

# GPS in Travel and Activity Surveys.

Thomas S. Nielsen, Assistant professor  
Department of Development and Planning, Aalborg University  
Tel: +45 26 200 360, Email: [tsn@plan.aau.dk](mailto:tsn@plan.aau.dk)

and

Henrik Harder Hovgesen, Assistant professor  
Department of Development and Planning, Aalborg University  
Tel: +45 96 35 84 30, Email: [hvh@plan.aau.dk](mailto:hvh@plan.aau.dk)

## Abstract.

The use of GPS-positioning as a monitoring tool in travel and activity surveys opens up a range of possibilities. Using a personal GPS device, the locations and movements of respondents can be followed over a longer period of time. It will then be possible to analyse how the use of urban spaces are embedded in the wider context of activity patterns (work, school etc.). The general pattern of everyday itineraries, including route choice and time spent at different locations “on the way” can also be analysed.

If the personal GPS device is combined with an electronic questionnaire, for example in the shape of a Personal Digital Assistant (PDA) or cell phone, a whole new array of survey possibilities comes into being. Respondents can be asked to register their activities, evaluate or in other ways describe the attractiveness of places or modes based on their actual position and doings in the urban area.

The paper presents the possibilities in travel and activity surveys with GPS and electronic questionnaires. Demonstrative mapping of test data from passive GPS registration of Copenhagen respondents is presented. The different survey possibilities given a combination of GPS and PDA based electronic questionnaires are presented together with a first generation PDA-based questionnaire.

## Background.

The satellite based Global Positioning System (GPS) allows for fairly accurate geographical positioning and tracking through the use of GPS receivers on the ground. In recent years GPS receivers have become smaller and cheaper and increasingly integrated into a number of consumer products: - onboard navigation systems, small computers, cell phones etc. As an offspring from this development GPS positioning also becomes available for surveys focussing on the geographical allocation of activities, destinations etc. As a survey tool GPS positioning is still relatively technically demanding and expensive. However the current development in for instance the cell phone market where GPS and PDA functionality is becoming commonly available will lower these obstacles significantly in the near future.

Early application of GPS positioning in spatial behaviour surveys has been limited to special cases such as the tracking of seals or other animals in order to get new knowledge of their territories and geographical flexibility. GPS surveys of human spatial behaviour began to be adopted in the mid nineties when the first transportation survey with GPS positioning of vehicles was conducted in the US. The majority of later applications of GPS as a transportation survey tool also use GPS to follow vehicles (Schönefelder et. al., 2002).

The Atlanta based Geostats company have developed equipment to track and log individual person's whereabouts independent of vehicle use. This method has been used in the part of Atlanta's transportation and urban planning survey (SMARTRAQ) that focuses on the relationships between urban structure and physical exercise (Georgia Institute of Technology, 2001). It will be possible to follow the movements of the individual respondents in the neighbourhood and the immediate vicinity of the home, information that would be difficult to retrieve through traditional recall and paper-based approaches.

In the Scandinavian countries recent studies of road pricing and intelligent speed adaptation (see: [www.infati.dk](http://www.infati.dk)) have employed GPS to position and monitor (charge) the vehicles. This has produced large data-sets of vehicle movements through long periods of time. The data has allowed additional analysis that would previously have been very difficult to approach, for example the monitoring of congestion on the basis of actual driving speeds (Nielsen, 2003) and the temporal variations of travel patterns within the individual household as opposed to the common cross sectional studies, (see. Schönefelder et. al. 2002)

GPS surveys of individuals are still few. The only GPS based registration of individual person's spatial behaviour in Denmark (known to the authors) is the assessments of exposure to air pollution based on spatial behaviour and emissions and undertaken by the National Environmental Research Institute (Jensen et. al. 2003). The claim in this paper is however that GPS positioning could be used generally to widen the possibility in spatial behaviour surveys, making them more precise and easier to handle. And to open up new analytical perspectives based on new knowledge on spatial behaviour and spatial patterns.

## **GPS Data.**

The GPS receiver in itself allows for a capture of geographical position in terms of lat/lon coordinates and height. With a continuous registration of geographical coordinates and time, travel speed and direction can be derived.

For the experiments presented in this paper a Garmin Navtalk GSM was used as the GPS unit. It is a cell phone with a built in GPS receiver. Its cell phone dimensions make it suitable to be used as a personal device, to be carried around by respondents at all times.

The specific product also allowed the GPS tracks to be continuously registered and exchanged with external media, either through SMS allowing continuous real-time tracking or storage of the tracks on the phone with the possibility to upload them to a computer.

The continuous capture of data through SMS messages is of course advantageous in that it allows equipment malfunctions and incorrect use to be detected and corrected. However the

size of the phone bill as well as the surveillance perspective, points to the use of the devices as passive equipment without ongoing exchange of information.



Figure 1: Garmin Navtalk GSM – cell phone with GPS. The phone was used in the experiments presented in this paper.

Position	Time	Altitude	Leg Length	Leg Time	Leg Speed	Leg Course
722826 6176713	19-12-2003 13:14	26.6 m	9.6 m	00:00:04	8.7 kph	188- true
722805 6176686	19-12-2003 13:14	26.6 m	34.8 m	00:00:25	5.0 kph	221- true

Table 1: “Raw”-data from passive GPS registration. Data for 2 “trackpoints”. The “Position” column contains X and Y coordinates in UTM zone 32, European Datum 1950.

The GPS receiver positions itself on the basis of signals from a large number of GPS satellites. The precision of this positioning depends on the number of satellites that are “visible” from the position of the GPS receiver. This is particularly important when GPS is used to monitor spatial behaviour in urban areas, where buildings block the view to the sky and makes GPS positioning more difficult and imprecise. The dense core areas of European cities can be seen as a critical test of the use of GPS in spatial behaviour surveys (Steer Davis Gleave and Geostats, 2003).

The GPS data that can be collected will have the character of a series of “points”, which in some circumstances may almost form a continuous itinerary, but in others may bear the marks of occasional drop outs of the GPS signal because of buildings, vehicles or such like blocking the view to the sky.

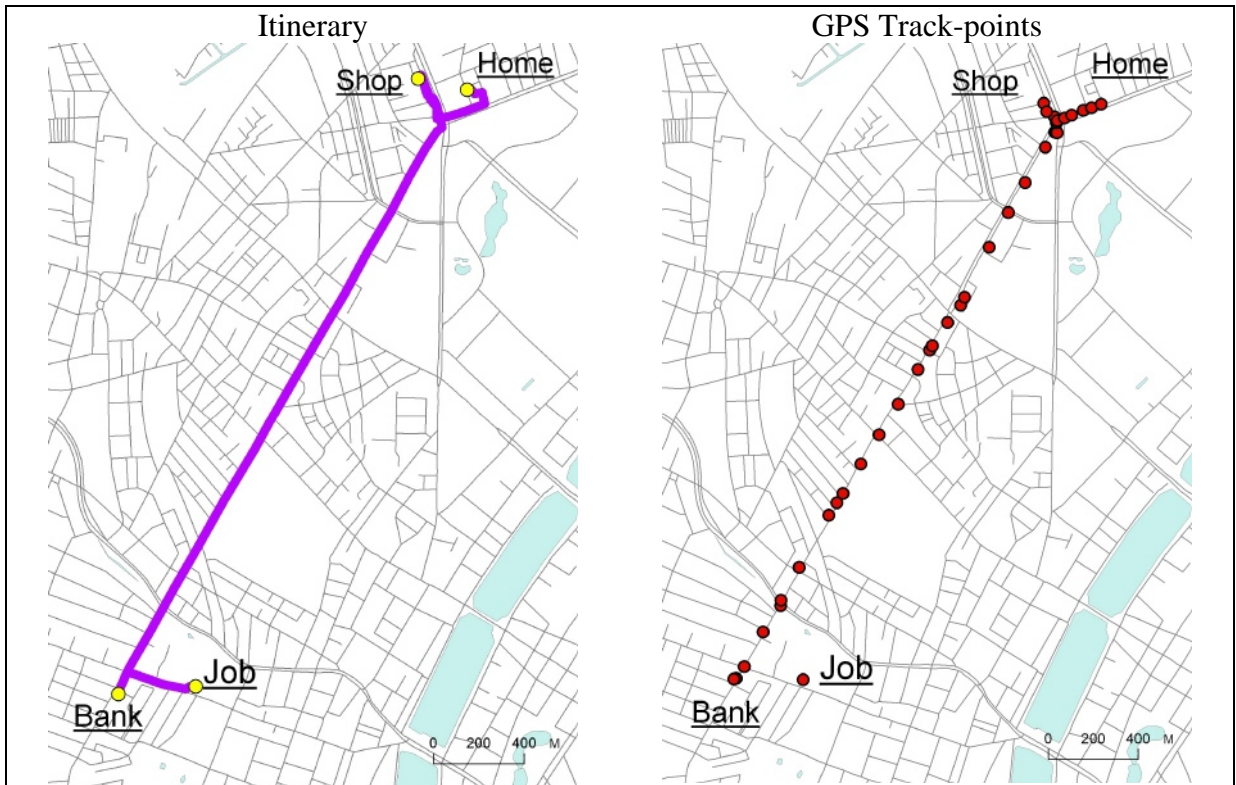


Figure 2: Comparison of the actual itinerary from a bicycle trip in a street canyon with stops on the route – with GPS track-points registered on the trip.

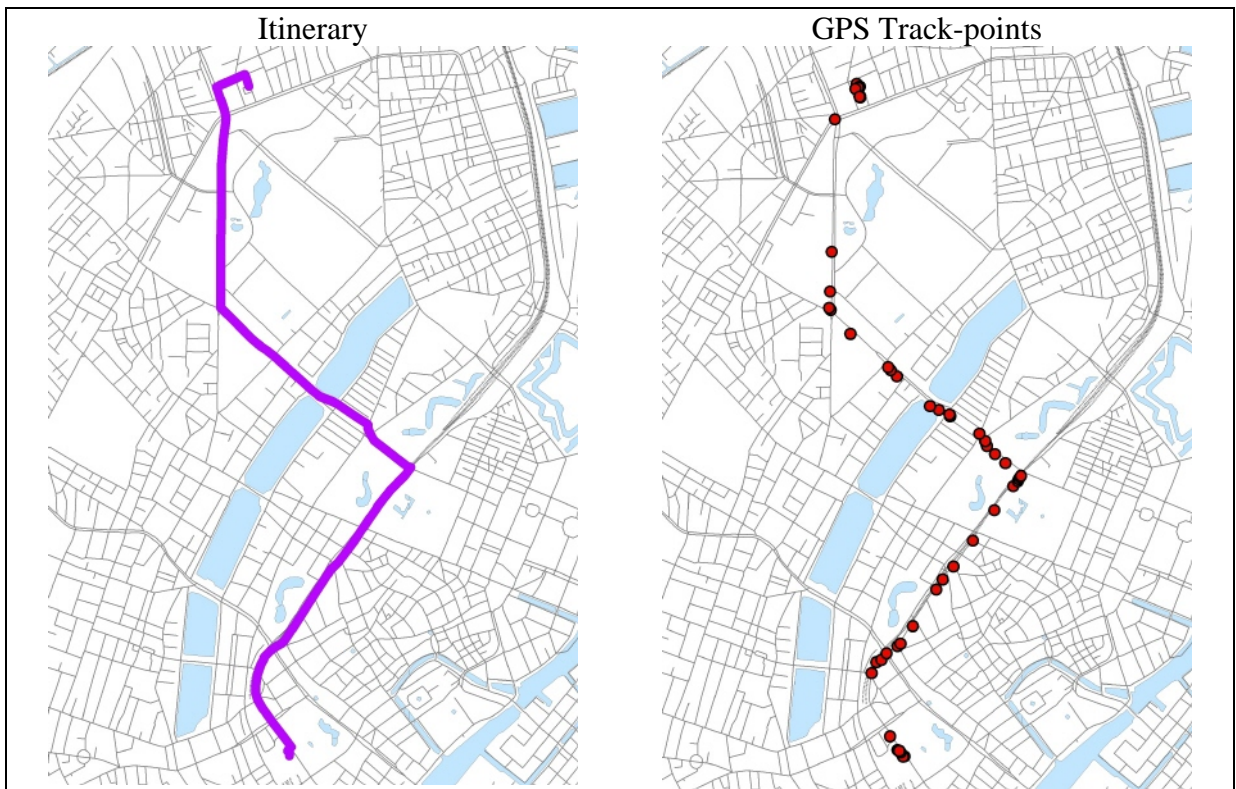


Figure 3: Comparison of the actual itinerary of a car trip from Copenhagen central station to a destination in the northern part of town – with GPS track-points registered on the trip.

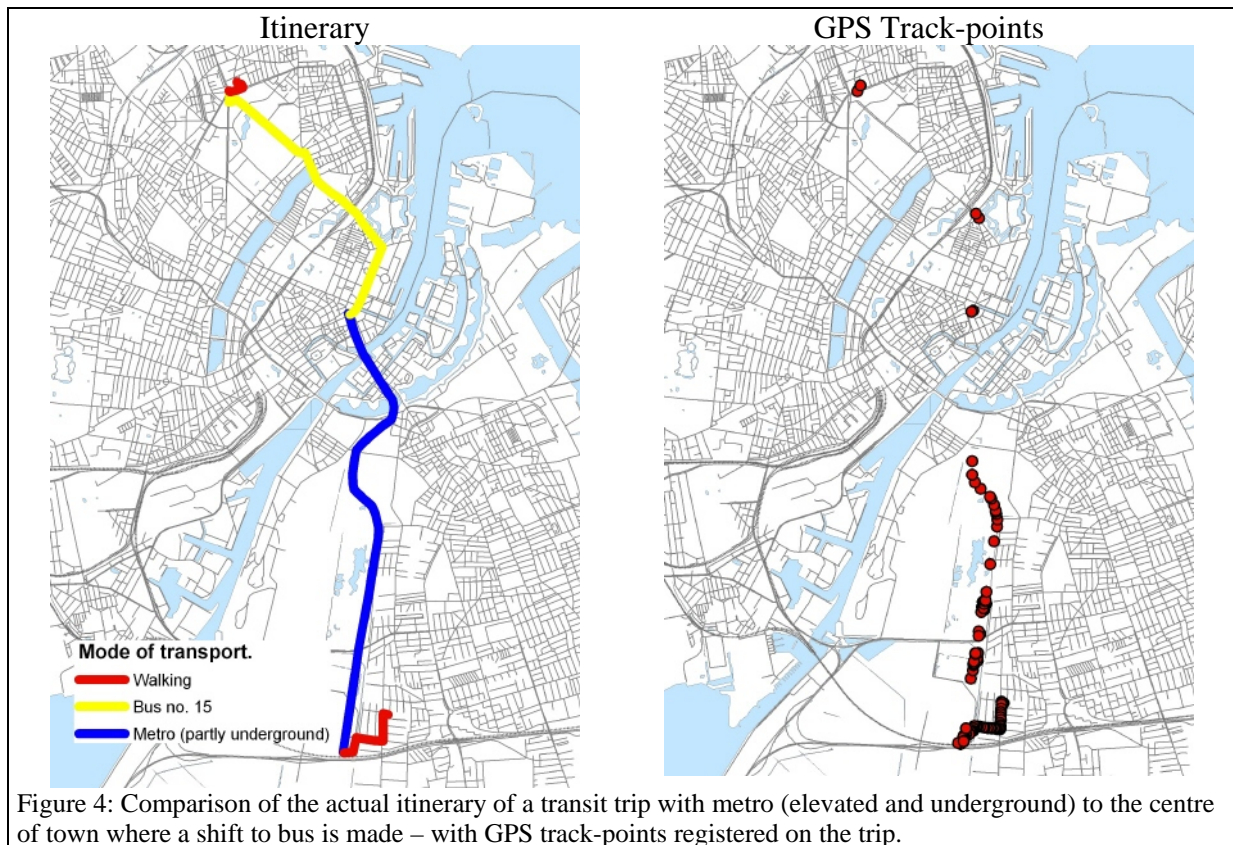


Figure 4: Comparison of the actual itinerary of a transit trip with metro (elevated and underground) to the centre of town where a shift to bus is made – with GPS track-points registered on the trip.

In the previous studies where vehicles have been equipped with GPS antennae and receivers, buildings blocking the view would be the main sources of GPS drop out. In the case of GPS receivers as personal devices, carried around by individuals, the specific location of the person holding the GPS becomes important. Positioning of GPS devices is generally very difficult inside buildings in urban areas (only possible in low rise - relatively open neighbourhoods). However, as the location of a person inside a building generally implies a stationary activity this is of less importance as long as he/she is positioned on entering and leaving. Some transportation modes, especially transit modes, have a similar effect - blocking the signal and causing GPS drop out.

Figures 2-4 show the itineraries as recollected by the travellers and the GPS track-points registered on the route - when 3 different transportation modes are used: bicycle, transit (bus and metro) and motorcar. The track-points were collected with Garmin Navtalk GSM carried by the travellers as a personal device (in a pocket, a briefcase or the like).

In figures 2 and 3, bicycle and motorcar obviously show the best representation of the actual itinerary with the GPS track-points. For the bicycle trip the track-points also seem to represent the stops on the route fairly well (information on time attached to the individual track-points could be employed to register the duration of stay at each stop). The car trip shows a number of drop outs in the south (dense area near the central station) and in the north (area with tall buildings west of the route) – however these are at a level where reconstruction of the actual itinerary is still possible.

Figure 4 shows a transit trip where the walking part at both ends of the trip is well represented together with the part of the trip on the elevated section of the Copenhagen metro (southern

part of the map). On the part of the metro trip that goes underground there is obviously no GPS signal and therefore no track-points. The part of the trip by bus also seems to pose a problem, and there are only track-points at the point where the bus is boarded and at a single location on the route (a location on relatively high ground with an open view to the east). As a result the track-points contain information on origin and destination for only parts of the route. A full reconstruction of the itinerary can not be based on the track-points alone but would require information on the mode of transport / bus routes. Whether this is desirable depends on the focus of the study.

The effect of taking the GPS receiver into a train resembles the effect from the bus, which can be seen on figure 4. The vertical orientation of the windows and the low probability of having a view in more than one direction (because of the size of the vehicle) is probably the main reason for the transit vehicles causing the GPS to drop out.

### Sample Data – Passive GPS Registration.

To test and demonstrate the potential for the analysis of behaviour patterns a sample dataset was created. Seven “respondents” employed at the Royal Veterinary and Agricultural University (KVL) in Copenhagen agreed to carry the Garmin Navtalk with them at all times when they were outside buildings for a one week period. This should allow for a demonstrative analysis and mapping of the spatial relationship of the individual respondents and of the Royal Veterinary and Agricultural University, as their “common activity bundle”.

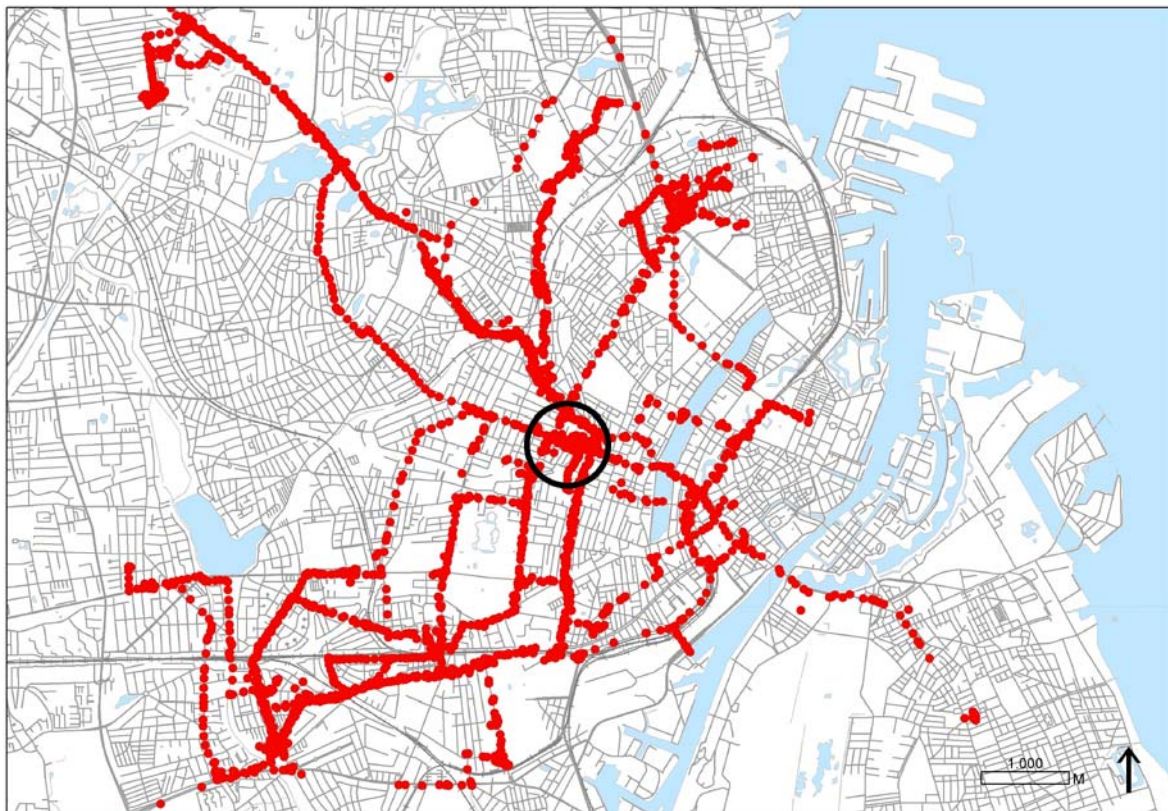


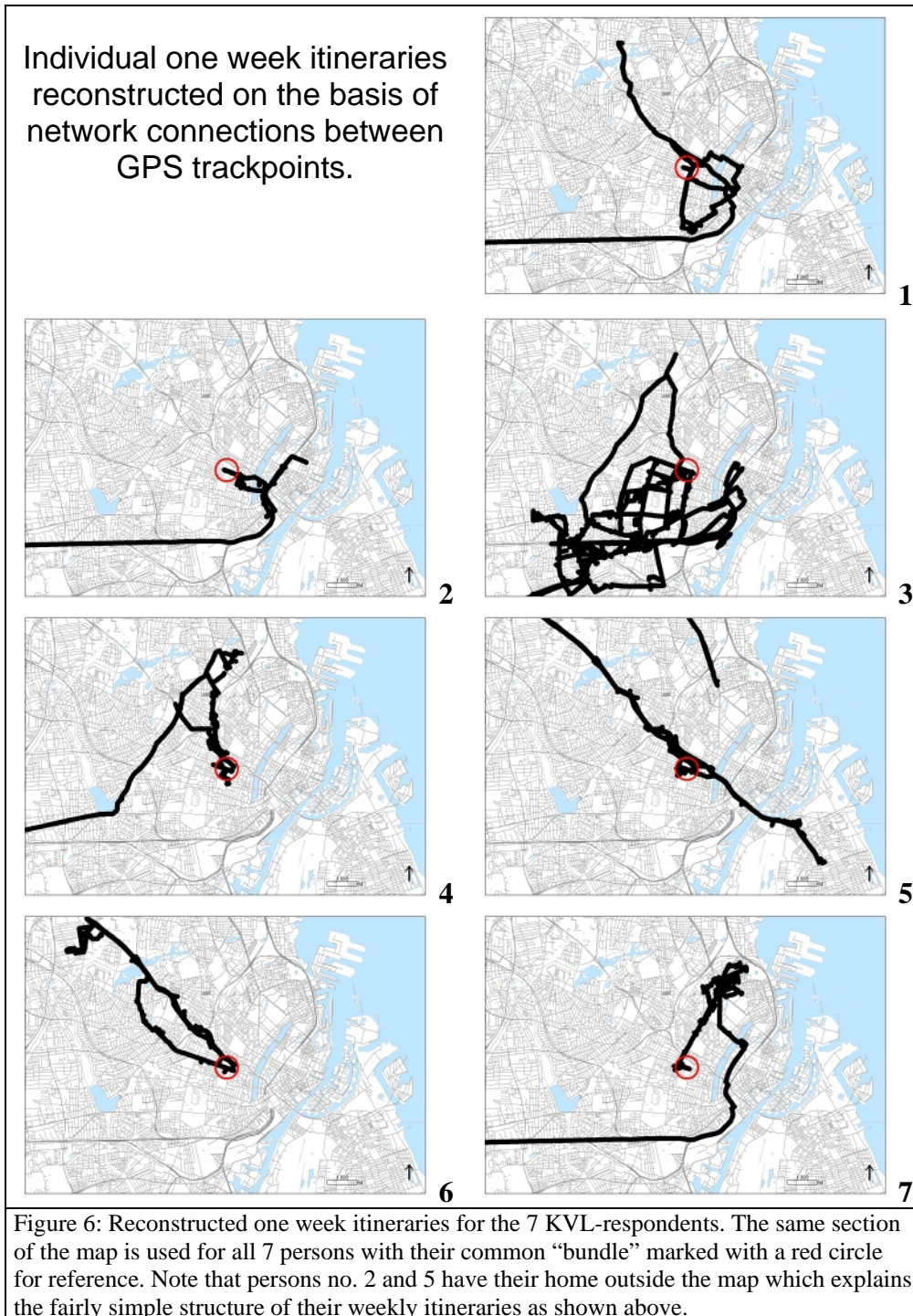
Figure 5: Track-points from the 7 KVL respondents “whereabouts” during approximately one week. Note that a section of the map focussing on the Royal Veterinary and Agricultural University (circled on the map) is chosen. Some of the respondents live outside the map area and or made trips to destinations outside the map area during the one week period.

The map in figure 5 shows the joint track-points from the 7 KVL respondents inside a section of central Copenhagen focussed on the Royal Veterinary and Agricultural University. The point data may be treated to illustrate the intensity of points for example, by using a spatial statistic like kernel density estimation.

#### Reconstruction of Itineraries.

Given the present state of the GPS technology, the track-points that can be attained from a person's movement over a longer time span is unlikely to be continuous. If a continuous itinerary is desirable, fore instance for mapping purposes, it will have to be reconstructed on the basis of the track-points and some predefined transportation network.

As a demonstration a rough reconstruction of continuous itineraries on the basis of network relations between points was attempted for each of the seven respondents (figure 6). The reconstruction is rough because it uses simple airline distance to assign track points to the network, and roads as transportation network.

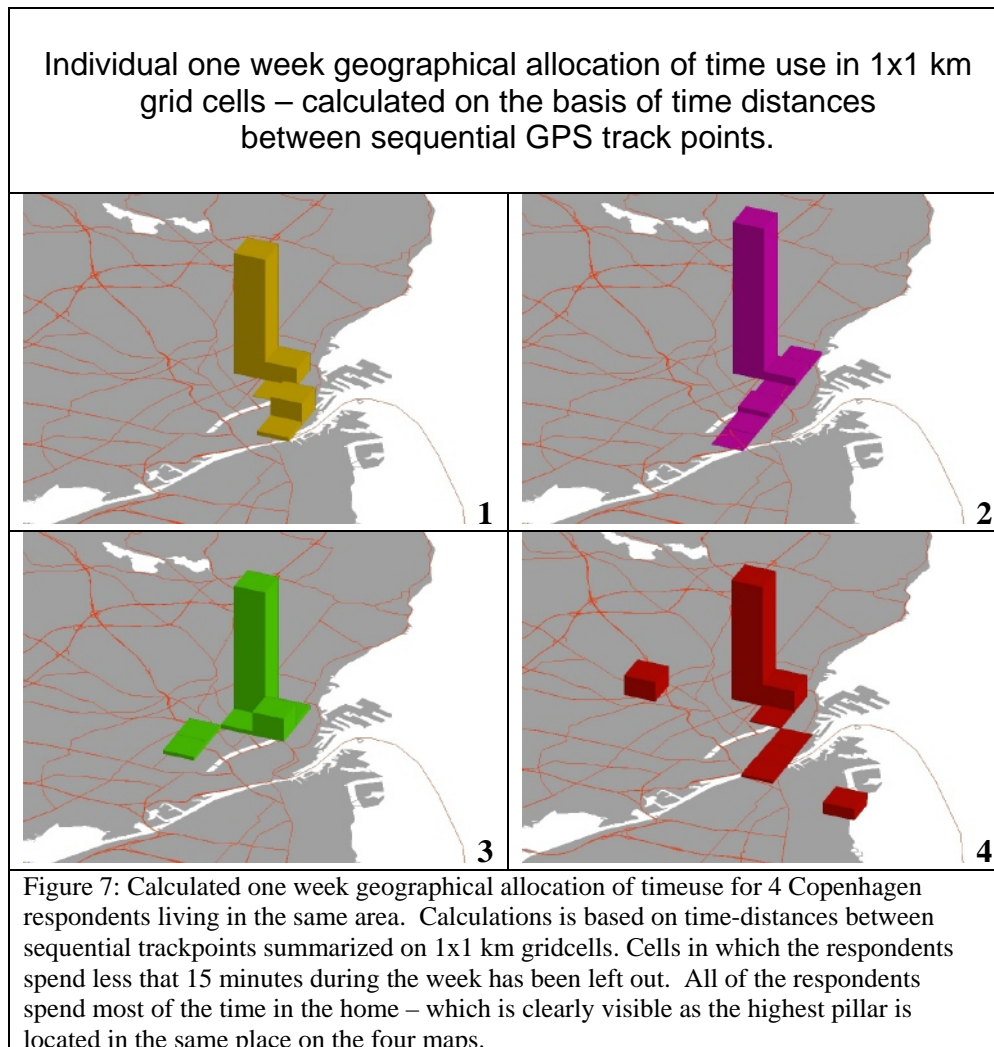


The reconstruction could be made better through assignment of track-points to the network on the basis of projections of direction or the like (see: Cederholm, 2000) and through the inclusion of travel speed as a proxy for travel mode, and relevant additional transportation networks. Whether this is necessary depends on what aspects of travel and spatial patterns and at what scale it is desired to represent on the maps. As a representation of the patterning of spatial behaviour within an urban area of the size shown on the maps above, the “rough” approach will probably be adequate in many cases.



### Calculation of time use

The GPS-trackpoints and the registered log-time also provides a basis for avaluation of the geographical allocation of time. For the use in this paper time-distances between sequential trackpoints where calculated for a group of four Copenhagen based respondents (also one GPS-registrations) and the time-laps where registered as an attribute of the origin trackpoint.



Total time use was summarised on the Danish data grid 1-km cells - for each respondent (figure 7). Even if logging with regular time intervals had been used (which was not the case) a calculation would be necessary in order to locate the time spend during GPS-dropout. Correct location of time use is of course very sensitive to GPS warm up and search periods after drop out of having been turned off. The use of relatively large area units for the final data presentation and analysis will of course reduce the “criticality” of this area – however special attention should be given to how time use is allocated geographically around the home and the workplace where the long time periods involved introduces a potentially large source of error.

## Extending the GPS Survey.

The value of GPS positioning as a tool for data capture can be greatly enhanced when it is combined with a Personal Digital Assistant (PDA) or a similar feature allowing the collection of additional data in full integration with GPS positions. From the field of urban planning and planning studies one could think of Francis Stuart Chapin Jr's activity based approach (1974). Following Chapin, planning was to rest upon studies of activities in time and space. Unfortunately the "space" part of the approach was never fully implemented, and was later left out from most studies concerned with the use of time (time use has generally been taken as synonymous with "activity pattern"). The likely reason for this was probably the difficulties associated with the collection and handling of spatial behaviour data. As a consequence spatial behaviour at the everyday level has only been studied when it was unavoidable as for instance in transportation studies concerned with travel from zones of origin to destination zones. The GPS positioning eases the scientific access to the spatial part of activity patterns. The integration of GPS positioning with an electronic questionnaire (PDA) will allow for registration of the activities undertaken, trip purposes and similar qualities that require a dialogue with the respondents.

The GPS integrated PDA interface, with the screen sizes now commonly available, allows for different approaches to electronic questioning. These will briefly be commented on in the following - taking the study of spatio-temporal activity patterns as a point of departure.

### Self Administered Questionnaire.

The PDA may be used as a self administered questionnaire where respondents could register changes of their main activities through the day.

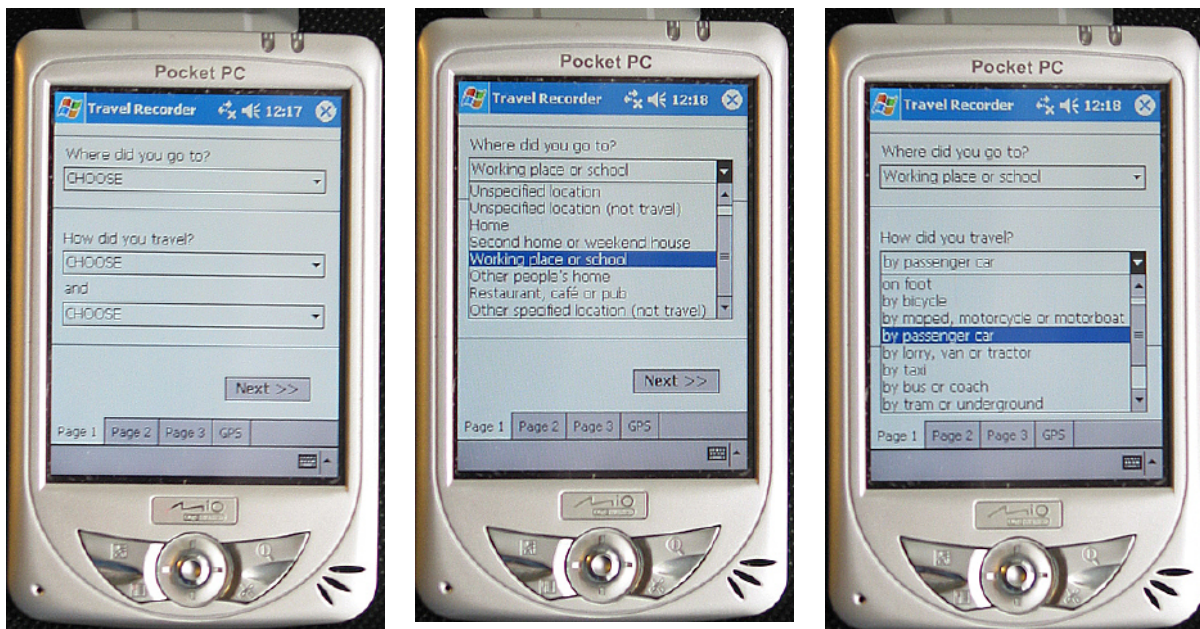


Figure 8: first generation PDA-based questionnaire focussing on purpose/destination type and mode. In its present state it is 100% self administered by the respondents. Answers are given through selections on drop-down lists and database records are automatically generated.

A first generation respondent administered PDA-based questionnaire can be seen in figure 8. Information resembling those collected with a traditional travel diary will be stored from the respondents choices on the drop down lists and the associated clock-time and GPS-position.

Some sort of heuristic in the assignment of position at times where there is no GPS-connection will of course be needed. In the case of a travel diary where the respondents could be assumed to be stationary when they fill in the questionnaire this is not likely to be problematic. A lack of GPS connection will then usually be associated with an indoor location that can be positioned adequately based on coordinates before and/or after GPS drop out.

The PDA-based questionnaire could in principle be extended to a full time-use questionnaire. As registration should happen in real-time it is of course very important to find a balance wherein respondents are not overburdened, but where details on time use are still satisfactorily high. Thus a direct implementation of the full range of time use categories used in for instance Eurostat standard (2000) will not be possible. One would realistically have to rely on main categories with the necessary differentiation on “target areas”.

0 Personal care
1 Employment
2 Study
3 Household and family care
4 Volunteer work and meetings
5 Social life and entertainment
6 Sports and outdoor activities
7 Hobbies and games
8 Mass media (reading, TV etc.)
9 Travel and unspecified time use

Table 2: Eurostats (2000) main activity categories for time use surveys.

### Temporal Questioning.

Another way to organise the time use survey would be to question the participants periodically on what they have been doing within the previous time period. To limit the burden on the respondents the time spans will have to be relatively long - probably one hour. The temporal questioning will impose a relatively rigid structure on the data, but would be relatively simple and overcome some problems of the forgetfulness of the respondents.

### Place or Behaviour Dependent Questioning.

The self administered as well as the temporal questioning is basically a direct substitution of pen and paper for a digital, PDA based registration system, with its obvious advantages in terms of data handling and dataset construction. The GPS positioning is of course added, but not really integrated in the methodology. It is also possible to integrate the GPS positioning in the questioning, either on the basis of pre-defined areas in which pre-defined questions are asked when the respondents is leaving or entering or on the basis of a distinction between whether the respondent is mobile or stationary at the moment.

The pre-defined areas may be a number of specially designated areas: CBD, Parks etc. or a grid covering a larger area. The delimitation of areas will be preloaded on to the PDA and the questioning will be coded (taking error margins into account) to question about their activities in the area when they are leaving the area. Given the knowledge of the specific location and a deliberate delimitation of areas the questioning may be targeted to the specific area (spending in the CBD/urban core or leisure activities in the park etc.). This approach is especially suited to address narrow questions on area problems, customers, use contexts and the like.

A distinction between mobility and stationarity could be employed as a means to capture actual locations of activities through the day. The continuing GPS positioning makes it possible to register when the respondents have not moved more than x meter in x minutes; and to use this information to question the respondents about their actions.

The integration of information on behaviour (mobility-stationarity) and in some cases specific places, into the questionnaire format, holds a potential to develop very reliable GPS/PDA

based accounts of activity patterns. However, the structure of the questioning and database build up must be rethought in comparison with the traditional activity/time use survey.

### **New Data Items.**

The market for PDAs and cell phones with similar functionality already promises a wide range of additional functionality that will widen the survey possibilities. Pictures, video clips and sound may be taken/recorded by respondents and related directly to the other information in the database, positions, activities etc. The taking of pictures may for instance be built into the questionnaire and may be prompted with a relevant task description in designated areas. It must, of course, be kept in mind that these functionalities will add to the need to educate the respondents on how to participate in the survey. On these grounds it may be of limited use in general surveys – but could be of great use in smaller more targeted surveys.

### **GPS in Travel and Activity surveys**

In the context of travel and activity surveys the use of GPS registration can be seen as advantageous on a number of grounds. Foremost is the fact that the GPS is a means to attain detailed registration of routes and activity allocation. The respondent's whereabouts can be monitored in relatively closely defined areas (for instance in a park or a housing development) as well as at the urban or regional level. Precision for small area studies may also be greatly enhanced through the employment of DGPS correction, yielding precision as high as +/- a few meters. Thus it should be possible to judge on what side of the street a person is walking etc.

New perspectives for analysis also seem to open up with the employment of GPS-registration; use context (location within activity schedule and routes) of urban areas, visual exposure, risk exposure, exposure to pollutants, and analysis of spatial patterning of behaviour and spatio-temporal rhythms (could be part of micro-level pedestrian modelling - see for instance Michael Batty, 2003). This will allow new insight to be gained and new representations of travel and activity patterns to be presented.

The disadvantages of GPS based data collection in travel and activity surveys are the costs of data collection and the need to hand out and retrieve the GPS units.

The price of the GPS units will in many cases make it unrealistic to equip a large number of respondents with one each. Thus larger surveys will probably demand that a number of GPS receivers are "recycled" among respondents over a period of time.

The need to hand out and retrieve the GPS receivers makes it obvious to contact respondents at home or at work, or some other "activity bundle" to which the respondents is attached. Other approaches could be to hand out GPS equipment on site and have respondents mail the equipment back.

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