THE USE OF GLOBAL POSITIONING DEVICES IN TRAVEL SURVEYS - A developing country application

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ABSTRACT
Global Positioning Systems (GPS) were used to track individuals and the results were compared with traditional pen and paper based travel surveys. The objective was to assess the capability of GPS to replace or, alternatively, to complement the traditional travel survey or diary. Small, non-intrusive GPS units were distributed to 130 respondents in the Western Cape. The respondents were also asked to complete a travel survey for the period of tracking. The results of the two techniques were compared on issues such as origin and destination of the trips, routes taken, total number of trips and tours, and type of information delivered. GPS tracking delivered accurate information on the origin and destination of trips, routes taken, number of trips and tours and with additional examination, on the transport mode used. Comparing GPS and traditional surveys showed that GPS captured significantly more trips and tours originating from home and work. These 'missed' trips in the diary are often shorter walks or 'strolling' trips. It was also found that respondents tend to round off their trip departure and arrival times and under-estimate trip duration. Generally, it was felt that the diary accurately recorded the work activity and the normal routine but did not capture short trips linked to the work trip. While GPS devices do deliver adequate information, the cost of the technology, the programming involved to extract information from the large datasets, and the auxiliary requirements, do not make GPS travel surveys an alternative to traditional techniques in the short term. The current role of GPS is more as validation or providing expansion factors for larger surveys on, for example, trip generation and route choice.

BACKGROUND AND LITERATURE REVIEW
Travel information, used in transport planning, modelling and analyses, has historically been accumulated with origin-destination (OD) surveys, travel diaries and associated travel questionnaires which collected information on place of residence, place of employment, transport mode used, time of departure/arrival, etc. (the information related chiefly to the main commute trip). All these techniques, however, suffer from some well-known inherent disadvantages including respondent burden, inaccurate response, limited information on routes, and an inability to accurately capture variability in travel behaviour between days.

Location-aware information communication technologies (ICT) and, specifically, GPS provide a useful alternative (or supplementary technological solution) to address some of the problems associated with comprehensive data collection requirements.

These technologies may augment (or even replace) complex and cumbersome travel/activity diaries which are difficult to administer, to complete and are time consuming. The literature, while still sparse on the subject, does reveal that there are potentially many benefits to using GPS (and other location aware technology) to collect travel behaviour, notably the reduction in missing trips reporting, improved accuracy in the reporting of trips and activities (time and space), better routing and speed data and the ability to capture longer periods of travel (Sharp and Murakami, 2004; Stopher, 2006, Wolf, 2004). The technology also provides many benefits for respondents such as low input requirements and little (if any) respondent burden (such as trying to recall activities/trips, etc.). The latter is especially important in a developing country context where lower levels of literacy, language barriers and costs, make administering travel diaries infeasible.

In general, the literature claims that GPS records of travel behaviour will undoubtedly become more important due to their manifold advances compared to classic surveys methods. The advantages include (Schuessler and Axhausen, 2008):

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- GPS records provide researchers with more detailed information in terms of both spatial and temporal resolution.
- GPS prevent under-reporting of trips, a well-known limitation of recollection-based surveys.
- They reduce participants' burden to a minimum, as long as they are not combined with extensive questioning to derive additional information, such as trip purposes and transport modes.
- Routes are recorded for all trips, including the start and end times of trips.
- GPS data can be used to verify self-reported data.

Most of the current GPS travel survey applications and presupposed advantages have been applied and tested only in a developed world environment. While the technology potentially holds much promise for use in developing countries, many technology and data quality issues still remain. This project is aimed at assessing the GPS in a developing world context.

CASE STUDY

The case study took place in October and November 2008 in the towns of eNduli, Bella Vista, Prince Alfred and Stellenbosch in the Western Cape. Households (excluding Stellenbosch) were contacted and recruited with a visit to their residences between 18h00 and 20h00 on weekdays. The area was surveyed as part of the larger survey for the Cape Winelands District Municipality. A sub-sample (100 respondents) of the larger survey was recruited to complete the travel survey and to carry a GPS unit for a two-week period.

Users taking part in the GPS survey were offered a R50 shopping voucher upon completion of the survey and the return of the GPS unit. A second wave of surveying was undertaken (second and third week of November) among staff from Stellenbosch University (35 respondents).

The GPS receiver used was developed by ITLS (Institute for Transport and Logistics Studies, the University of Sydney, Australia (Figure 1). A South African unit (also shown in Figure 1) was tested in a pre-pilot but was found to be bulky and not suitable for the exercise. The ITLS units were rented for A$ 0.5 cents per day while purchasing GPS units in South Africa costs between R1500 and R3500 per unit.

Figure 1: TRIMTRACK unit (right) and GPS-BTT08 Data Logging GPS Receiver (left)

The physical properties of the ITLS unit are:

- The device is smaller than a modern cell phone which makes it easy and comfortable to carry on your person. Size: 76mm x 46mm x 20mm; weight: 50 grams.
- It has display lights that indicate the status of the device (on/off, satellite signal/no signal).
- It has voice messages to announce when it is looking for a position, when it has a fixed position, and when the battery is low.

- The device has 3 buttons which have several functionalities depending on whether they are pressed for short or long periods. The functionalities include: Power On/Off, Volume Up/Down, Tag Marker Start/End and GPS mode change.

The survey questionnaires covered two days of travel (the last two work days) while the GPS unit tracked the entire week. Once the GPS units were retrieved and the questionnaires recovered, the GPS data were downloaded and the survey data captured. The GPS data were visually inspected in Google Earth as well as with the aid of GIS plots. In a few instances, GPS information could not be retrieved from the GPS units and two of the GPS units incorrectly recorded the time information. In the final instance, the case study delivered 124 sets (respondents) of data. Not all respondents, however, answered all questions or provided incorrect answers and in some cases data could not be retrieved from the GPS units. This led to fewer data sets being available for some questions and analysis.

GPS DATA PRE- AND POST-PROCESSING

The GPS units deliver data in data streams which comprise text files. The data were downloaded to a personal computer for processing. The files, shown in Figure 2, contained second-by-second interval data recording *Longitude, Latitude Speed (km), Course(degrees), Number of Satellites, Horizontal Dilution of Position, Altitude (metres), DD/MM/YY, HH:MM:SS and Distance (metres)*. This information was subsequently subjected to data processing. The first step was to convert the longitude and latitude values to metres using the ARCGIS program.

Longitude	Latitude	Speed(km)	Course(deg)	Number Satellites	HDOP	Altitude	DD/MM/YY	HH:MM:SS	Distance
19.31685	-33.3287	0	186	209	36.1	7710	0/0/2000	00:00:00	0
19.31685	-33.32871	0	118	209	36.1	10526	0/0/2000	00:00:00	0
19.31679	-33.32864	0	72	209	36.1	13086	0/0/2000	00:00:00	9
19.31667	-33.32893	0	6		36.1	6431	0/0/2000	00:00:00	34
19.3167	-33.3288	2	48	209	36.1	9247	0/0/2000	00:00:00	14
19.3168	-33.32874	0	132	209	36.1	12063	0/0/2000	00:00:00	11

Figure 2: Output GPS data file

These files can be quite large with second-by-second tracking resulting in a possible 86400 records over a two-day period! An integrated accelerometer detects movement and the unit stops recording position if no movement is detected after a specified time. Figure 3 shows the raw data plotted in a GIS. The raw data, while containing some mistakes, look intuitively appealing. Clear patterns emerge and trips can be identified along routes. A closer examination reveals some inherent mistakes. Some records show unnatural movement while some records seem to be removed from ‘preceding’ and ‘following’ records.

Unnatural movements are records that are not linked to preceding or following records. The GPS unit, in other words, has simply not found or established an accurate ‘position’. These records are deleted. In some cases the GPS has either too few satellites in position or the satellites are aligned on the horizontal axis. The GPS unit then automatically interpolates, leading to very unnatural movements as indicated by the GPS recording in the ellipse in Figure 3. These GPS records are spurious and should be removed. Before the GPS data can be analysed, the information should be cleaned and the records classified.

A six-step process was followed to clean and interpret the data. The steps are not discussed here as they involve a rather complex process consisting of approximately 10000 lines of SAS/SPSS code. The steps involve deleting unreliable data and identifying movement and non-movement and subsequently classifying movement as home, work or other 1 – 4 activities.

An aspect that affects quality of GPS data is the number of satellites visible for the receiver and the horizontal dilution of precision (HDOP). It is recommended that records where the number of satellites visible is less than 4, or HDOP values of greater than 5, be deleted. If a stricter policy is adopted, i.e. delete records with the number of satellites < 5 or HDOP > 2.5, the result is longer stops and shorter trips.

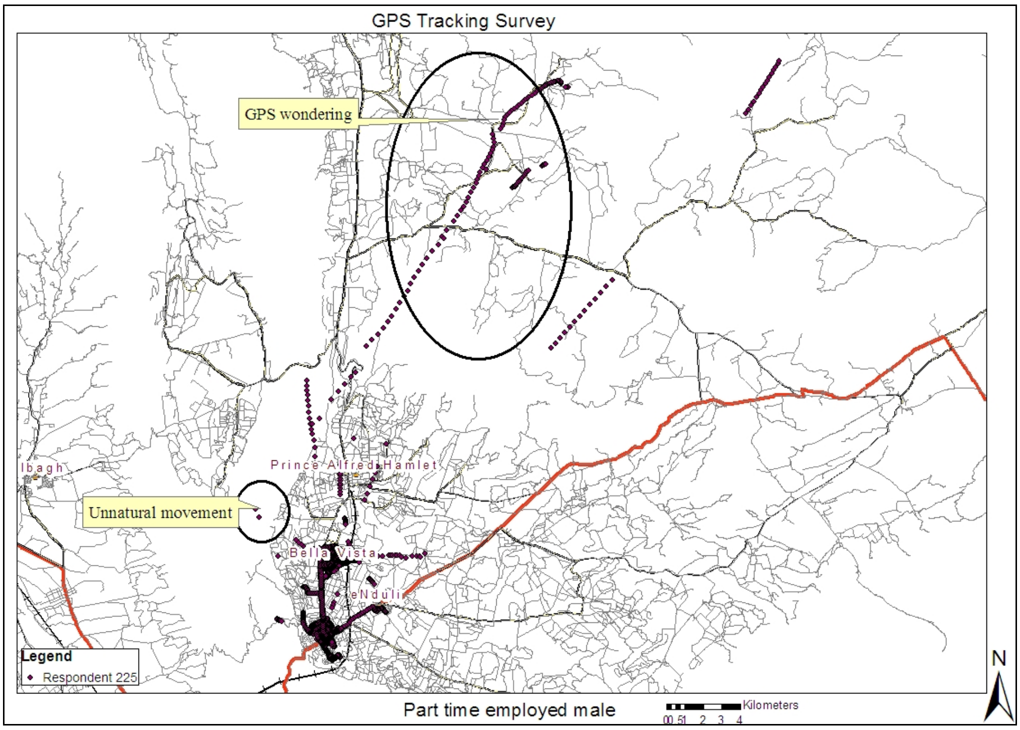
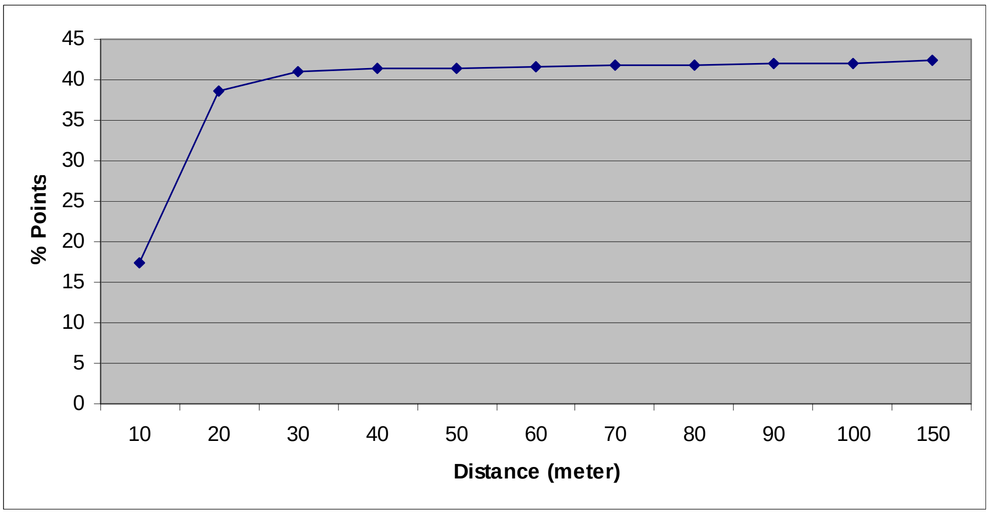


Figure 3: GPS recording mistakes

Various graphs of the percentage of points versus the distance between the points and the point labelled "Stop 1" were plotted (see Figure 4 as an example). It was decided to use 100 metres as a cut-off point, implying that all points within a radius of 100 metres represent the same position. If this distance is too small, more stops than the number of actual stops could be recorded. If this number is too large, possible stops could be missed. Because of the smaller size of the stands (real estate lots), especially in the Ceres group, this cut-off was used instead of the normal 200 metres, as encountered in the literature (Wolf, 2006).

Figure 4: Percentage of points within a given distance (in metres) from the first stop



GPS Results

Once cleaned, *an activity and trip record* (a file summarising the activities and trips) for each individual is delivered as shown in Table 1.

Table 1: Aggregated activity and trip data for GPS 248, Stellenbosch data

Date From	Time From	Date To	Time To	Position		1&	2	3	4	5	6	s/ m*	Time (sec)	Distance (metres)	Speed (km/hr)
2008/11/29	16:50:24	2008/12/01	07:20:54	495987	3702544	1	.	.	.	.	.	1	13863	.	.

													0		
2008/12/01	07:20:54	2008/12/01	08:09:16	495858	3702513	.	.	.	.	.	.	0	2902	.	.
2008/12/01	08:09:16	2008/12/01	08:32:30	476863	3711301	.	.	1	.	.	.	1	1394	21033.60	26.09
2008/12/01	08:32:30	2008/12/01	08:55:28	476956	3711189	.	.	.	1	.	.	0	1378	.	.
2008/12/01	08:55:28	2008/12/01	12:56:33	476863	3711301	.	.	1	.	.	.	1	14465	0.00	0.00
2008/12/01	12:56:33	2008/12/01	12:56:53	476956	3711189	.	.	.	1	.	.	0	20	.	.
2008/12/01	12:56:53	2008/12/01	16:45:57	477080	3711287	.	1	.	.	.	.	1	13744	217.45	39.14
2008/12/01	16:45:57	2008/12/01	17:22:32	477173	3710842	.	.	.	.	.	.	0	2195	.	.
2008/12/01	17:22:32	2008/12/02	07:36:39	495987	3702544	1	.	.	.	.	.	1	51247	20830.62	34.16
2008/12/02	07:36:39	2008/12/02	08:39:25	495917	3702182	.	.	.	.	.	.	0	3766	.	.
2008/12/02	08:39:25	2008/12/02	12:25:53	476756	3711369	.	.	.	.	1	.	1	13588	21159.21	20.23
2008/12/02	12:25:53	2008/12/02	12:27:20	476947	3711357	.	.	.	.	.	.	0	87	.	.
2008/12/02	12:27:20	2008/12/02	12:44:39	477080	3711287	.	1	.	.	.	.	1	1039	334.22	13.83
2008/12/02	12:44:39	2008/12/02	12:44:49	476958	3711353	.	.	.	.	.	.	0	10	.	.
2008/12/02	12:44:49	2008/12/02	13:46:48	476863	3711301	.	.	1	.	.	.	1	3719	217.45	78.28
2008/12/02	13:46:48	2008/12/02	13:47:03	476962	3711317	.	.	.	.	.	.	0	15	.	.
2008/12/02	13:47:03	2008/12/02	14:11:19	476863	3711301	.	.	1	.	.	.	1	1456	0.00	0.00
2008/12/02	14:11:19	2008/12/02	14:13:29	477080	3711287	.	1	.	.	.	.	0	130	.	.
2008/12/02	14:13:29	2008/12/02	16:04:57	476956	3711189	.	.	.	1	.	.	1	6688	145.58	4.03
2008/12/02	16:04:57	2008/12/02	16:43:16	476860	3710624	.	.	.	.	.	.	0	2299	.	.
2008/12/02	16:43:16	2008/12/02	16:51:50	495993	3700138	.	.	.	.	.	1	1	514	22012.09	34.47
2008/12/02	16:51:50	2008/12/02	17:46:37	495993	3700138	.	.	.	.	.	1	0	3287	.	.

[&]*(1), (2), …, (6) = Stop 1, Stop 2, …, Stop 6.*
**s/m: 1 = stop, 0 = move.*

The file contains the aggregated records for each individual of all travel and activities over two days of tracking. Figure 5 plots the aggregated information for respondent 248 (as summarised in Table 1). The home and work locations are correctly identified (stops 1 and 3 respectively) and three additional activities are identified at the work location (stops 2, 4 and 5). Interrogating the data in Table 1 reveals that the respondent spent some hours at these three other work locations. The nature of the specific individual's work (administration manager) requires meeting with several departments at her work location and moving between these departments.

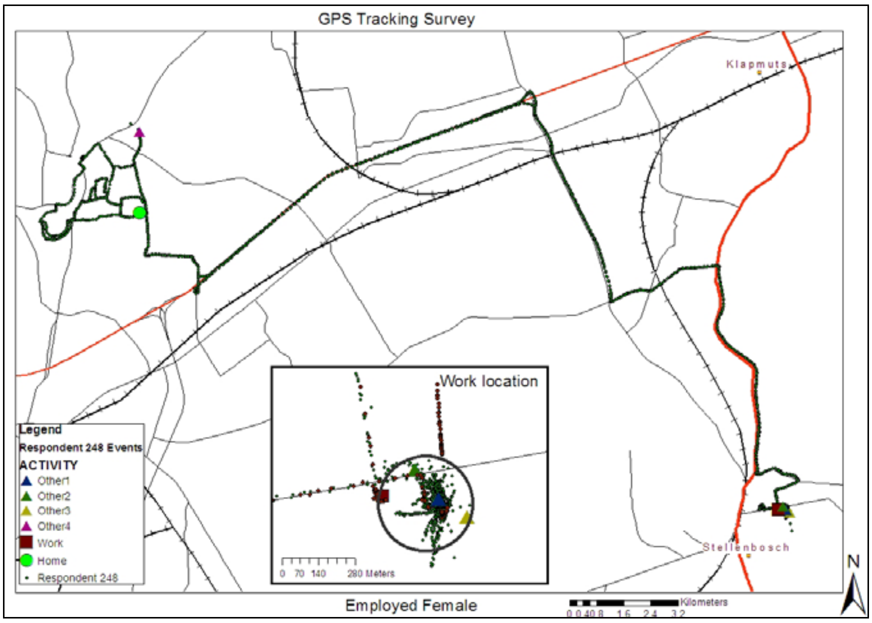


Figure 4: Activities and travel of respondent 248

The distance beween stops 2, 4 and 5 and the work location are only 280 metres (diameter of circle on figure). This individual was simply engaged in other work-related activities at the work location. Table 1 also shows how the mode and location can be identified. Following from the previous discussion, record 1 reveals that the respondent was at the home location for 138630 seconds (38.5 hours) before moving (or before the GPS was taken along on the first trip). Record 2 reveals that the trip with a car (as a function of speed) lasted 48 minutes at an average speed of 26 km per hour. Summary tables, however, become rather difficult to interpret. Plotting the respondent activity/trip profile possibly makes for a clearer interpretation of activity / travel behaviour.

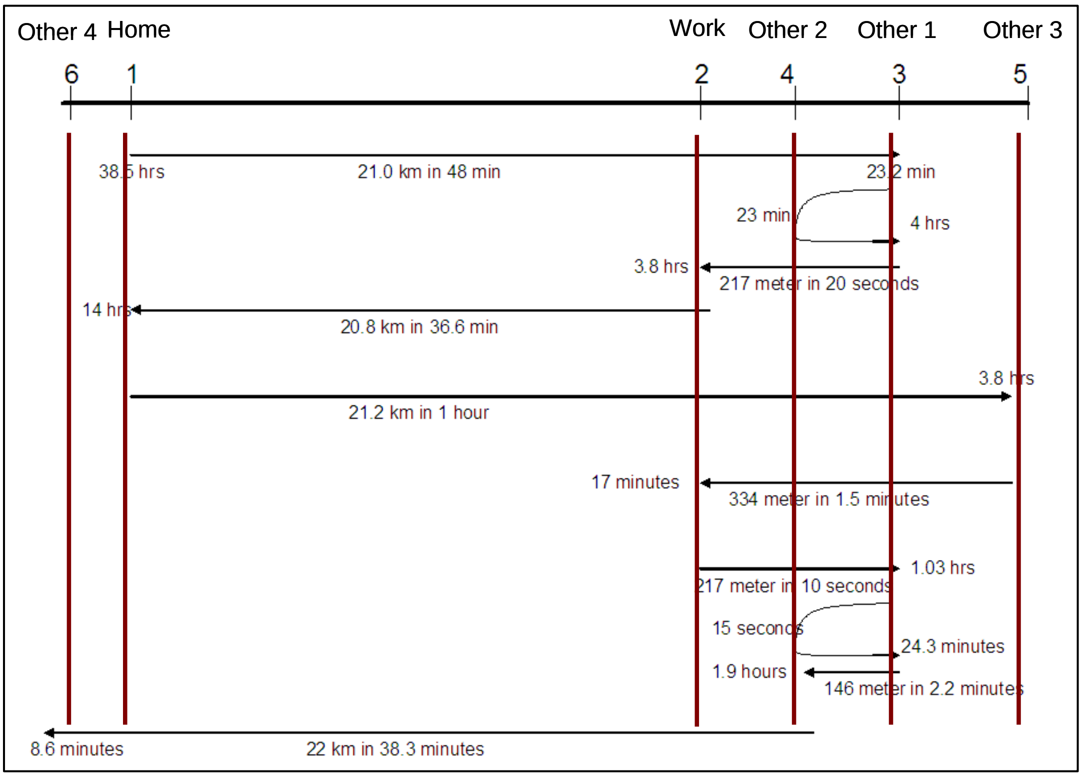


Figure 5 shows that the respondent travelled to stop 3 – stayed for 23.2 min. – travelled for 23 min. via stop 4 back to stop 3 – stayed for 4 hours – travelled to stop 2 in 20 seconds and stayed for 3.8 hours – then travelled back home. It should be remembered that stops shorter than 5 minutes are not recorded and hence the trip from stop 3 via stop 4 back to stop 4 did not record a stop which might have been shorter than 5 minutes. The home-based tour can subsequently be classified as H (home) – W (work) (3) – W (3) – W (2) - H on day 1, and H – W (5) – W (2) – W (3) – W (3) – W (4) – After Work – H on day 2. An inspection of the respondent's travel diary revealed a slightly different picture: the individual did indicate a trip to work and back on the day but no other intermediate (or work related) trips.

Considering the aggregated two-day statistics, the GPS records reveal that the respondent undertook 2 tours with multiple stops (from home back to home), 11 trips with a total travel time of 4.5 hours (or 2.23 hours per day); the latter includes walking trips. Also, the person spent 15.7 hours away from home over the two days (or 7.9 hours per day). The person also travelled a straight line distance of 86 km for the two days. Considering the travel diary, the respondent reported 8 trips lasting 320 minutes over two days (thus 160 minutes per day or 2.7 hours of travelling time) which compares well with the travel diary.

Figure 5: Activity/trip profile for respondent 248

The following section compares individual GPS and travel survey results in more detail.

Comparing individual GPS and travel survey data

Table 2 shows a summary of the questionnaire and GPS data for 2 respondents. Their questionnaire and GPS results are compared in terms of trips, time and activities. These five respondents represent different socio-economics groups but they are not necessarily representative of their respective populations. The following general observations are made:

Travel: Non-motorised modes and short trips at the work location (non-home and/or work related) and short trips originating from home seem to be missing from the travel diary (or not recorded). In all instances more trips were captured with the GPS than with the diary (specifically non-motorised trips). Travel modes reported by respondents are mainly private and public with virtually all non-motorised (and specifically) walk modes reported.

Time: The travel diary was structured to obtain information on the respondents' most important trip (which was assumed work) and to record the time (departure and arrival times). All the respondents rounded off their departure and arrival times of trips and activities. It seems from the GPS records that there were considerable variations in trip times but that respondents noted their usual (average time when leaving for work) departure and arrival times. Considering the other activities during the day (i.e. not the most important trip) respondents usually noted less information and even less accurate times (often only indicating the hour).

Activities: Similar to travel, the respondents under-estimated the number of activities visited. While the work activity was generally well captured, other activities (and their duration), were not captured. Respondents generally had a problem recalling their other activities but seemed to remember their daily routine activity. Activities at the work location were as a rule not considered.

Table 2 also provides a brief statement as a possible reason for the differences between the two measurement instruments.

Table 2: Summary comparative statistics

Questionnaire	GPS
Respondent 225 Male, no car, farm worker (low income)	
Travel ▪ Usually travels by taxi ▪ Walked to the primary school for a *meeting* (16:10 – 16:20 (twice) ▪ Total travel time: ***40 minutes to other*** (i.e. school meeting) **Time** Leaves 16h10; arrives 16h40 **Activities** ▪ No work activity ▪ Only trips noted were to school	**Travel** ▪ Travel by taxi *and walking* ▪ Respondent made 13 stops, but mainly moved between two points about 3.5 times in the two days. ▪ Total travel time: ***643 minutes*** o *Includes strolling* ▪ Total distance = 32 km (straight line) **Time** (departure times) 06:08:14, 09:09:22, 09:41:27, 15:00:15, 16:36:42, 18:31:22, ***07:38:45***, 10:46:09, 12:02:29, 13:24:55, 15:05:19, 17:47:27 **Activities** ▪ Three visits to Ceres town centre by taxi ▪ One visit to school ▪ A lot of visits to an open area in the neighbourhood ▪ Total distance = 33km ***Mismatch between diary and GPS: Stopher warns about this as a finding in his projects***
Respondent 230 Female (high income), car, full time employed	
Full two day record of all activities **Travel** ▪ Travel 2x to work in two days ▪ Travel to 2x other activities **Time** ▪ Leaves 7:25 – 7:40 **Activities** ▪ Home ▪ Work ▪ Crèche ▪ Gym ▪ Strand	*(Person interviewed afterwards)* **Travel** ▪ Respondent made 3 stops o Day one, stop at crèche o Day two, crèche and then work ▪ Total travel time = 171 minutes ▪ Total distance 61 km **Time** ***07:05:54***, 17:00:06, ***07:12:16***, 16:42:49 **Activities** o Home o Work o Gym o Crèche o *GPS did not pick up stop at Strand to pick-up/drop-off other passengers (possibly too short < 10 min.)* ***Short duration trips (> 5 minutes) linked to the tour not captured by GPS***

Aggregate results and Interpretation

As a rule, the GPS units recorded more activities and trips than the travel diary, notwithstanding only selecting activities of which the duration exceeded 5 minutes. When comparing the number of trips over the two days as reported in the questionnaires and as calculated from the GPS data, the GPS data recorded more trips in both the Ceres group (6.6 for GPS and 3.2 for the questionnaires on average) and the Stellenbosch group (10.4 for the GPS and 5.0 for the questionnaires on average).

For both groups, the total travel time is significantly more for the GPS data than reported by the questionnaires. (4.7 hours versus 1.3 hours on average for Ceres group, and 5.4 hours versus 1.9 hours for the Stellenbosch group over the two days). The total distance travelled, on the other hand, is significantly less for the GPS data (Stellenbosch group) than reported in the questionnaires (870 km per month for GPS data vs. 1379 km per month for the questionnaires). This might be that respondents included weekend trips in their estimates of distance travelled per month, whereas the GPS data only considered travelling during the week. The Ceres group did not supply distance values. When comparing the time of leaving, the median values reflect a more accurate comparison. When considering all subjects in the Ceres and Stellenbosch groups respectively, the Ceres subjects leave the house in the morning (median values considered) around 08h00 for both questionnaire and GPS data, and the Stellenbosch subjects leave the house around 07h00 for both. There are no significant differences between the questionnaire data and the GPS data regarding the time of leaving in the Ceres and Stellenbosch groups respectively. (Sign test, p-value >0.05 for both the Ceres and Stellenbosch groups).There is a significant difference of an hour when the median values of the time of departure in the questionnaire data and the GPS data for the employed group in Ceres are compared (p=0.0347, Sign Test).

Table 3: Comparison of GPS aggregated data and results from the questionnaires per employment group

	Ceres group: No employed Mean (std dev) Median (Q1 – Q3)		Ceres group: Employed Mean (std dev) Median (Q1 – Q3)		Ceres group: All Mean (std dev) Median (Q1 – Q3)	
	Questions (n=41)	GPS (n=33)	Questions (n=46)	GPS (n=44)	Questions (n=88)	GPS (n=81)
Number of trips in two days	3.3 (1.9)*** 3 (2 – 4)	7.8 (4.7) 7 (5 – 12)	3.2 (1.8) 3 (2 – 4)	5.9 (4.4) 5 (2.5 – 9)	3.2 (1.8)*** 3 (2 – 4)	6.6 (4.6) 6 (3 – 9)
Total travel time in two days (Hours)	1.2 (0.6)*** 1.1 (0.8 – 1.7)	5.4 (4.2) 4.9 (2.1 – 8.2)	1.4 (0.9)** 1.2 (0.8 – 1.8)	4.4 (5.0) 2.8 (1.2 – 5.4)	1.3 (0.8)*** 1.1 (0.8 – 1.8)	4.7 (4.6) 3.7 (1.2 – 6.5)
Total distance per month (20 days, (straight linex1.7) (km)	-	284.0 (381) 152 (25 – 462)	-	172.2(220.8) 99 (24 – 263)	-	224.6(303.8) 112 (25 – 329)
Time of leaving	9.9 (2.8) 9 (8.5 – 10)	9.6 (2.9) 9 (7 – 11)	7.4 (2.9)* 7 (6 – 7)	9.6 (3.8) 8 (7 – 12)	8.6 (3.1) 8 (6 – 10)	9.6 (3.5) 8 (7 – 12)

***Significant difference between questionnaire data and GPS results, p<0.0001, Sign Test (Pairwise comparisons)
**Significant difference between questionnaire data and GPS results, p<0.01, Sign Test (Pairwise comparisons)
*Significant difference between questionnaire data and GPS results, p<0.05, Sign Test (Pairwise comparisons)

Table 4: Comparison of GPS aggregated data and results from the questionnaires per employment group

	Stellenbosch group: No employed Mean (std dev) Median (Q1 – Q3)		Stellenbosch group: Employed Mean (std dev) Median (Q1 – Q3)		Stellenbosch group: All Mean (std dev) Median (Q1 – Q3)	
	Questions (n=2)	GPS (n=2)	Questions (n=25)	GPS (n=23)	Questions (n=27)	GPS (n=27)
Number of trips in two days	6.5 (0.7) 6.5 (6 – 7)	13.5 (10.6) 13.5(6– 21)	4.8 (2.5)** 5 (2 – 7)	9.1 (4.9) 9 (5 – 11)	5.0 (2.4)** 5 (2 – 7)	10.4 (6.1) 10 (6 – 13)
Total travel time in two days (Hours)	1.3 (0) 1.3 (1.3 – 1.3)	2.6 (2.1) 2.6 (1.1 – 4.1)	1.9 (1.1)** 1.8 (1.2 – 2.3)	5.1 (4.1) 4.5 (2.1 – 5.4)	1.9 (1.1)** 1.8 (1.2 – 2.3)	5.4 (4.9) 4.1 (2.1 – 5.4)
Total distance per month (20 days, (straight linex1.7) (km)	1000 (283) 1000 (800 – 1200)	600 (536) 600 (221 - 980)	1410 (912)* 1300 (1000 - 1800	906 (631) 767 (395 – 1461)	1379 (885)** 1230 (1000 – 1800)	870 (609) 767 (275 – 1396)
Time of leaving	14.5 (2.1) 14.5 (13 – 16)	13.0 (5.7) 13 (9 – 17)	8.0 (3.0) 7 (7 – 8)	7.1 (1.3) 7 (6 – 7)	8.4 (3.3) 7 (7 – 8)	7.6 (2.3) 7 (7 – 8)

**Significant difference between questionnaire data and GPS results, p<0.01, Sign Test (Pairwise comparisons)
*Significant difference between questionnaire data and GPS results, p<0.05, Sign Test (Pairwise comparisons)

Table 5: It was possible to identify work in 16 cases of the Stellenbosch data from the aggregated spreadsheet. From this one could identify stops before work, during work and after work. Ten of the subjects did not make any stops before work, 2 subjects made 1 stop before work, 2 subjects made 2 stops before work, and 2 subjects made 3 stops before work. This also applies to stops after work and stops during work.

Table 5: Identification of stops before, during and after work

	0 stops	1 stop	2 stops	3 stops	4 stops	> 5 stops
Before Work	10	2	2	2		
After Work	5	5	4	1		1
During Work	8	2	3	2		

Conclusions and recommendations

The objective of this project was to assess the reliability of GPS-based surveys and to establish whether such surveys can, or should, replace or complement more conventional surveys. The results indicate that present GPS surveys and capability do have a complementary role in travel surveys as opposed to substituting traditional travel surveys. The results also reveal, however, that further development work is necessary to refine the GPS capabilities.

While the findings in this study are mainly positive, the results are not necessarily completely conclusive - as is the case with most new technology.

- GPS data entail an entirely new data supply chain and analysis framework requiring a great deal of computer-based rules and heuristics.
- The administration of GPS travel surveys requires a new approach that takes cognisance of privacy and ethnical issues.
- Respondent behaviour, especially among lower income groups when confronted with GPS-based surveys, should also be considered (including other household members using the GPS unit, children carrying the GPS unit, units not being charged or neglecting to take the units along).

Some issues still hamper the full implementation of GPS surveys, including the costs of the collection devices. These costs, however, can be significantly reduced with new advances in manufacturing processes and by reducing sample sizes and increasing the duration of the tracking.

The researchers believe that GPS technology has a valuable role to play in travel data collection in developing countries and in South Africa specifically. The obvious benefit of GPS is in augmenting many large-scale regional and provincial and national household travel surveys. Smaller GPS-based sub-samples will potentially lower the cost of GPS survey administration while delivering additional information that can be used to calibrate larger samples or provide correction factors to expand sample statistics to a wider general population. Trip generation rates, route choice, departure time and trip length are typical examples of GPS data that can be used to calibrate larger, more complex samples. *GPS, however, also allows an entirely new look at and use for travel data and it would be a mistake to see and use GPS data as a simple substitute for travel surveys. Mapping travel over an extended period will allow a near-automatic and visually impressive insight in travel behaviour - something that is not possible with existing survey elements*.

Further research is being undertaken to refine both person-based tracking and travel surveys and in-vehicle units.

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