Daily rhythms of suburban commuters’ movements in the Tallinn metropolitan area: Case study with mobile positioning data

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\textbf{Abstract}

The objective of this study is to analyse the diurnal rhythms of city life and its spatial differences in Tallinn, using mobile telephone positioning data. The positioning experiment was carried out in April 2006 over an 8-day period and 15-min intervals, with a random sample of 277 respondents living in new residential areas outside the city of Tallinn.

The investigation of the space–time movements and daily distances of respondents showed that the majority of respondents had a similar temporal rhythm related to work, school, services and leisure in the city. Because of the different timing of those activities, the mobile positioning data made it possible to map functional differences in the city. The advantages and disadvantages of mobile positioning data in mapping urban life are discussed in the final section of the study.

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1. Introduction

The quality of urban space is dependent on the extent people use it for living, leisure, work or services. If urban space is attractive and multifunctional, it will be used actively by diverse social groups to the maximum temporal extent. The use of mono-functional urban space such as sleeping cities or service centres is limited in social spectrum and temporal use. The temporal pattern of the presence and movement of people in urban space can be used as an indicator to measure functional diversity and evaluate the quality of urban space.

Urban life and its temporal variability are dependent on weekdays. The main distinction can be drawn between work days and weekend days. There are also more specific movement characteristics for each day, such as the impact of weekend activities on Friday and Monday; Saturday is influenced by the impacts of working days or by the shopping day mentality. In many cultures or social groups such as students or office workers, party evenings in the middle of the week are important. Since Hägerstrand (1968) postulated time geography, the daily movement rhythm of traffic and city life has been studied and modelled by geographers, logistics experts and civil engineers (Newsome et al., 1998; Axhausen et al., 2002; Woudsma, 2001; Bromley et al., 2003). There are different approaches for analysing the space–time variability of activities, such as GIS-based approaches (Kwan, 2000; Dykes and Mountain, 2003) or special software for analysing activity spaces (Schwarze and Schönfelder, 2001). The results have been used to understand the quality of urban life and better organise public services and accessibility (Weber and Kwan, 2002). Temporal movement in cities can be measured (Weber and Kwan, 2002) using different methods, for instance surveys, visual mapping, traffic counters or video tracking. One new and interesting source of data is mobile positioning. Mobile phones are widespread, and their positioning has achieved such accuracy that it can be used for geographical research. Positioning data has been proposed and exploited by different authors and working groups.
(Mountain and Raper, 2001; Ratti, 2005; Ohmori et al., 2005; Reades et al., 2007; Spinney, 2003; Shoval and Isaacson, 2007) as a potential new source for space–time movement studies. The most detailed approach for using mobile positioning in travel behaviour has been developed by the University of Kobe in Japan at the beginning of the 21st century (Asakura and Hato, 2004). In Estonia the University of Tartu and Positium LBS use active and passive mobile positioning data for the analysis of space–time behaviour in cities. This has been called the social positioning method (SPM) (Ahas and Mark, 2005, Ahas et al., 2007b, 2008). The MIT sensible city lab is developing a passive mobile positioning system for sensing city life, and this is also called cellular census (Reades et al., 2007).

The objective of this paper is to study the differences in the temporal movement patterns of suburban commuters in the city of Tallinn in Estonia. Suburbanisation and sprawling development is a rapid and ongoing process in Eastern European cities, including Tallinn. Studies show that suburbanisation is most active among wealthy and highly educated families with young children – the burgeoning middle class. For example, average income per capita of suburbanised families is almost double, and the percentage of persons with higher education is much higher than the average in the city of Tallinn (Tammaru, 2005). The best taxpayers leave the city with their taxes. The number of persons who have moved to suburbs is estimated to be 17,000 only in the new settlement areas, which is 5% of the city’s total population. Suburbanised families are car-dependent, with 90% of trips made by car (Ahas et al., 2007b), and they are a major source of growing traffic problems and also administrative problems in Tallinn.

The objective of this paper is to study the temporal patterns of the space consumption of these suburbanised families. This question is of direct interest to Tallinn’s city planners due to the increasing traffic problems and the need to evaluate the degree of connection between the suburban community and the city. There is a need for better traffic timing, with the changing of the opening hours of public service providers such as schools and kindergartens. There is a need to know how much of the infrastructure and services suburban commuters actually use. What kinds of places and functions do they use in the city? The question WHEN they visit the city and what differences there are between the days of the week is key to creating a monitoring system for a changing city, using new methods such as mobile positioning. The study’s second objective is to develop and discuss the methods and peculiarities of individual mobile phone positioning data for geographical studies.

2. Mobile positioning

The collection of mobile positioning data is technically possible in the majority of mobile networks. The positioning method and data quality can differ greatly due to the different hardware and software used in mobile networks (Spinney, 2003; Asakura and Hato, 2004). In general, mobile positioning data is similar to movement data gathered using different means: travel diaries, GPS, counters, questionnaires and video tracking. The data has two or three location coordinates \((x, y, z)\) and a time co-ordinate \(t\).

Mobile positioning data has different sources and collection methods. Our experiments in Estonia have used active and passive mobile positioning data (Ahas and Mark, 2005; Ahas et al., 2008). Active mobile positioning (tracing) data is collected after a special query/request to determine the location of a mobile phone. This active query can be made using network-based positioning or handset-based positioning methods. Active mobile positioning is very often used in tracing experiments, such as the social positioning method (SPM) used in Estonia.

For the collection of active positioning data regarding commuters’ space–time movements, we used queries from the Internet-based positioning environment www.positium.com, which was developed by Estonian company Positium LBS (Positium, 2006). Passive mobile positioning data is collected from secondary sources such as the memory or log files of mobile operators. Location data is stored in the log files of mobile operators as billing records when a person uses a mobile phone or as enabler data describing how crowded a base station is. These memory files can be used to gather space–time movement data. We have used this type of data to study tourists’ space–time movements in Estonia (Ahas et al., 2007a, 2008).

3. Data and methods

3.1. Data

We introduce data from two positioning experiments in the Tallinn metropolitan area. A random sample of 576 residents of new settlement areas outside the city (Fig. 1) was questioned in February and March 2006. The random sample was selected from 5589 households in new settlement areas and questioned by polling firm TNS Emor. Together with family members, the questionnaires include data on 1800 persons. The questionnaire was very detailed, with 100 questions lasting approximately 1 h. The questionnaire data was important because of the need to know all of the details of the respondents’ travel behaviour and personal profile. Of 576 persons questioned, 231 agreed to participate in the positioning study and 46 respondents were recruited additionally from the same communities.

Positium LBS has a direct secure data collection channel to the two major Estonian mobile operators’ positioning servers. Queries including positioning time, interval and persons were entered in a web-based form. For positioning, double approval from the phone’s user is needed: one in web or paper form, and a second confirmation with an SMS text message from the telephone he/she uses. This double check allows mobile operators to ensure that the positioning is legal and approved by the phone’s real user. Data was collected in the networks of Estonia’s two largest mobile operators: EMT and Elisa. EMT, Estonia’s
largest operator, uses the CGI + TA positioning method in the ERICSSON Ltd. MPS system. Elisa uses the Nokia positioning system. For mobile tracking we used the Cell Global Identity + Timing Advance (CGI + TA) method for positioning, which recorded the positioning sector in the proximity of the phone. We used the gravity centre (area centroid) method to calculate the central point of a positioning sector.

Tracking was performed with 15 min frequency during daytime and 2 h in night (00:00–6:00 AM), as our pilot studies showed that this is the most cost-effective mode (Ahas et al., 2007c). The accuracy of CGI + TA positioning is dependent on the type of base station (omnicell or sector cell) and the distance from the antenna; the positioning result will be either a sector/arc or a circle. This positioning sector with a standard width of 550 m is the main characteristic for using positioning data and calculating error. The closer the phone is to the antenna, the smaller the positioning inaccuracy, i.e. error. The proximity of an antenna depends on the density and load of the network and the location of the mobile phones.

A total of 277 persons were positioned during 5–12 April 2006 (8 days) with intervals of 15 min from 06:00 to 00:00 and with a 2 h interval from 00:00 to 06:00. The night-time positioning frequency was lower because of the need to save money for positioning. A total of more than 140,000 positioning points were collected.

The distribution of men and women in the sample is similar to the Estonian average. In new settlement areas 47% were men, and 46% in the positioning study (the Estonian average is 46%), and in new settlement areas 53% were women, compared to 54% in the positioning study (the Estonian average is 54%). In new settlement areas women made up 74% of the paid workforce, and 77% in the positioning study; non-working women were correspondingly 26% and 23% (Table 1).

Table 1
Distribution of men and women in the new settlement areas and in the positioning study.

<table>
<thead>
<tr>
<th></th>
<th>New settlement areas</th>
<th>Positioning study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>%</td>
</tr>
<tr>
<td>Men</td>
<td>273</td>
<td>47</td>
</tr>
<tr>
<td>Women</td>
<td>303</td>
<td>53</td>
</tr>
<tr>
<td>Total</td>
<td>576</td>
<td>100</td>
</tr>
<tr>
<td>Working women</td>
<td>223</td>
<td>74</td>
</tr>
<tr>
<td>Non-working women</td>
<td>80</td>
<td>26</td>
</tr>
<tr>
<td>Total, women by working</td>
<td>303</td>
<td>100</td>
</tr>
</tbody>
</table>
3.2. Methods

Mobile positioning data makes it possible to analyse the daily variability of movements and space consumption in greater detail and from several points of view: (1) we have a more frequent distribution of positioning points than with travel diaries or interviews; (2) we have data on the entire study area, and the models’ traffic counters estimate it for certain locations; and (3) we have individual data, so we can connect features from personal questionnaires with all of the visited locations.

One limiting factor of social positioning is the accuracy of the positioning data. Our experiments in Tallinn and Tartu conducted in 2004 and 2006 showed that the problem of the accuracy of positioning can be solved by selecting the correct scale for the study. The calculations of theoretical positioning error, based on 180,000 positioning cases in the Estonian EMT network, showed that the accuracy of 61% of positioning is within 1000 m in urban areas and within 3000 m for 53% of positioning cases in rural areas in Estonia. An accuracy check conducted with GPS during a study of commuters in Tallinn indicated that the mean error for positioning was 488 m (median 323 m) in urban areas and 1381 m (median 872 m) in rural areas (Ahas et al., 2007b). The new generation of telephones with the A–GPS function will soon solve problems with positioning accuracy, as they have an accuracy of up to a few meters.

Using data from the mobile positioning study, we studied different parameters measured using the location and time of the positioning points: (a) the space–time distribution of positioning points; (b) respondents’ main anchor points; (c) respondents’ average distance from the city centre; and (d) the cumulative sums of respondents’ daily movements. The space–time movement of respondents was analysed using statistical and GIS methods. Anchor points were determined automatically as places where respondents spend a minimum of 2 h (eight positioning points). Such a quantitative frame was selected for the determining of personal anchor points due to experiences from other research projects in which personal anchors were determined (Dijst, 1999; Golledge, 1990). Flamm and Kaufmann (2006) used the Moby drive dataset to determine anchor points (centres of daily life) with a 20% presence in a certain location from the entire study period. Our 2 h corresponds to 1.4%, but according to our test this is suitable in order to determine places visited regularly by one person. The GIS experts have also performed interesting studies to determine regularly visited places with mobile positioning data, with the aim of optimising location-based services (Kang et al., 2004; Nurmi and Koolwaaij, 2006).

The location of home and work was verified manually through a questionnaire and compared with positioning data. Distance from the city centre was measured in a straight line from Town Hall Square in Tallinn’s Old Town. Cumulative sums were calculated on the basis of all 15 min positioning points and presented as curves. We studied these statistics in greater detail using median and mean value simultaneously, because the mean value was too greatly influenced by a few long trips by respondents. We also studied the maximum trips (the 10% of respondents with the longest daily distances) and the minimum trips (the 10% of respondents with the shortest daily distances) for the analysis of diversity in the cumulative sums of daily trips.

4. Results

4.1. Temporal rhythm

The generalised temporal rhythm of the movements of 277 suburban commuters over the 8 days of the study shows a predictable routine timing over 6 workdays and differences over 2 weekend days. The best measure of daily temporal rhythm with mobile positioning was the distance (average or median) of respondents from the city centre (Fig. 2). On workdays, the median of distances shows a routine fluctuation of 5 km in the daytime and 11.5 km during the night, and the values of the median are almost the same for all of the workdays studied. The mean distances of respondents’ locations from the city centre have greater values than the median: 8–12 km during daytime and 13–16 km at night. Mean values also vary little over 6 workdays, whereas 3 days (Th 6.04, Tu 11.04 and We 12.04) have slightly closer positions to the city centre during lunch time than during other workdays.

Weekend days differ from the workday routine, and both median and mean values show that people stay out of city, in the suburbs or even farther. The average distance of 277 respondents’ locations from the city centre is much greater (up to 18 km) on weekends, which indicates visits to other parts of Estonia. Saturday afternoon is a typical time for activities in the city, i.e. shopping or leisure, and this is also marked as close locations to the city centre by the curve in both graphs.

We also studied the daily routine of the movements of the female respondents who stayed home (housewives). There were 25 women staying home (21 housewives, 1 unemployed, 3 pensioners), and 88 women who worked every day. The graphical representation of women and men in Fig. 3 shows that even when staying home, housewives are very much connected with activities in the city (kindergarten, school, services, shopping). The daily rhythm of movements is also very similar to that of working women. This may also be due to parents driving their children to school; most schools were located in the city centre. The average location of the positioning points of working women was more distant from the city centre than that of housewives. This may be caused by the location of female jobs, as our questionnaire of 1800 persons showed that female jobs were 15.4 and male jobs 25.2 km from home, and this difference was statistically significant at a level of 97%.

The routine rhythm of movements over 6 workdays is also visible in the length of trips measured using positioning points. The daily rhythm of the median and mean values of the cumulative sums of the daily movements of 277 respondents is very similar on workdays: an average of 44–45 km, and a median of 60–62 km (Fig. 4). The sum is smaller on Wednesday April 12,
as the positioning server was jammed for two morning hours, and the sum of kilometres is therefore smaller. The lengths of daily routes on the weekend are similar to that on weekdays. The difference is that the curve of the graph is more linear, which means that respondents’ movements are distributed more evenly than on workdays. The curves of workday movements follow the morning and evening rush hour. As average values show, on Sundays people move 7 km less than on other days.

The daily differences in the length of the daily trips of the 10% most active respondents showed that there are slight differences between workdays, within limits of 5 km, and weekends have more movements than average, with a maximum on Saturday, with 120 km per person. The average length for the 10% less active respondents demonstrated that several persons just stay home on the weekend, with movement of only 2–3 km.

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**Fig. 2.** The mean and median distance of the locations of 277 respondents from the city centre over the eight study days.

**Fig. 3.** The median of the distance from the city centre for all males (115), working females (88) and housewives (25) during the eight days studied.
The temporal routine of workdays can be generalised through the determination of the locations of the 277 positioned respondents in the main anchor points (Fig. 5). The commuters start leaving their homes at 7:00 AM; the greatest number of people is on the move at 7:45 AM, which is the same time as rush hour in the city. The majority of respondents reach their workplaces after 8:30 AM, and will stay there until 17:00 PM. Fifty percent of respondents are back at home by 18:30 PM, and 80% are home after 21:00 PM. During the evening hours of 16:45–19:15, one finds the greatest number of persons on the move during the working day – up to 35%. The location of workplaces related with these movements is presented as anchor points in Fig. 1.

4.2. Spatial differences

The differences in commuters’ daily movements are better explained through geographical distribution. Fig. 6 presents the distribution of respondents’ positioning points for eight study days in the major urban districts of Tallinn and suburban...
parishes. The city centre and surrounding districts such as Põhja-Tallinn, Kristiine, Mustamäe, Lasnamäe and the satellite city of Keila west of Tallinn are actively used on weekdays, as most workplaces and high quality services are situated there. 26% of the 1800 respondents surveyed and 28% of the 277 positioned respondents had work or a school in the city centre. The city centre is also the region with the best jobs; for instance the biggest financial, governmental and business organisations are located there. Therefore activities are concentrated on workdays, and of weekend days, Saturday is of greater importance. For example, in the city centre average workdays have 3289 positioning points; Saturday has 1231 and Sunday 567.

The diurnal use of the city centre and surrounding districts shows interesting differences for average workdays and weekends. The majority of positioning points are recorded during workdays, from the working hours of 8:00 AM to 18:00 PM (Fig. 7). In the city centre, for example, the average number of points between 8:00 and 18:00 is 286. On workdays the night has almost no movements in the city centre, and the majority of respondents reside in suburban homes. In the evening there is a smooth decrease in movement until 23:00 PM.

The number of positioning points is smaller at night, because of the lower frequency (2 h) in positioning from 00:00 to 06:00 instead of the regular 15 min interval, and because some respondents turn off their phones at night.

The weekend has a different pattern of movement in the city centre and surrounding districts. Midday is a popular time for visits, especially on Saturday, when at 13:00–14:00, for example, there were 135 positioning points in the city centre.
According to the location of the positioning points and the questionnaire answers, this time is used for shopping, services and restaurant visits in the best commercial centres. Commuters visit the city centre relatively frequently during weekend evenings, and in some regions they stay there long after midnight. This shows that the city and its centre are not only a place of work and schooling for commuters, but also a leisure destination for weekend and night-time activities. We also mapped the anchor points of free time (not home and work anchor points) locations for all 277 respondents. This map very clearly shows that places that are used in addition to work and home are clearly concentrated in the city, and especially in the city centre of Tallinn (Fig. 8). The temporal distribution of visits to free time anchor points is distributed equally over work-time during business days with 5–10% share (see Fig. 5). During weekend days the free-time anchors were still very much concentrated to the city centre.

The second type of area with a similar weekly and diurnal distribution of positioning points is dominated by suburban homes. Pirita and Viimsi (the north-eastern suburbs), Harku (the north-western suburbs), Rae (south-eastern), Saku, Kiili (southern) and Saue (south-western) administrative units have a high number of positioning points on all days, but a maximum on weekdays. The diurnal distribution of positioning points has a specific distribution in the suburbs. There are less positioning points during workday office hours, and more in the evening and at night. For example, the average number of positioning points in Viimsi parish is 77 from 11:00 to 16:00, and over 200 after 21:00. On the weekend, the daytime, evening and night are relatively evenly covered with positioning points – people stay home. The typical situation for Saturday is that noon (14:00–16:00) has fewer positioned points; this is the time for shopping, a late breakfast out or outdoor sports.

According to the temporal rhythm of commuter positioning points on weekdays and around the clock, there is a third type of counties in the suburban region of Tallinn. Regions such as Haabersti, Jõelähtme, Keila and Maardu have an even distribution during workdays and weekends and around the clock, as the region has a mixture of homes, workplaces and commuter transit flows.

The general distribution of positioning points in the urban region of Tallinn is the following: on workdays 46% are located in the city of Tallinn; 50% in the suburban area of Tallinn; 2% in the rest of Estonia; 2% on the Baltic Sea. During the weekend 26% are located in the city of Tallinn; 68% in the suburban areas of Tallinn; 3% in the rest of Estonia; 3% on the Baltic Sea.

5. Discussion and conclusions

The results of the analysis showed that the movement of suburban commuters in the urban parts of Tallinn clearly demonstrates a temporal rhythm on weekdays and around the clock. The temporal rhythm of commuters’ movements is so clear because of the distant location of homes, which limits the number of unplanned trips. It is not a great surprise that workdays have a similar rhythm, and that suburban commuters like to stay at home on the weekend, as this has been studied and modelled in many cities. Mobile positioning allows us to study these movements in space and time more exactly than using
traditional methods such as travel diaries. Our results showed that the mobility of respondents measured using the cumulative sums of daily movements can be very different for the active and passive fractions of a sample. For example, the 10% less active respondents stay home on the weekend, and they move only a few kilometres.

An interesting result of our study was that the movement of housewives and working wives is almost similar on weekdays and weekends, because they all travel to the city in the morning and return in the afternoon. Working women even stay closer to home than housewives, because female jobs are significantly closer to home than male jobs in the suburbs of Tallinn. Due to traditional family roles, women have to be more flexible with jobs in Estonia. One important result for positioning was also the location of free time anchor points in the Tallinn city centre. This shows that not only working day routine but also the free time of respondents is very much connected with the city and city centre. This result changed speculations that suburbanisation is distancing people from city services and urban life.

The results of the mapping of weekday rhythms and the diurnal distribution of positioning points gave us a very interesting temporal typology of districts and counties. The city centre and its surroundings, suburbs and transit zones have a different rhythm of commuter visits on weekdays and the weekend. The map of the diurnal distribution of positioning points was most interesting and useful in this respect. This is probably the point where the advantages of mobile positioning are most clearly visible – we can record the space–time variability of space consumption with a good interval and without spatial limits. GPS can be used for similar purposes, but handling 277 GPS devices and charging their batteries over 8 days of study is truly complicated. Mobile phones are widespread; everyone carries one all the time and charges their battery very regularly. Mobile positioning leads to problems with privacy, and there is a possibility that potential respondents will not want to sign contracts with researchers. In our studies in Estonia, however, this has not been a great problem. During the current experiment, our agents performed a survey with 576 respondents, 452 had phones of operators cooperating with our study (EMT and Elisa), 231 of them agreed to participate in the positioning study, and another 46 respondents were additionally recruited from the same communities. This was a very good result. The main reason for rejection from the study was not the issue of privacy but the fact that respondents had a contract with the wrong telephone operator who was not positioned. Only 10% of the respondents questioned were clearly afraid of surveillance.

Another problem with mobile positioning data is its low spatial accuracy, because as mentioned in the data section, the average positioning bias in the city of Tallinn is 200–500 m, and 300–1000 m in the suburbs. This degree of precision is insufficient to study exact locations such as houses, streets or blocks. As statistics on districts and transport zones, however, this data is very good. The data is also good for working with anchor points such as the technical aspects of the CGI + TA positioning method used in this study, and in most GSM networks it is cheapest to position phones in certain locations determined by network cell geometry (Ahas et al., 2007c). The problem of the low accuracy of mobile positioning data has been one of the major problems concerning the use of positioning data in geographical studies and developing LBS (Nhan et al., 2006). Inexpensive positioning data such as passive mobile positioning data (Ahas et al., 2008) has lower precision, normally at the level of network cells. The higher quality of positioning data today is related to A–GPS, and this new accuracy may change a lot in LBS and travel behaviour research, because there are two sides to the precision problem. First, the low precision of tracking is a problem for the development of research methods or services using positioning data. The precision of positioning at the level of A–GPS creates a new problem – the data is too accurate and allows one to pinpoint a single person, and therefore it is certain that with A–GPS we will step into an era of a real fear of surveillance.

Despite its low spatial accuracy, temporal accuracy is very good, and it has many more possible research directions than those mentioned in this paper for the investigation of the tempo of respondents’ movements and its generalisation to social networks or locations. As the aim of this paper is to describe the temporal rhythm and applicability of city life, we must conclude that the main results were used by the city planners of Tallinn in the development of the master plan. The city planners’ greatest interest was in the connection of respondents with different time-functions in different locations, as the city is concerned that wealthy taxpayers will leave the city. The second aspect that was of interest to city planners was the temporal density of activity spaces, especially in connection with school children, as there is a need to develop a system of school buses or a policy for planning school hours. One reason for the growing traffic problems in Tallinn is that wealthy suburban families have children who attend schools in the city centre, and the bad timing of schools in the centre creates an artificial rush.

As a result of our research project and other experiences with mobile positioning data, we must conclude that mobile positioning is an attractive source for travel behaviour research. This data is similar to tracking data gathered by different means such as GPS, Moby drive, travel diaries, questionnaires and video tracking. Mobile positioning data does, however, have some advantages:

1. mobile phones are widespread and popular in developed and developing countries;
2. people like to carry mobile phone with them, and they recharge the battery carefully;
3. data is originally digital, free from respondents’ memory bias or manual digitalisation errors and;
4. it is possible to ask respondents extra questions or location-aware questions during a study, using text messages or special environments (Ohmori et al., 2005; Bellemans et al., 2008).

There are more advantages of using mobile positioning, as it is possible to save more movement points than using traditional diaries or questionnaires. The most promising feature is the possibility to organise nation-wide positioning studies with large samples of passive mobile positioning data that may open up new perspectives in travel behaviour or mobility studies. One example is the latest discoveries published in leading scientific papers, for instance Nature (Gonzales et al., 2008).
Problems related to mobile positioning based systems are related to the quantitative matter of data and privacy issues. In today’s travel behaviour research, simple movement tracks are not very attractive, as there is a need for activity data (Timmermans et al., 2002). The immense quantity of positioning data creates problems of its own, as traditional programs and methods are not designed for tens or hundreds of thousands of entries. This creates a need for special data management systems by research groups, because of the large quantities of data (location points) collected. The cost of a positioning data unit is still lower than that of questionnaire surveys. The biggest problem in this field is actually the willingness of mobile operators to participate in research. Both active and passive mobile positioning experiments require cooperation with mobile operators, but privacy issues and business secrets, operators are not open to that. As a result, there are a number of independent handset based mobile positioning systems under development that do not need a contract with an operator, for instance Google Mobile (www.google.com/mobile/) or Nutimap (www.nutiteq.ee/nutimap).

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