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Application of Tracking Technologies in Spatial Planning Processes: An Exploration of Possibilities

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1 SHORT ABSTRACT

While the application of tracking technologies, like GPS, has been developed substantially in the social sciences and transportation sciences in the last decade, it has failed to make a significant impression in the scientific field of spatial planning. This paper explores the current and future possibilities and the limitations for the application of tracking technologies in spatial planning processes. It is built up around the results of an expert meeting in combination with bibliographical and literature research. After defining the principle application areas of current research on tracking technologies within planning and after sketching its crossdisciplinary character, the paper concludes by formulating major challenges and a future research agenda.

2 INTRODUCTION

2.1 Setting the scene

Contemporary technologies are capable of tracking indviduals and groups of people in their daily life paths. Tracking in the context of this paper can be defined as the capturing and registration of the position in time and in space of a person or a transportation vehicle over a period of time in a technological information device and/or system. Individual movement patterns are the main concern. In addition, tracking includes the registration of the accumulation of multiple tracks of individually tracked people or vehicles over time. In this case, intensity (mutliple people or vehicles) and frequency (multiple moments) are the main concerns. GPS (Geographical Positioning System) and other tracking systems in navigation devices, mobile phones, PDAs (Personal Digital Assistants) and laptops, although, have been developed for other purposes than research applications in urban design and planning. Research in sociology, geography, transport planning, logistics, biology have already been using tracking technologies for their research purposes since the 1990s.

From the start of the millenium, accuracy of tracking technologies increased substantially and mobile technologies were steadily invading daily life. Research using tracking technologies has boomed since. However, the fields of spatial planning and urban design have yet to embrace these information and communication technologies (ICTs) in both their conceptualisation of urban systems (see for an exception e.g. Drewe 2003) and in their possibilities in urban research. Moreover, the application of knowledge on activity patterns of people in spatial planning seems to be standing still since the 1980s. Although the reasons for these two omissions are an interesting study object, this paper focuses on possibilities rather than on causes. Furthermore, this paper focuses on spatial planning rather than on urban design, although both are subject of research within the overall research approach for Urbanism On Track .

2.2 Why tracking technologies?

There are a number of reasons why urban designers and planners should embrace these new technologies as part of their research repertoire. First, urban design and planning influence the long-term spatial conditions for daily activity patterns of people (Klaasen 2004). We claim in this paper that without knowledge of the activity patterns of people, urban designers and planners run a larger risk of their plans creating the spatial conditions for undesirable behaviour (e.g. with larger energy consumption), limiting desirable behaviour or excluding groups of people with limited possibilities from desirable or even necessary daily activities. One of the most prominent, although not exclusive, tools to get insight in daily activity patterns of people is tracking technology.

Second, the contemporary flexibilisation, emancipation and diversification of the rhythms and places through which people shape their lives puts pressure on the suppositions held by contemporary urban designers and planners about the behaviour of people. Moreover, recent studies on public space show urban designers ill capable of estimating the use of space (e.g. Golicnik 2005). Tracking technologies might offer insight in these dynamics.

Third, tracking technologies offer the possibility to collect and relate large data sets on activity patterns of people. Computation and modelling of these large data sets, e.g. in Geographic Information Systems (GIS), but also other systems, can give insight in the relations between the temporo-spatial configuration of activity patterns, the temporo-spatial configuration of physical infrastructure, the temporo-spatial configuration of socio-economic clusters and networks and the temporo-spatial configuration of urban functions. This way tracking technologies offer a diagnostic tool in urban design and planning that can deal with contemporary urban complexity.

A fourth reason for using tracking technologies in urban design and planning, following this last line of thinking, is that they have proven useful – or at the least are being explored - as additional research method or even replacing traditional methods such as travel diaries in time-use, activity and transport research (see e.g. Wolf, Guensler & Bachman 2001; Verbree, Maat, Bohte, Nieuwburg, Oosterom & Quak 2005) With respect to urban design and planning, an important step forward is the possibility to overcome problems related to visualising verbal or numerical data through tracking technologies.

2.3 Outline of the paper

This paper explores the current and future possibilities and limitations of the use of tracking people in planning processes, in fundamental research in spatial planning and with regard to the translation of tracking-based empirical findings to applicable knowledge for spatial planning. The preliminary research results presented here combine the outcome of bibliographical and literature research with the results from the expert meeting Urbanism On Track on January 18, 2007 at the Delft School of Design (DSD) at the Faculty of Architecture, Delft University of Technology (see also Schaick & Spek 2007).

The following section sets the scene by describing the demarcation lines and common ground in tracking research. Section 4 elaborates by defining the field of application for tracking research in light of urban design and planning. Next, section 5 gives additional insight into the multidisciplinary character of this field of application. This paper concludes in section 6 with a sketch of the conditions necessary to establish a coherent, multidisciplinary research agenda for the application of tracking technologies in spatial planning. The research agenda proposed in this last part of the paper distinguishes between short term, mid-term and long-term suggestions for future research.

3 URBANISM ON TRACK: A PLATFORM FOR APPLICATIONS OF TRACKING RESEARCH

3.1 Demarcation lines in tracking research

Knowledge on introducing, using and applying tracking technologies is distributed over different fields of expertise. Moreover, the application of tracking technologies in scientific research is in its infancy and artists' projects have played and still play an important role in innovation of applications (see e.g. the project Amsterdam Real Time by Waag Society, 2000). The January 2007 expert meeting Urbanism On Track brought together a number of different research perspectives and methods to learn from each other and to advance on the current state of the art (see Schaick & Spek 2007; compare Goulias and Janelle, 2006, on the FHWA Peer Exchange and CSISS Specialist Meeting: GPS Tracking and Time Geography; compare also the GeoPKDD workshop 'Knowledge discovery for sustainable mobility. The challenges and repercussions of discovering behavioural patterns from people in motion').

Research using tracking technologies shows to be subdivided along several lines. First, one can distinguish between the tracking technologies used. Research results seem to be strongly influenced by the choice of hardware. Similarly, different types of hardware can cater to different types of research questions. The major distinction along this line distinguishes between the use of GPS-technology (e.g. Kochans, Janssen, Bellemans & Wets 2005; Shoval & Isaacson 2006; Nielsen & Hovgesen 2004) and the use of triangulation of mobile phone signals (e.g. Ratti et al 2005, 2006, 2007; Shoval 2007 forthcoming). Accuracy of geographical position measures and the agility of finding geographical position fast are important factors.

Although less relevant to spatial planning on higher scales, visual tracking with video technology is a strong field of research as well, in particular based in surveillance-oriented research (see e.g the Joint IEEE International Workshops on Visual Surveillance and Performance Evaluation of Tracking and Surveillance [editions 1998-2006; in conjunction with International Conference on Computer Vision]).

Second, research differentiates along the lines of dominant modes of transport in the research project. Dominant categories are pedestrian tracking (Spek 2006, see fig.1), automobile tracking by in-vehicle GPS-devices (see the Lexington-dataset from 1997, see Zhou & Golledge 1999 and Kwan 2000 for subsequent research, see fig.2) and tracking of vehicles of public transport such as buses (see Sevtsuk & Ratti 2007) or other service transport such as taxis (an artistic example can be found at http://www.cabspotting.org [acc. March 14, 2007], see fig.3). The distinction between unimodal and multimodal tracking studies is a point of attention as well when looking at results form tracking studies.

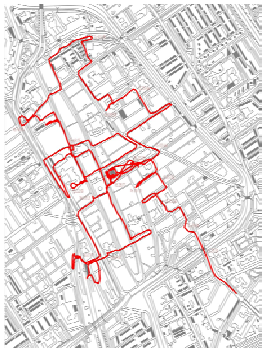

Figure 1: Example of pedestrian tracking from Delft, the Netherlands. Source: Spek (2006)

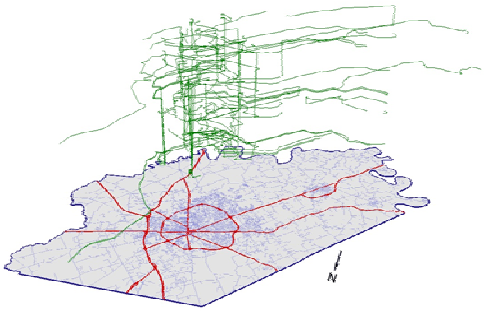

Fig 2: Example of automobile tracking based on the 1997/1998 Lexington GPS dataset. Source: Kwan (2004)

Fig.3 Example of tracking taxis in San Francisco. Source: http://www.cabspotting.org [accessed 14 March, 2007]; courtesy of The Exploratorium

Third, research using tracking technologies develops distinctively different research results by focusing on specific target groups, such as children (Nielsen & Hovgesen 2007), women or ethnic groups (Kwan 2000b, 2002). Specific household configurations have not yet been used as starting point in tracking research, but have been in diary-based activity research (Dijst 1995). A common factor is the attention given to the complete activity patterns of people and the problematisation – e.g. in terms policy recommendations - of the situation of the group under survey. An occasionally made subdistintinction along the same line is the

demarcation of the research project by fousing on inhabitants or visitors based on a demarcation of specific places, neighborhoods or towns such as suburbs, urban centres, recreational areas, events, etc.

The fourth and last major line of differentiation is determined by the scale and scope of the research. Scale and scope of (a) spatial activity pattern, (b) time and (c) number of people are all relevant denominators. Choices with regard to the temporal scale of a study can be, but are not necessarily related to the spatial scale or to the number of participants and vice versa. Research budget is an important factor in making choices regarding scale demarcations of research projects.

A. Both method and outcome differ substantially when the research is spatially limited to a small area, e.g. a train terminal (Millonig 2007) or a large area, e.g. regional activity patterns (research in progress by research institute OTB; see Verbree, Maat, Bohte, Nieuwburg, Oosterom & Quak (2005) and Bohte, Maat, Quak (2006) for starting documents) or the relation between areas and trips of different scales, e.g. in research on touristic travel patterns (Xia & Arrowsmith 2005; compare Shoval & Isaacson 2007). The differences between tracking studies focussing on one activity, on activity chains or on complete activity patterns show similar lines of distinction.

B. Most researchers seem to agree on 7-day periods as the most relevant and feasible time unit for tracking an individuals activity pattern, but research not focusing on activity patterns on an individual level do show different temporal grains of research (e.g. research on the use of a public space in one day and night).

C. The size of the group of respondents is also important, effecting for example differences in the logistics of research and other requirements for data management, but also other types of research claims on for example aggregate effects of behaviour. The choice of tracking technology partially determines this type of scale of a tracking study (see in particular Shoval (2007) and Ratti, Pulselli, Williams, Frenchman (2006) for the large scale possibilities of aggregate mobile phone data due to its ubiquity).

3.2 Common ground in tracking research

Despite these differences, research using tracking technologies builds from a very specific, shared knowledge base. The knowledge brought together in Urbanism On Track shows a strong grounding in research on activity patterns, although on different scales, and in research on travel behaviour formerly using low-tech techniques such as travel diaries (e.g. Dijst 1995), or counting and tracing routes of people by visual observation in stead of tracking technologies (e.g. Gehl & Soholt 2002). A second starting point for most tracking based research is the awareness that the development of tracking technologies as a research tool goes hand in hand with the development of tracking based servcies (see Janelle & Gillespie 2004). The continuing integration in and growing ubiquity of tracking technologies in daily life contributes to an increase of possibilities for scientific research benefiting from commercial applications and vice versa. In this light, ethic considerations on privacy are an integral part of knowledge advancement in the scientific application of tracking technologies. The third and last major pilar for research using tracking technologies is the increased importance attributed to visualising research results. Data from GPS-devices offer simple possibilities to visualise individual tracks. Data-visualisation or geovisualisation is an existent rich field of research (in the context of time-space visualisation e.g. Kraak 2003; Kwan & Lee 2003; Andrienko, Andrienko & Gatalsky 2003) Still, translating aggregate data or large amounts of data of individual tracks into meaningful visualisations remains a challenge.

Although the grounding of tracking technologies seems firm, so far literature research and exchange of knowledge confirms tracking-based research to be poorly linked to spatial planning and its research culture, vocabulary and research questions. This goes as well for urban design. These are grounded in the applied sciences rather than the empirical sciences (see for more on this distinction Klaasen 2004). The following paragraphs (4.1 to 4.3) will go into the possibilities to establish this link despite this distinction.

4 THE FIELD OF APPLICATION

4.1 Tracking People in Planning Processes

Basically, Urbanism On Track is about tracking people in planning and design processes. Most commonly addressed in round table meetings is the desire to test the effects of spatial interventions. Although tracking

people with this purpose seems to be a logical step, it is not simple. Hardly any longitudinal studies exist (see for a notable exception the MOBIDRIVE dataset: Axhausen, Zimmermann, Schönfelder, Rindsfüser & Haupt 2002; also Schönfelder, Axhausen, Antille & Bierliare 2002 on matching longitudinal data from different sources). Moreover, no studies using tracking technologies are known to have purposefully tested before and after spatial interventions. One can ask if this is because the technique is relatively new and still in development – most studies so far can be regarded pilot studies, only since a couple of years research is focussing structurally on tracking techniques – or because there are structural problems in applying tracking technologies this way, such as unwillingness to commission longitudinal research from spatial planning practice. However, examples are available where planning practice has commisioned research on activity patterns for spatial planning purposes (see Boelens, Sanders, Schwanen, Dijst & Verburg 2005, fig. 4).

Awareness of the importance of use-aspects is prevalent in the field of spatial planning and design, although to a limited degree (see e.g. from different angles Klaasen 2005 and Gehl & Soholt 2002). Application of tracking technologies in education of planning professionals and in concrete design and planning projects can be an important step forwards in the development of awareness of activity patterns of people. Besides scientific knowledge derived from tracking people, aspects of playing with the tracking instrument by stakeholders in planning processes and communicating through tracking-based visualisations are most relevant in this context. The use of layer approaches where visualised tracks are superimposed on geographical and functional maps can add value to this application (for a critical review see e.g. Schaick 2005).

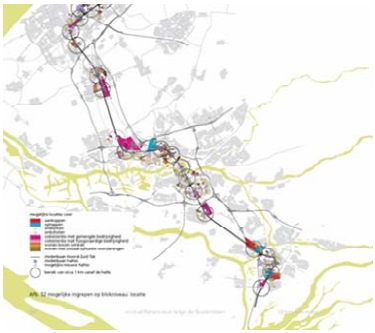

Figure 4: An example of a planning process incorporating knowledge on activity patterns in the development phase: the initiative for the lightrail project Stedenbaan, South Wing, The Neterlands. Source: Boelens, Sanders, Schwanen, Dijst & Verburg (2005)

A last concrete starting point for using tracking technologies in light of spatial planning and design is to actually avoid the necessity for physical planning. Knowledge derived from tracking people can deliver the information to manage the movements of people and vehicles, real-time or through delivering information and services. Dynamic management has been developed mainly in traffic planning where the investment in new physical infrastructure is high enough to trigger alternatives to physical planning. Tracking technologies offer a shift in focus for spatial planning from hardware planning, creating spatial conditions, to software and orgware planning, creating temporal and information conditions (compare Boelens 2005). The effect is that the time scale of planning shortens considerably, implicating both positive and negative aspects, which will not be addressed here. This paper focuses primarily on long term spatial planning in relation to urban design interventions.

4.2 Supporting Fundamental Research in Spatial Planning

Besides planning practice, the field of application for tracking technologies in spatial planning and design extends to fundamental research, testing hypotheses on the interplay between physical networks, functional networks and behaviour of people. One can distinguish two angles to approach fundamental research in spatial planning with tracking technologies. First, tracking technologies can be used to test old hypotheses, such as constraint-based theories (e.g. Hagerstrand 1970) and choice-based theories (e.g. Chapin 1974) of human behaviour. Second, knowledge from tracking technologies can be used to develop spatial organisation principles. Spatial organisation principles are theoretical models of the complex configuration of urban systems, which can be used as design guides in the development of site-specific spatial designs and plans (see Klaasen 2004, see fig.5). Still, it is a big step to get from the data collected in tracking based research to

an organisation principle or a theoretical model of an urban system. One of the main problems is the use of empirical findings in designs and plans, which the following paragraph addresses.

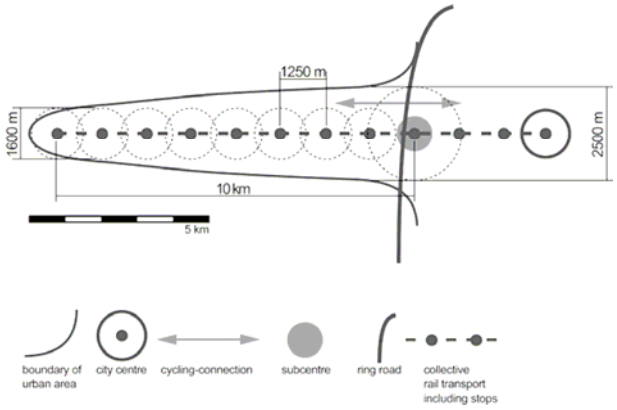

Figure 5: An example of a spatial principle in the form of a theoretical model of an urban system, that can be based on knowledge of activity patterns: an urban lobe. Source: Klaasen (2004)

4.3 Translation of Empirical Findings to Applicable Knowledge

A fundamental problem in using the results of tracking based research in spatial planning is that the results are empirical data, while spatial planning and urban design deal with changing the spatial setting in which empirical data is collected. One can question if the results of tracking technologies have any meaning for the situation after a spatial intervention. A spatial intervention seems to render the tracking outcomes irrelevant. How can we overcome this problem? Another problem of translating empirical findings is related to getting representative samples in tracking studies that have sufficient value and validity for drawing general conclusions for the specific purpose of spatial planning and design on activities and travel behaviour of people.The research field interested in tracking technologies, both within spatial planning circles and elsewhere, is not unanimous on handling these problems. Different solutions are suggested and attempts undertaken in literature and round table discussions.

Overstating the unanimity within scientific fields, one can list a few preferences, based on the findings from the expert meeting Urbanism On Track. Transportation oriented scientists prefer a modelling and simulation approach. Urban designers seem to prefer an approach focussing on increasing awareness of human behaviour. Some express the desirability of developing design principles through tracking based research. Spatial planners and for a part geographic information specialists seem to prefer multi-tier and/or multi-method approaches. Geographic information specialists and transportation specialists both trust in the long run for answers to be provided by the development of extensive databases or data warehousing. More generally supported by different specializations are (1) the application of longitudinal measurements using tracking technologies before and after spatial interventions and (2) multi-actor, multidisciplinary approaches to planning. Both these approaches are said to encounter significant problems in research and planning practice. The remainder of this paper focuses on the latter.

5 INCENTIVES FOR MULTIDISCIPLINARY RESEARCH

Previous sections have established the main distinctions between several types of tracking research and discovered common ground for tracking research. The last paragraphs focused on specific possibilities for the application of tracking technologies in spatial planning and design. The remainder of this paper focuses on the multidisciplinary character of applying tracking research in spatial planning and a research agenda based on this multidisciplinarity.

5.1 Blurred distinctions between fields of knowledge and between science and pratice

The introduction of tracking technologies is giving a new incentive for multidisciplinary research initiatives on spatial planning processes which combine knowledge from (a) human geography, (b) transportation sciences, (c) environmental psychology, (d) geographic information systems and (e) spatial planning and design (compare Goulias & Janelle 2006). For example, this can result in the application of more accurate transportation models, which can be applied in spatial planning with a mobility perspective or transportation planning with a spatial perspective. Also, the use of tracking data of mobile phones and research on urban

navigation and route choice is starting to blur the distinction between spatial planning and mobile services (also LBS – Location Based Services). Moreover, the introduction of ICTs in general seems to offer new possibilities to refresh the theoretical frameworks of both time geography and planning, for example with the concept extensibility (see Kwan 2000a). However, most of the current research still relies for the major part on the solid theories on people's activity patterns of several decades ago (Hagerstand 1970, Chapin 1974). Artistic projects using tracking technologies are pioneering research rather than scientists. The following parapgraphs will develop this blurred vision of existing expertise along three lines: from the perspective of what tracking technologies offer and do not offer (par. 5.2), from the perspective of possible and existing overlaps between bodies of knowledge (par 5.3 and 5.4). and from a theoretical perspective (par 5.4).

5.2 Beyond Technological Novelty: Enriching Tracking Data

The attractiveness of the novelty of tracking technologies can be regarded a major factor in putting effort in gathering specialists together for research purposes. The complexity of research projects using tracking devices seems much larger than those using traditional techniques. This is not only due to the complexity of using the technology. It also seems to be an effect of the eagerness displayed by researchers from multiple fields to take part in research in this pioneering stage. However, research limiting itself to the technology will probably fail to get beyond playful exercises and have an artisitic rather than a scientific output.

Raw tracking data basically consists of the coordinates of a series of locations in time and space of a tracking device. Exactly this accuracy in location and time is the greatest advantage of tracking devices in comparison with diary techniques or questionnaires. However, as such, the information directly derived from the raw data is most often not enough to draw significant conclusions about behaviour or activity patterns. Additional information is needed to answer most research questions relevant to spatial planning, e.g. on the type of activity, together with whom an activity took place or the question if the tracking device was carried all the time and by the right person (compare Lee-Gosselin 2002). Additional data can be collected simultaneously or indirectly from other sources (see Verbree, Maat, Bohte, Nieuwburg, Oosterom & Quak 2005; Janssen, Wets, De Beuckeleer & Vanhoof 2004). It can also be derived from the raw data or previously derived information through the use of algorithms or other computational techniques (see e.g. Wolf, Guensler & Bachman 2001). To decide on relevant research questions and methods to collect additional data and to interpret results, research teams are currently developing multidisciplinary teams, including several technology specialists, database specialists, geographers and planners. Most often the last group is limited to transportation specialists, but spatial planners or urban designers do get in on research teams occassionally (see e.g. Institute for Mobility Research IMOB at University Hasselt, Belgium).

5.2 Transportation and Pedestrian Mobility in Spatial Planning

Besides the binding force of the new technology itself, mobility as a theme has developed in recent years as an important vehicle for multidisciplinary research. Although the research culture of transportation sciences and practice differs substantially from that in spatial sciences and practice, research programmes and knowledge centres based in policy practices have been developed (e.g. Ruimte & Mobiliteit, Synergin and Transumo). Awareness of the relation between infrastructural development and spatial development is grounded in the introduction of innovative applications of information and communication technologies (e.g. dynamic traffic management) as well as innovation of transportation technologies (e.g. light rail and high speed rail networks). A central concept to this multidisciplinary field is door-to-door mobility (Ministerie van Verkeer en Waterstaat 2005), although in the tool network analyses this concept has not gained firm ground after all (Peijs 2006). Research on pedestrian mobility shows similar starting pints for multidisciplinary research (Spek 2006). Tracking technologies could help in this respect.

5.3 Mobile services, ICTs and Spatial Planning

In addition to research-driven motives for multidisciplinary research, earning money by adopting and developing tracking technologies is a major incentive to bring together multidisciplinary teams. On the one hand commercial companies are doing research on tracking technologies for the innovation of services. On the other hand spatial, transport and information sciences are doing research focussing on innovation of knowledge on human behaviour. Management and ownership of tracking databases is the holy grail in this context. However, the organisation of knowledge exchange between specialists and between different stakeholders is a major problem. Universities, companies and governmental bodies each hold part of the

puzzle. Round table discussions suggest universities, in particular research groups in spatial planning, can play a relatively neutral role through which all parties can benefit of exchanging data and information.

5.4 Cross-disciplinary Theoretical Frameworks

The potential to develop large databases of human behaviour is one of the attractions of tracking research. In this light, database specialists are currently developing the conceptual frameworks to deal with these datasets. Simultaneously, as an effect of an accumulation of research on network theory in multiple fields (computer sciences, sociology, geography, mathematics, urbanism, etc.) hypotheses are being developed to grasp the complexity of interaction of individual people, social networks, functional networks and physical networks (see e.g. Carrasco, Hogan, Wellman & Miller, 2007; Knaap, 1997; Larsen, Urry & Axhausen, 2006; Dupuy, 2007 forthcoming). Although large differences can be distinguished, convergence of ideas on the structure and workings of networks is perceivable and conceivable (see Schaick 2005, ongoing research). Three trends seem relevant for the application of tracking technologies in urban design and planning:

- The focus on the individual as unit of analysis, as a crucial addition to area-based, flow-based or network-based views. Especially the vocabulary around the concept activity patterns (originally developed in social geography mid 20th century) seems fit to reflect this trend. The question What about people in regional science? from Törsten Hägerstrand seems to be taken seriously in tracking research.
- The reoccurence of multi-tier or multi-layered frameworks in research on conceptual models from different fields (e.g. see Wachowicz 2007). The layer approach in spatial planning helps prioritizing agendas and mobilizing knowledge (see e.g. http://www.ruimtexmilieu.nl >> lagenbenadering [accessed March 14, 2007]). Similarly, multi-layered frameworks, focusing on the application of tracking technologies in spatial planning as well as being applicable in modelling or other data-oriented apporaches, can be useful in bridging gaps between research cultures and vocabularies.
- The importance attached to visualising data.

As already came forward from different angles in previous sections in this paper, some of the largest challenges for applying tracking in spatial planning are related to the visualisation of tracking data. One risk of using visualisations of tracking data directly in spatial planning lies in its empirical nature. Another challenge is the coherency between visualisations of tracking data and spatial planning visualisations. Still, the possibility to raise awareness in the minds of urban designers and other spatial planners of, for example, people's commuting and shopping patterns is a major step forward that can be taken by introducing tracking technologies. This goes as well for the awareness of recreational patterns in spatial planning processes, since nowadays in the Netherlands non-work-related transport of people takes up more than a third of both the number of displacements and distance travelled (Harms 2006).

One can hypothesise that stimulating the convergence of theoretical frameworks on this level can help developing multidisciplinary research on the application of tracking technologies in spatial design and planning.

6 A FUTURE RESEARCH AGENDA

This last section defines the necessary conditions to establish a coherent, multidisciplinary research agenda for the application of tracking technologies in spatial planning. The research agenda proposed in this last part of the paper distinguishes between short term, mid-term and long-term goals for future research. All goals ask for starting up research initiatives in the near future.

6.1 Future research goals

On the short term, starting now, the expert meeting and the literature offer a number of starting points to apply tracking technologies as existing at the moment: (a) raise funding for multidisciplinary work, (b) develop a discourse on privacy and ethical considerations on using tracking technologies in the conctext of urban planning and design, (c) develop a road map for implementation in urban design and planning, (d) start using tracking technologies in participatory planning processes as a serious gaming tool, (e) develop sophisticated visualistion tools and principles beyond the hype of Google Earth, building from geovisualisation, but focussing more on meaningful representations for planning and design processes.

Other goals can be aimed for on a relatively longer term, for example in five years time. Research on these subjects is already starting, but can be strengthened in both research effort and multidisciplinarity: (a) creating conditions for comparitive research using data from studies using tracking technolog. Different directions of research could focus on standards and/or compatibility of tracking data, data warehousing and supportive comparitive research on transportation systems and urban systems alike; (b) operationalising behavioral and decision models based on tracking data; (c) develop new ways to collect data using innovative tracking technologies or innovative applications of tracking technologies for specific design and planning oriented research, for example the development of longitudinal studies.

Trying to formulate research goals on a longer term runs the risk of becoming futuristic. Both technological advancements and societal trends become highly insecure and unpredictable on this time horizon. Two tiers of thinking seem to dominate discussions on this long-term research future: (a) real-time planning and (b) sustainability. However, for this paper, these subjects are too large to develop. We can conclude that tracking technologies are here to stay. It can be regarded the task of multiple disciplines to develop in cooperation applications of tracking technologies in urban design and planning that, metaphorically, go beyond "building iron bridges as if they were made of wood" .

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8 REFERENCES

ANDRIENKO, N., G. ANDRINEKO & P. GATALSKY: Exploratory Spatio-Temporal Visualization: An Analytical Review. 2003, Journal of Visual Languages & Computing 14(6): 503.

AXHAUSEN, K.W., A. ZIMMERMANN, S. SCHÖNFELDER, G. RINDSFÜSER & T. HAUPT: Observing the Rhythms of Daily Life: A Six-Week Travel Diary. 2002, Transportation, 29(2) 95-124.

BOELENS, L., W. SANDERS, T. SCHWANEN, M. DIJST & T. VERBURG: Milieudifferentiatie langs de Stedenbaan - Mobiliteitsstijlen en Ketenprogramma's voor Milieu's die Sporen. 2005, Rotterdam/Utrecht, Urban Unlimited/Universiteit Utrecht, in opdracht van Provincie Zuid Holland - Afdeling Ruimtelijke Ontwikkeling.

BOELENS, L.: Fluviology - a new approach of spatial planning. 2005, Utrecht, University of Utrecht. Inaugural speech.

BOHTE, W, MAAT, K, & QUAK, C.W.: Integratie van GPS, GIS en Internet voor het Meten van Verplaatsingsgedrag. In CVS (Ed.), Samenwerken is Topsport (pp. 1329-1349). 2006, Rotterdam: Colloquium Vervoersplanologisch Speurwerk (CVS).

CARRASCO, J.A., HOGAN, B., WELLMANN, B., MILLER, E.J.: Collecting social network data to study social activity–travel behavior: An egocentred approach. Forthcoming 2007, Environment & Planning B

CHAPIN, F.S., Jr.:Human Activity Patterns in the City. 1974, New York: John Wiley and Sons.

DIJST, M.: Het Elliptisch Leven : Actieruimte als Integrale Maat voor Bereik en Mobiliteit. 1995, Utrecht: Royal Dutch Geographical Society

DREWE, P.: ICT and urban form, 'old dogma, new tricks'. 2003, Delft: Faculty of Architecture, Delft University of Technology

DUPUY, G.: Urban Networks – Network Urbanism. Forthcoming 2007, Amsterdam: Techne Press

GEHL, J. & SOHOLT, H.L.: Public Spaces and Public Life – City of Adelaide. 2002, South Australian Government, Planning SA/City of Adelaide/Capital City Committee/Gehl Architects

GOLICNIK, B: Urban landscape between design practice, usage and reseach. 2005, Conference Life in the Urban Landscape. International Conference for Integrating Urban Knowledge & Practice Gothenburg, Sweden. May 29 – June 3, 2005

GOULIAS, K. & JANELLE, D.: Report on The FHWA Peer Exchange and CSISS Specialist Meeting: GPS Tracking and Time Geography. 2006, FHWA/CSISS: 10-11 October 2005 The Upham Hotel — Santa Barbara, California

HÄGERSTRAND, T.: what about people in Regional Science? 1970, European Congress of The Regional Science Association Copenhagen '69, Copenhagen, Regional Science Association.

HARMS, L.: Op weg in de vrije tijd - Context, kenmerken en dynamiek van vrijetijdsmobiliteit. 2006, Den Haag: Sociaal Cultureel Planbureau (SCP)

JANELLE, D. G. and A. GILLESPIE: Space-Time Constructs for Linking Information and Communication Technologies with Issues in Sustainable Transportation. 2004, Transport Reviews 24(6): 665-677.

JANSSENS, D., WETS, G., BEUCKELEER, E. de, VANHOOF, K.: Collecting activity-travel diary data by means of a new computer-assisted data collection tool. In: 2004, Proceedings of the European Concurrent Engineering Conference (ECEC), April 19-21, Hasselt, Belgium, s.l., , pp. 19-21

KLAASEN, I.T.: Knowledge-based Design: Developing Urban & Regional Design into a Science. 2004, Delft, Delft University Press.

KLAASEN, I.T.: Putting Time in the Picture. In: 2005, HULSBERGEN, E.D., KLAASEN, I.T. & KRIENS, I.: Shifting Sense: Looking Back to the Future in Spatial Planning. Amsterdam, Techne Press.

KNAAP, W.G.M. van der: The tourist's drives: GIS oriented methods for analysing tourist recreation complexes. WAU dissertation, 1997

KOCHAN, B., D. JANSSENS, T. BELLEMANS & G. WETS. Collecting Activity-Travel Diary Data by Means of a Hand-Held Computer-Assisted Data Collection Tool. In: Proceedings of the 16th Mini - EURO Conference and 10th Meeting of EWGT. Poznan (Poland), 13-16 September, 2005

KRAAK, M.P. (2003). The space-time cube revisited from a geovisualization perspective. 21st International Cartographic Conference (ICC) 'Cartographic Renaissance', Durban.

KWAN, M.-P.: Feminist Visualization: Re-envisioning GIS as a Method in Feminist Geographic Research. 2002, Annals of the Association of American Geographers, 92(4):645-661.

KWAN, M.-P.: Human extensibility and individual hybrid-accessibility in space-time: A multi-scale representation using GIS. 2000a; In:, D. JANELLE & D. HODGE (eds.), Information,Place, and Cyberspace: Issues in Accessibility. Berlin: Springer-Verlag, 241-256.

KWAN, M.-P.:Evaluating Gender Differences in Individual Accessibility: A Study Using Trip Data Collected by the Global Positioning System. Final Report to the Federal Highway Administration. 2000b, FHWA/Department of Geography, The Ohio State University

KWAN, M.-P. & LEE, J.: Geovisualization of Human Activity Patterns Using 3D GIS: A Time-Geographic Approach. 2003; in M.F. GOODCHILD & D.G. JANELLE. Eds. 2003. Spatially Integrated Social Science: Examples in Best Practice, Chapter 3. Oxford: Oxford University Press.

KWAN, M.-P. & LEE, J.: Geovisualization of Human Activity Patterns Using 3D GIS: A Time-Geographic Approach. 2004; in M.GOODCHILD & D. JANELLE, eds., Spatially Integrated Social Science, 48-66. New York: Oxford University Press.

LARSEN, J., URRY, J. & AXHAUSEN, K.: Mobilities, Networks, Geographies. London: Ashgate, 2006

LEE-GOSSELIN, M.: Some reflections on GPS-supported travel survey methods in an increasingly ICT-rich environment, Presentation at Workshop on ICT, Innovation and the Transport System, Arlington, January 2002.

MILLONIG, A.: Application of Tracking-Based Research in the Development of Mobile Pedestrian Navigation Systems. In SCHAICK, J. van & SPEK, S.C. van der: Urbanism On Track – Expertmeeting on the application in Urban Design and Planning of GPS-based and other tracking-based research; Pre-seminar proceedings, 2007. Delft: DSD, Delft University of Technology.

MINISTERIE van VERKEER en WATERSTAAT: Innovatie voor Mobiliteit – Innovatieacties uit de Uitvoeringsagenda Nota Mobiliteit. 2005, Den Haag: Ministerie VWS

NIELSEN, T.S. & HOVGESEN, H.H.: GPS in Pedestrian and Spatial Behaviour Surveys. Paper for Cities for People, The Fifth International Conference on Walking in the 21st Century, June 9-11 2004, Copenhagen, Denmark

NIELSEN, T.S. & HOVGESEN, H.H.: STM Research – The Suburb Case. 2007; in: Presentation for Urbanism On Track. Delft: DSD, Delft University of Technology.

PEIJS, K.: Van Netwerkanalyse naar Netwerkaanpak. Letter by the Minister of Traffic to the parliament (Tweede Kamer). Ministerie van Verkeer en Waterstaat, 2006. [available from http://www.verkeerenwaterstaat.nl/onderwerpen/mobiliteit_en_bereikbaarheid/; accessed March 14, 2007]

RATTI, C, PULSELLI, R.M.,WILLIAMS, S., FRENCHMAN, D.: Mobile Landscapes: Using Location Data from Cell-Phones for Urban Analysis. 2006, Environment and Planning B: Planning and Design. Vol. 33; pp. 727 - 748

SCHAICK, J. van: Integrating the Social and Spatial Aspects of Urban Systems. In: 2005, HULSBERGEN, E.D., KLAASEN, I.T. & KRIENS, I.: Shifting Sense: Looking Back to the Future in Spatial Planning. Amsterdam, Techne Press.

SCHAICK, J. van & SPEK, S.C. van der: Urbanism On Track – Expertmeeting on the application in Urban Design and Planning of GPS-based and other tracking-based research; Pre-seminar proceedings, 2007. Delft: DSD, Delft University of Technology.

SCHÖNFELDER, S., K.W. AXHAUSEN, N. ANTILLE & M. BIERLAIRE: Exploring the potentials of automatically collected GPS data for travel behaviour analysis – A Swedish data source. 2002; in J. Möltgen, and A. Wytzisk (Eds.) GI-Technologien für Verkehr und Logistik, IfGIprints, 13, Institut für Geoinformatik, Universität Münster, Münster, 155-179.

SEVTSUK, A. & C. RATTI: Experiments in Urban Mobility Analysis in Rome Using Mobile Phone Data. In: SCHAICK, J. van & SPEK, S.C. van der: Urbanism On Track – Expertmeeting on the application in Urban Design and Planning of GPS-based and other tracking-based research; Pre-seminar proceedings, 2007. Delft: DSD, Delft University of Technology.

SHOVAL, N., ISAACSON, M.: The Application of Tracking Technologies to the Study of Pedestrian Spatial Behaviour. 2006, The Professional Geographer. Vol. 58, pp. 172 - 183

SHOVAL, N.: Commentary: Sensing Human Society. 2007, Environment and Planning B: Planning and Design 34(2), pp. 191 – 195

SHOVAL, N., ISAACSON, M.: Tracking Tourists in the Digital Age. 2007, Annals of Tourism Research. Vol.34 pp. 141 - 159

SPEK, S.C. van der: Optimizing Routing and Safety for Pedestrians: a Tool for Pedestrian Oriented Design. Presented at Walk21, Melbourne 2006. [available at http://www.walk21.com/conferences/conference_papers_detail.asp?Paper=85&Conference=Melbourne; accessed March 14, 2007]

VERBREE, E., MAAT, K., BOHTE, W., NIEUWBURG, E. van, OOSTEROM, P.J.M. van, & QUAK, C.W.: GPS-Monitored Itineray Tracking: Where have you been and how did you get there. 2005; in G Gartner (Ed.), Proceedings of the symposium 2005 location based services & telecartography Vol. 74. Geowissenschaftliche Mitteilungen (pp. 73-80). Wenen: TU Wien.

WACHOWICZ, M.: Towards an Ontological Framework for Representing People in Motion. 2007; in SCHAICK, J. van & SPEK, S.C. van der: Urbanism On Track – Expertmeeting on the application in Urban Design and Planning of GPS-based and other tracking-based research; Pre-seminar proceedings, 2007. Delft: DSD, Delft University of Technology.

WOLF, J., GUENSLER, R., & BACHMAN, W.: Elimination of the Travel Diary: Experiment to Derive Trip Purpose from GPS Travel Data. 2001, Transportation Research Record; No. 1768; pp. 125-134.

Xia, J. & ARROWSMITH, C.: Managing Scale Issues in Spatio-Temporal Movement of Tourist Modelling. 2005, Proceedings of the Spatial Science Institute Conference: Spatial Intelligence, Innovation and Praxis. MODISM 2005 International

Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand. Spatial Sciences Institute of Australia, Melbourne 12-15 December 2005.

ZHOU, J.J., R. GOLLEDGE: A GPS-based Analysis Of Household Travel Behaviour. WRSA Annual Meeting, Kauai, Hawaii, August 1999.