The potential for the exploration of activity patterns in the urban landscape with GPS-positioning and electronic activity diaries

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Title of paper

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Abstract

The integration of GPS-devices with handheld cell phones or small computers opens new perspectives for urban and regional research. Detailed knowledge may now be gained on peoples itineraries through the urban landscape, how places are embedded in use contexts with each others and how temporal rythms affects the different parts of the city. GPS-based tracking has previously mainly been used to track vehicle movements, fx. in transportation surveys. The use of personal devices makes it foremost possible to place the individual respondents use of urban space in its context of transport routes, other locations visited and the individuals total time budget.

In the cross-disciplinary research project Space – Time – Flows currently being started at Aalborg University, the GPS/electronic diary technology is intended as a means to disclosure the imprint of information and communication technologies on the use of urban space. The core of the work will be an equal treatment of activities in the virtual as well as the physical world. Substitution effects between the virtual and the physical world will be in focus, together with differences between the spatio-temporal patterns of groups with different attachments and investments in the "virtual lifescape".

This paper is a part of the ongoing work towards GPS-based activity surveys. It addresses the problems with GPS-precision in dense urban areas and it presents the possibilities in GPS-based tracking of individuals. Analysis of itineraries and spatio-temporal activity patterns is presented based on sample data from the Greater Copenhagen area in Denmark. This is followed by a status of the work with the combination of GPS-based tracking and a suitable electronic personal/handheld activity diary.

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) 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 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

*) Including illustrations and references

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. 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 in a spatial behaviour survey 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. 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. Figure 1 show the itinerary of a roundtrip as recollected by the traveller and the GPS track-points registered on the route (with Garmin Foretrex 201). Outdoor activities and transportation on foot, bicycle or private motorcar can be registered very accurately with person-carried GPS devices. The exception being very dense build environments, where contact with the nessasary number of satellites becomes impossible. However in the Danish context this seems to be limited to certain sections of the dense historical core areas. The individuals use of trains and busses poses a greater challenge to GPS as a survey tool. In the case of a survey participant taking the GPS-devise into a bus or a train - positioning and thus the tracking of actual position will usually only be possible for some part of the trip – and the success will depend considerably on the weather and other features of the environment (especially building density).

*) Including illustrations and references

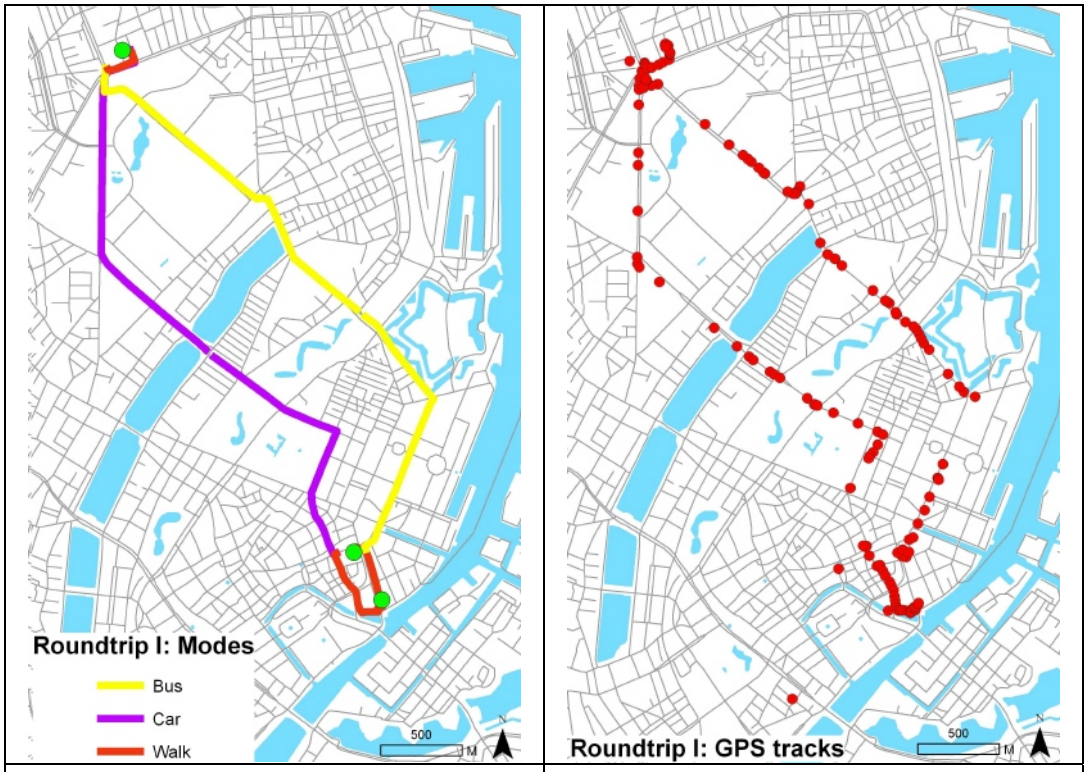

Figure 1: Actual one day itinerary | GPS "recording"

Sample Data – Passive GPS Registration.

The passive GPS-registration – that only contains information on geographical position and time (and no qualifications with respect to what activities that occurs where etc.) – is in itself a powerful tool for the survey of spatial behaviour. It will allow for the reconstruction and analysis of itineraries (routes), geographical allocation of time, time-variation more generally and the interconnectedness of the different arenas and functions in the urban area. Theses information has generally been very difficult to handle and surveys that cover these aspects are consequently rare.

Itineraries through space

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 a group of seven respondents (figure 2). The

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reconstruction is rough because is uses simple airline distance to assign track points to the network, and roads as transportation network.

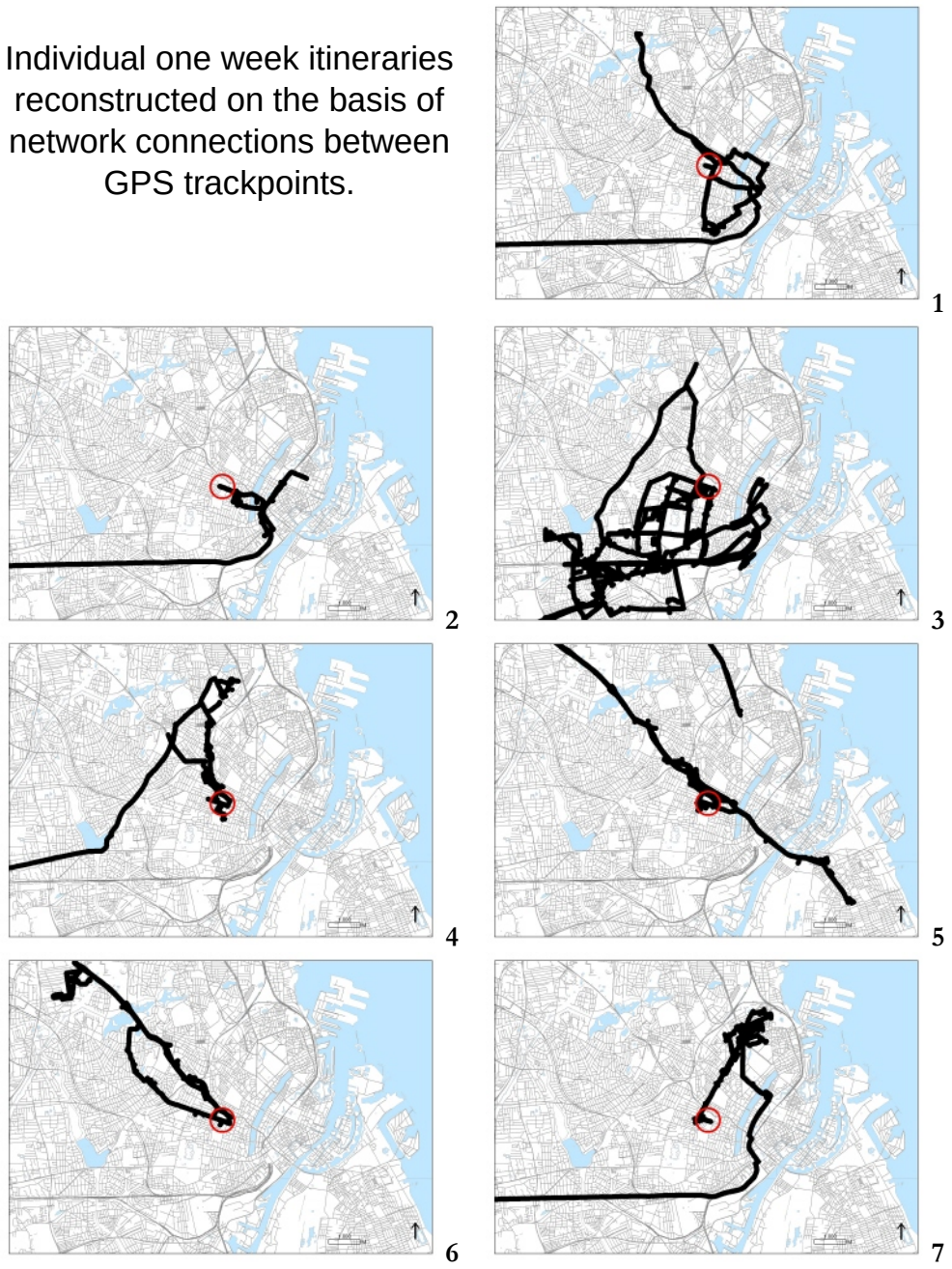

Figure 2: Reconstructed one week itineraries for respondents employed at the Royal Veterinary and Agricultural University in Copenhagen. The same section of the map is used for all 7 persons with their common "activity bundle" marked with a red circle for reference. Note that persons no. 2 and 5 have their home outside the map which explains the fairly simple structure of their weekly itineraries on the map above.

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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.

Geographical allocation of time use

The GPS-trackpoints and the registered log-time also provides a basis for evaluation 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 and the time-laps where registered as an attribute of the origin trackpoint.

Individual one week geographical allocation of time use in 1x1 km grid cells – calculated on the basis of time distances between sequential GPS track points.

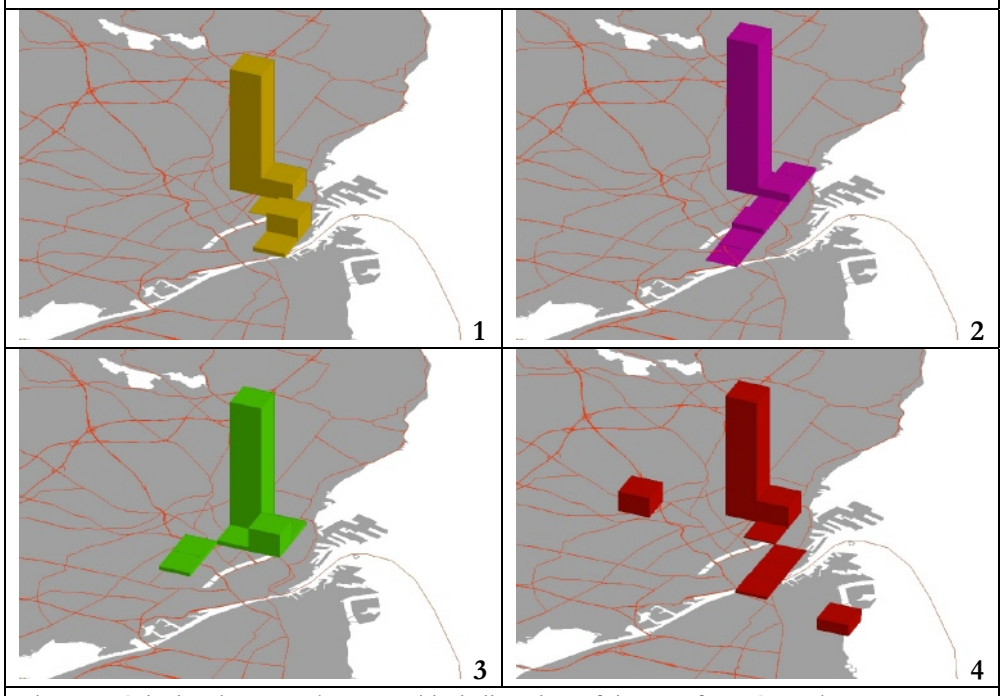

Figure 3: Calculated one week geographical allocation of timeuse for 4 Copenhagen respondents living in the same area. Calculations is based on time-distances between sequential trackpoints summarized on 1x1 km gridcells. Cells in which the respondents spend less that 15 minutes during the week has been left out. All of the respondents spend most of the time in the home – which is clearly visible as the highest pillar is located in the same place on the four maps.

Total time use was summarised on the Danish data grid 1-km cells - for each respondent (figure 3). Even if logging with regular time intervals had been used (which was not the case)

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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 or having been turned off. The use of relatively large area units for the final data presentation and analysis will reduce the "criticality" of this issue – 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 location and/or changes in their main activities through the day. A first generation respondent administered cell phone-based travel diary can be seen in table 1. The respondent will answer the three/four questions (schroll down or press the digit to select) upon arrival to a new place/a new activity site. The distance / time question is added for test purposes. In the longer run it would be desirable to extract duration and distance covered directly from the GPS-registrations, to increase precision and relieve the burden on the respondents.

*) Including illustrations and references

Dear participant	Question I: Where are you now?	Question II: How did you get there?	Question III: What was the lenght of the trip?
Use the online travel diary to register your activities and the transport in between. When you arrive at a new site – a new activity – you must answer 3 questions on where you are, how you got there and the lenght of the trip. Press # to answer the questions.	1 Home 2 Work 3 School/education 4 Shop /bank etc. 5 Kindergarten 6 Visiting friends 7 Leisure 9 Other	(choose the mode that you used to cover most of the journey length) 1 Walk 2 Bicycle 3 Car as driver 4 Car as passenger 5 Bus 6 Train / metro 9 Other	Approx. minutes [write] Approx. km [write]

Table 1: Three question travel diary intended for use on cell phone (SPV C500). The respondents will answer the questions upon arrival to the destination. Answers will be exchanged over web and automatically added to a database with phone id and time.

The PDA-based questionnaire could in principle be extended to a full time-use questionnaire. The question is what burden that realistically can be put on the respondents without endangering the reliability of the result and the participation rate. Realistically one would have to rely on main categories with the necessary differentiation on target areas of specific interest to the research.

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. An argument in favour of this is that the one aspect of the survey may be successfully completed independently of the other – as opposed to an integrated survey methodology where multiple sources of error and malfunctions are introduced and where it will not be possible to extract a usable result if something goes

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wrong. The available techniques and software development may however change the validity of this reservation quickly. It is 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. A challenge at present is also GPS dropout and how the time periods without a GPS-position and information on stationarity should be handled in a questioning procedure that relies on position and movement. In the case of movement the problem may be partly resolved through the setting of time-margins on the questioning (question is posed when the respondent has not moved more than 200 meter in ten minutes, or when the GPS has been unable to get a position in 10 minutes).

Research project: Space- time – flow.

The GPS-based registration of travel and activity patterns is intended for use in the research project: Space – time – flow. The project is a coorperation between Aalborg University, the Danish IT-University and the University of Copenhagen. The project focuses on the spatial and social consequences of the use of digital technologies based on micro-level, detailed empirical analysis. As such the project aims to take up the challenge formulated by Graham (2004):

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"There is a desperate need (…) to move beyond generalised and deterministic discources about the "impact" of "cyberspace" on society to look in rich empirical detail at the complex ways in which ICT [Information and Communication Technology] technologies are being used in real ways, in real urban regions, in the real world" (page 11)

The projects sub-projects will analyse different aspects based on quantitative as well as qualitative methodologies: use- and activity patterns, place independent communicative practises, the use of digital aids for navigation in space, and the perception of physical and virtual space.

As a common input to all parts of the project - virtual and real/physical activities will be surveyed simultaneously among a representative sample of respondents from the city of Copenhagen. A detailed registration of itineraries in time and space and its associated activities as well as an equal treatment of real and virtual spheres is intended. Thus activities and itineraries through the virtual sphere will be registered to the same level of detail as the allocation of activities and movement in physical space. To achieve this it will be nessesary to develop and test the GPS as data collecting tool. The GPS and travel/activity diary based survey will be supplemented by a monitoring of especially web-activities. This may be done either automatically or on a diary form, the procedure most suited for the purpose of the project is yet to be specified.

The survey results should allow for rigid analysis in the quantitative part of the project: use patterns of physical and virtual space, combinations of physical and virtual space and categorisation of physical/virtual time/space styles.

The project is expected to produce new results on how the knowledge society and the virtual world is likely to affect urban life and the role of place and the physical environment in this. The results should be of specific interest to urban planners of policy makers trying to adapt their strategies to what is thought to be a new reality of overarching significance. The results will however also be related to questions of a more general character, fore instance the changing perceptions derived from the mixing of physical and virtual modes of life and the new practises that develops within and on the premises of the virtual sphere.

*) Including illustrations and references

References

Batty, Michael (2003), *"Agent based pedestrian modelling"*, Centre for advanced spatial analysis, working paper 61, University College London

Cederholm, Peter (2000), "Integrating GPS with Dead Reckoning Sensors", *Surveying and Land Information systems*, vol. 60, no. 4

Chapin, Francis Stuart (1974), *"Human activity patterns in the city. The things people do in time and space"*, John Wiley and sons, New York/London/Sydney/Toronto

Eurostat (2000), *"Survey on time use, Activity coding list, Final draft"*, DOC E2/TUS/5/00

Georgia Institute of Technology (2001), *"Americas Auto dependent urban form: Researchers in Atlanta studying land use and transportation alternatives to decrease traffic congestion and improve quality of life"*, Press release April 19, 2001

Graham, S. (ed.) (2004), *"The cybercities reader"*. London, Routledge

Jensen, Hertel, Berkowicz, Hvidberg, Loft and Raaschou-Nielsen (2003), "Menneskers eksponering en vigtig brik mellem luftforurening og helbredseffekter", *Miljøforskning*, no. 57

Nielsen, Otto Anker (2003), "Analyse af trængsel og hastigheder v.h.a. GPS-data", *Trafikdage 2003*

Schönefelder, S., Axhausen, K., Antille, N. & Bierlaire, M., (2002) Exploring the potentials of automatically collected GPS data for travel behaviour analysis – A Swedish data source", *Arbeitsberichte Verkehr- und Raumplanung*, 124, IVT, ETH, Zurich.

Steer Davies Gleave and GeoStats LP (2003*), "The use of GPS to improve travel data. Study report*", Prepared for DTLR New horizons programme

*) Including illustrations and references