	25	3:19 PM	3:23 PM	Outside	Walk Trip	20	3:18 PM	3:23 PM	Outside	Walk Trip
19	33						26	3:25 PM	3:30 PM		Bus Trip	21	3:25 PM	3:30 PM		Bus Trip
19	34						27	3:31 PM	3:32 PM		Walk Trip (change busses?)	22	3:30 PM	3:32 PM		Walk Trip (change busses?)
19	35						28	3:33 PM	4:08 PM		Bus Trip	23	3:33 PM	4:06 PM		Bus Trip
19	36						29	4:12 PM	4:20 PM		Bus Trip	24	4:13 PM	4:22 PM		Bus Trip
20	37	2008-7-15	7:05 PM	7:35 PM	Bus-Bus	Work to Shopping	30	7:07 PM	7:28 PM	Outside	Bus Trip - Cold Start	25	7:05 PM	7:28 PM	Outside	Bus Trip - Cold Start
21	38	2008-7-15	7:40 PM	7:50 PM	Bus	Shopping to Home	31	7:34 PM	7:38 PM	Outside	Bus Trip	26	7:34 PM	7:38 PM	Outside	Bus Trip
21	39						32	7:38 PM	7:42 PM		Walk Home	27	7:38 PM	7:42 PM		Walk Home
22	40	2008-7-16	9:00 AM	9:30 AM	Bus	Work to Home				Outside		28	8:38 AM	8:43 AM	Outside	Walk to Bus
22	41						33	8:42 AM	9:13 AM		Bus (missing previous trip - cold start).	29	8:43 AM	9:13 AM		Bus Trip
22	42						34	9:13 AM	9:21 AM		Walk Trip	30	9:14 AM	9:20 AM		Walk Trip
23	43	2008-7-16	7:10 PM	7:35 PM	Bus	Home to Work	35	7:33 PM	7:35 PM	Outside	Bus Trip - Trace Drops	31	7:33 PM	8:02 PM	Outside	Bus Trip
23	44						36	8:03 PM	8:07 PM		Walk Home - Missing Several Miles of Trip	32	8:02 PM	8:07 PM		Walk Home
24	45	2008-7-17	8:45 AM	9:20 AM	Walk-Tube-Walk	Home to Work	37	8:43 AM	8:57 AM	Outside	Walk to Train	33	8:41 AM	8:56 AM	Outside	Walk to Train
24	46						38	9:09 AM	9:16 AM		Walk Trip - Missing trip above likely due to underground	34	9:08 AM	9:16 AM		Walk Trip - Missing trip above likely due to underground
25	47	2008-7-17	6:00 PM	7:00 PM	Walk-Bus-Walk	Work to Home	39	6:09 PM	6:39 PM	In Bag	Walk Trip - Cold start	35	6:18 PM	6:37 PM	In Bag	Walk Trip - Cold start
25	48						40	6:41 PM	6:47 PM		Bus Trip	36	6:41 PM	6:48 PM		Bus Trip
25	49						41	6:52 PM	7:04 PM		Walk Trip Home	37	6:52 PM	7:03 PM		Walk Trip Home

APPENDIX E GPS LEAFLET

Frequently Asked Questions

I don't use much technology, what if I can't work the monitor properly?
The GPS monitors are simple to use and do not require any specialist knowledge. You will be given full, clear instructions on how to use the monitor and your interviewer will be happy to help if you have any problems during the week. You can also call the number provided on the GPS instruction sheet.

Will the GPS monitor harm me in any way?
No, the GPS monitor cannot harm you. The rechargeable battery is securely housed in the device shell. The monitor does not emit radiation, electrical current, vibration, or heat.

What if I lose or damage the monitor?
The monitor is an expensive piece of equipment. We would appreciate your help in keeping it safe at all times, however we will not hold you responsible if any harm comes to it.

I'm already completing a diary, why do you need me to carry a GPS device as well?
The GPS monitor will provide us with additional information on routes taken and speed of travel, as well as accurate distance and time data.

Are you doing this so you can keep track of where I go?
The GPS monitor does not transmit your position back to a central computer but simply stores the data in its memory until the device is returned.

I don't travel much, will I need to use a GPS monitor?
It is important that we include everyone's experiences of travel however much or little they do. Carrying a GPS monitor on the journeys you do make will help to ensure the information we collect is representative of the different types of journeys that people make.

P2803 NTS GPS

NATIONAL TRAVEL SURVEY

National Travel Survey – GPS Study

The National Travel Survey collects information on personal travel within Great Britain. Each year we ask over 15,000 households to take part, asking household members to complete a travel diary for seven days.

As part of this study, we would also like participants to use a GPS monitor. This leaflet provides more information about the GPS monitor and why we are asking you to use it.

Department for Transport

NatCen
National Centre for Social Research

What is a GPS monitor?
GPS stands for Global Positioning System. A GPS monitor is a small device, about the size of a mobile phone, that logs your position every few seconds. This information is then stored on the device itself until the memory is cleared.

Why do we want to collect information using GPS?
The diaries used on the National Travel Survey give us detailed information about people's travel patterns including the modes of transport they use and the reasons for the journeys they make. However sometimes people are not sure about the exact distances they have travelled or how long a particular journey has taken them. The GPS monitors will give researchers accurate information on the times and distance of journeys, as well as information on speed and the route type, helping to complete our understanding of travel patterns.

What will be done with information collected?
The GPS data will be securely transferred to GeoStats in the United States, alongside the information you recorded in your diary and some of the information given to the interviewer during the interview. GeoStats are GPS experts and will be linking the diary and GPS information.

The combined information will then be used by NatCen and the main users of the data, the Statistics Travel Division of the Department for Transport (DfT).

Is the study confidential?
Yes. NatCen and the main users of the data, the Statistics Travel division of the Department for Transport (DfT), are bound by the same code of confidentiality, which GeoStats are also committed to uphold. (See http://www.geostats.com/privacy.htm for further details).

Your answers and information will be treated in strict confidence in accordance with the Data Protection Act. They will be used for statistical research purposes only. Names and addresses are never included in the results and are never passed to DfT.

Is using the GPS monitor compulsory?
No. We rely on voluntary co-operation for all aspects of our surveys. The success of the study depends on the goodwill and co-operation of those asked to take part. The more people who do use a GPS monitor, the more useful the results will be. However, you are free to withdraw from the study at any time.

What am I supposed to do with the GPS monitor?
We would like you to carry the monitor whenever you travel during the same seven days as you complete the travel diary. Please take the monitor with you whenever you travel no matter how short the journey. You do not need to wear it when you are moving around indoors but you may prefer to keep the monitor on you at all times so that you do not forget it.

The GPS monitor operates using a rechargeable battery. To ensure that the battery does not run out, please recharge the monitor every night (including the night before you use it for the first time).

Do I get anything for using the GPS monitor?
If you complete the diary and use the GPS monitor, you will be sent a £10 high street voucher as a token of appreciation for your time and to thank you for taking part.

Any other questions?
You can find some frequently asked questions on the next page but if you have any other questions about the survey or the GPS monitor, please do not hesitate to ring either Sandra Laver or Sheila Duke on freephone 0800 652 4568.

APPENDIX F PROXY CONSENT FORM

National Travel Survey
GPS monitor consent form

(Interviewer to leave for household members who are interviewed by proxy)

Thank you for taking part in the National Travel Survey. A member of your household has already answered a survey questionnaire on your behalf and has been given a travel diary which we would like you to complete over the next seven days. During this period, we would also like to ask you to carry a personal GPS monitor with you when you are travelling.

What are GPS monitors?
GPS stands for global positioning system. The GPS monitors used in this study automatically log your position every few seconds. This information will allow us to accurately identify start/finish times of journeys you make, distance travelled and route taken.

A set of instructions have been provided. Please read these before you start using the GPS monitor.

Further Information
Your NatCen interviewer has provided a leaflet that provides further information on the National Travel Survey and the use of GPS monitors. Please familiarise yourself with this information before signing this consent form.

If you have any further questions please contact Sheila Duke on 01277 690043

I, ____(*write in name),*

have read the leaflet 'National Travel Survey - GPS Study' and agree to the data recorded on my GPS monitor to be used for the purposes of this study, as described in the leaflet.

Signed____

Date____________________________________

APPENDIX G GPS DEVICE INSTRUCTION SHEET

GPS INSTRUCTIONS FOR PARTICIPANTS

HOW TO CHARGE THE GPS DEVICE

Please plug in and charge the GPS device as soon as possible and leave it charging overnight before you begin using it.

1. Insert the small end of the charger into the opening on the bottom of the GPS device.

2. Plug the other end of the charger into the UK adaptor, and plug the UK adaptor into the electric socket.

Central green light will blink twice quickly when charging. When complete the light will blink once quickly.

3. When the adaptor is plugged in, the central green light on the GPS device will begin blinking twice, quickly, indicating that it is charging. When charging is complete, the light will only blink once quickly.

4. Recharge the GPS device every evening once you are home for the night so that it is fully charged for the following day.

HOW TO SWITCH ON THE GPS DEVICE

1. Turn the GPS device on by pressing and holding the center power button for three seconds. The green and blue lights will flash when the device is turned on.

2. The green light should then start blinking, meaning the device is ready to collect data.

3. Make sure that the device is switched on at the start of every day and throughout the day.

4. To turn the device off, press and hold the middle button until the green light is solid.

HOW DO I KNOW IF THE DEVICE IS WORKING?

1. If the device is working, the green light should be on and flashing. The red light (to the left of the green) will also flash sometimes.

2. If this is not the case or you are unsure, restart the device by pressing and holding the power button until the green light is solid, and then pressing and holding the power button again until the green and blue lights flash together.

HOW AND WHEN DO I CARRY THE GPS DEVICE?

You can either:

- wear the device around your neck using the strap provided, or
- clip the device on to the outside of your bag, rucksack or belt loop.

The device should be worn outside of coats or jackets, as far as possible. It should not be carried inside a bag as this can result in the signal being interrupted and/or accidental changing of the device settings.

WHEN DO I NEED TO CARRY THE DEVICE?

- Wear the GPS device whenever you are traveling, regardless of the method of transport used (i.e. car, bus, train, bicycle, foot etc).
- Wear the GPS device whenever you go for a walk, jog or bike ride.
- You do not need to wear the GPS device when you are inside a building, but remember to put it back on whenever you go outside.

FREQUENTLY ASKED QUESTIONS

What should I do if there is a red flashing light?

- This is fine – you do not need to do anything.

What should I do if there is a blue flashing light?

- If there is a blue light, please press and hold the middle power button and the 'BT' button on the right hand side at the same time. This should turn off the blue light.

What should I do if the device starts speaking?

- This device has a voice feature that is not needed for this study. If you hear the voice, repeatedly press the right 'BT' button to turn the volume down until you can no longer hear the voice.

What should I do if it rains?

- The GPS device is shower-proof so please continue to use the device as normal in the event of light rain. If it is raining very heavily, you may temporarily place the device inside your clothing. This will affect the quality of the signal so please revert to carrying the device as normal as soon as the heavy rain stops.

What should I do if I am playing sport outdoors?

- If you play tennis, football or other outdoor sports, take the GPS device off and place it next to the court or field facing up. Be sure to take it with you when you leave.

Should I switch the device off when I am indoors?

- There is no need to switch the device off when you are indoors as the battery should last for a full day. However, please switch off the GPS device if you are entering a hospital to prevent the device interfering with any of the medical equipment - but remember to switch it back on as you leave.

If you have any other questions or are having problems with your GPS device, please contact Sheila Duke on 01277 690043.

APPENDIX H GPS USE DOCUMENT

Area | | | | | | Add | | | H | | Chkl | | P | | |

NatCen
National Centre for Social Research

Department for Transport

National Travel Survey - GPS daily record sheet

Please complete this for each day of the travel diary.

Did you charge the GPS monitor at all today?
Tick one box for each day

	Before Day 1	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Yes								
No								

Did you carry your GPS monitor when you were travelling today?
Tick one box for each day

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Yes – for all journeys							
Yes – for some journeys							
No – but did make journeys							
Did not travel today							

PLEASE TURN OVER

Did you experience any problems using the monitor today?
Tick all that apply for each day

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
No problems							
Forgot to carry							
Inconvenient to carry							
Battery ran out							
Problem with charging							
Device started talking							
Other problems (please provide details in the box below)							

Are there any other comments you would like to make about the GPS monitor and how you found using it? If so, please write below.

Thank you.

Information classification Level 3 – Respondent – Confidential