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# Mapping geographical distribution of highway traffic using passive mobile positioning data

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## 1. Introduction

There are different approaches for analysing space-time variability of human movements as traffic models and travel behaviour models, GIS and econometric approaches. The study of space time behaviour and geography of transportation has been limited with data collection methods (Timmermans et al., 2002) . Travel diaries and questionnaires are effective but costs of geographical data are high; GPS tracking is limited by visibility and battery capacity; traffic counters have problems with geographical data. For tracking purposes is during last years often proposed mobile (cellular) telephone positioning data (Mountain and Raper, 2001; Spinney, 2003; Ahas and Mark 2005; Ohmori et al., 2005, Ratti et al 2006, Ahas et al 2007a; Ahas et al 2007b; Reades et al., 2007). Mobile positioning and tracing data has advantages and problems for geographical studies.

The objective of this paper is to introduce method developed in Estonia for studying traffic flows and geography of destinations of highway traffic using passive mobile positioning data. Passive mobile positioning data is location data of mobile phones extracted from memory files of mobile operators and this data has great potential for geographical research. We developed model for using passive mobile positioning data for studying traffic flows on highways canyons and geographical distributions of movements. Issues of privacy and surveillance are very important aspects of mobile positioning studies, but they are not deeply discussed in this paper.

## 2. Data and methods

We used passive mobile positioning data (cellular tracking) for current study. *Passive mobile positioning data* is automatically stored in the memory files (billing memory; hand-over between network cells, Home Location Register logs etc) of mobile operators (Ahas et al 2007a). In current study, the passive mobile positioning data was collected for all call activities of network subscribers of Estonian biggest mobile operator EMT with the precision of network cells. There is more than 800 network cells in EMT network in Estonia, covering 99% of territory. *Call activity* is defined as any active use of a mobile phone in networks: outgoing and incoming calls; outgoing and incoming SMSs;

Internet or GPRS services; location-based services (Ahas et al 2007a). In travel behaviour research is used also *active mobile positioning data* – mobile tracing data in which the location of the mobile phone is determined (asked) with a special query using a radio wave (Ahas et al 2007c).

For the research purposes the EMT aggregated anonymous geographical records for 12 months for 1.10.2006-30.09.2007. All together database consisted more than 800 million location points of call activities of more than 0,5 million phone owners. Total population of Estonia is 1,34 million. Data collection and processing was organised by positioning firm Positium LBS which is specialised for geographical analysis/monitoring with LBS data and for developing LBS based solutions (Positium 2008). Phone owners of EMT network were marked with anonymous (randomly generated) 8 digits ID which allowed linking all locations of call activities made by same phone during 12 months studied. Because of privacy issue, there is not possible to present single movement tracks but only statistical overview or moving persons with minimal representation 5 persons in one cell/time. The data protection regulation is strict, the data security and privacy matters are regulated according to EU directives on handling personal data (Directive 95/46/EC) and on the protection of privacy in the electronic communications sector (Directive 2002/58/EC).

We developed model for: a) generating movement vectors from location points of call activities; b) downscaling movement vectors into highway canyon; c) for analysing traffic frequencies in highway profile; d) linking traffic frequencies with geographical destinations of trips; e) analysing geography of movements in perspectives of home and work anchor points. Home, work and secondary anchor points of phones were determined using model based on timing, geographical regularity and standard deviation of call activities. Movements were named as "local movements" if home anchor point was in same municipalities (Kõue and Ardu), other movements were named as transit movements. We separated also 3 categories of movements: a) everyday movement between home and work anchor points; b) regular movements between one anchor point and secondary anchor point; c) irregular movements which are not connected with home and work anchor points.

As there was huge geographical database with more than 800 million location points the data was handled with PostgreSQL database manager and PostGIS spatial data manager and Map Server. The point data was transformed to movement vectors and downscaled to highway canyon using model developed for network cells.

Study area was selected in major highway between biggest (capital) city Tallinn and second largest city Tartu. Profile line for current study was located to Ardu village which locates about 55 km from Tallinn (Figure 1). The traffic counter data was used from Võõbu counter in same highway, 66 km from Tallinn.


Figure 1. Location of Tallinn-Tartu highway, network cells and location of study place Ardu.

## 3. Results

### 3.1. Traffic frequencies

Traffic frequencies estimated in Ardu using passive mobile positioning data is almost identical to automatic traffic counter dataset in Võõbu. Correlations between two databases reached 0,9 (p <0,01). The seasonal differences in daily distribution of traffic are similar to most of Estonian highway counters on bigger highways, summer have longer traffic days, especially during evening hours. Winter days have more concentrated on afternoon, with maximum distribution in 16:00. Traffic variability for weekdays calculated by passive mobile positioning model is also similar to regular traffic counters in Estonia: Friday with maximum traffic with peak on afternoon; rest or business days are homogenous; Saturday with later morning and Sunday with smallest number of cars passing our profile line in Ardu (Figure 2).

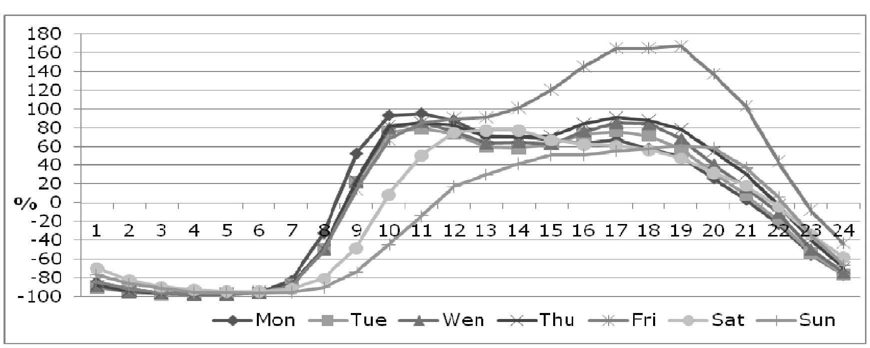

Figure 2. Daily distribution of traffic passing Ardu. Estimated from passive mobile positioning dataset.

## 3.2. Local and transit traffic

Passive mobile positioning dataset used for study allowed us to distinguish easily between local traffic and transit traffic. As mentioned in methods the local traffic was determined when moving phone had home anchor point in same municipality as study area as Ardu region with Paide and Kõue municipalities (Figure 1). Our results showed that as average the 13% of traffic was local in study area and 87% was transit to other regions. Among transit phones were 1-3% of foreign phones marked as tourists which were distinguished by foreign registration code of phones. The share of local transportation is higher during afternoon and evening and lower during night time. The biggest difference in frequency of local and transit traffic is studied in Fridays, when number of transit cars is rising rapidly in afternoon (Figure 3).

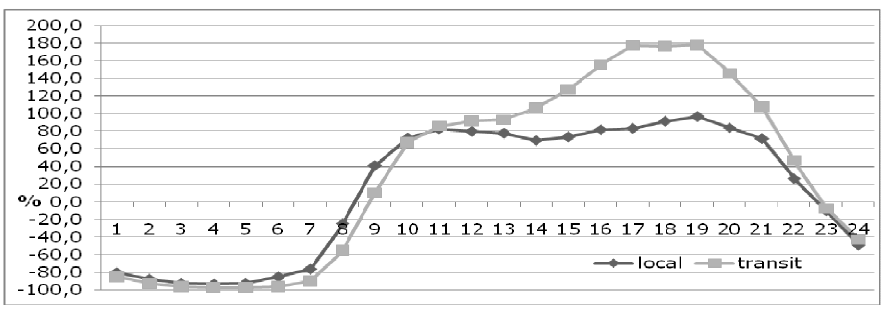


Figure 3. Difference in traffic frequencies of local (destination in local community) and transit traffic in Fridays crossing Ardu. Estimated from passive mobile positioning dataset.

## 3.3. Geographical distribution of traffic flows

The study of geographical distribution of traffic passing Ardu showed that from passed phones 33,1% had home and 44,2% work place in Tallinn. Second place had second biggest city in Estonia Tartu with 12,2% of homes and 11,3% work places (Table 1). The geographical distribution of home and work anchor points was mostly determined by size of municipality and by distance from Tallinn (Figure 4). The geographical distribution of traffic passing Ardu between bigger administrative units of Estonia counties (Maakond) shows also similar distribution determined by size (number of inhabitants) and distance from Tallinn (Table 1).

Table 1. Distribution of main home and work anchor points of travellers (phones) passing Ardu.

| home | % | work | % |
|---|---|---|---|
| Tallinn | 33,1 | Tallinn | 44,2 |
| Tartu | 12,2 | Tartu | 11,3 |

| County | home (%) | work (%) |
|---|---|---|
| Harjumaa | 42,2 | 57,8 |
| Tartumaa | 15,7 | 14,9 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Paide town | 8,0 | Paide town | 3,7 | Järvamaa | 12,4 | 6,5 |
| Viljandi town | 4,4 | Viljandi town | 2,9 | Viljandimaa | 9,4 | 6,7 |
| Põltsamaa town | 3,0 | Rae municip. | 2,9 | Jõgevamaa | 7,4 | 4,6 |
| Türi municip. | 2,6 | Türi municip. | 1,9 | Valgamaa | 4,0 | 3,2 |
| Jõgeva town | 2,5 | Põltsamaa town | 1,8 | Põlvamaa | 3,7 | 2,4 |
| Võru town | 2,4 | Võru town | 1,7 | Võrumaa | 3,7 | 2,5 |
| Rae municip. | 2,1 | Jõgeva town | 1,6 | Lääne-Virumaa | 0,6 | 0,3 |
| Valga town | 1,3 | Maardu town | 1,3 | Pärnumaa | 0,5 | 0,3 |
| Suure-Jaani municip. | 1,3 | Harku municip. | 1,3 | Raplamaa | 0,4 | 0,8 |

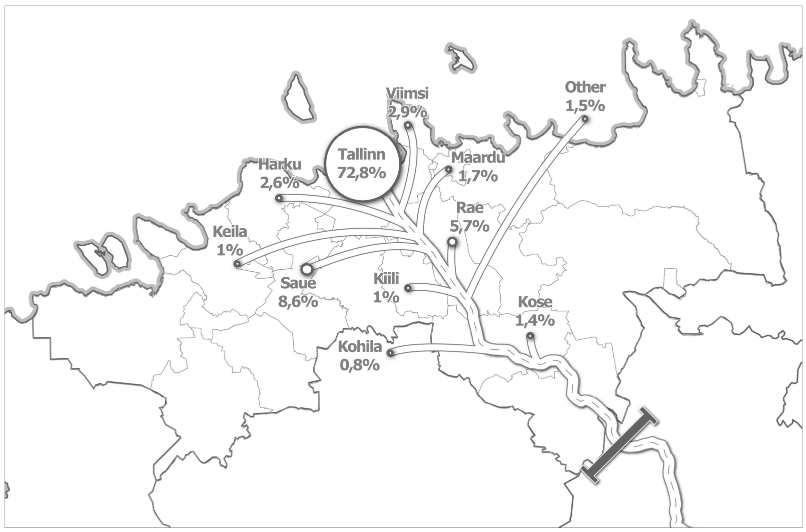


Figure 4. Location of home anchor points of traffic passed Ardu on Fridays in Tallinn metropolitan area.

Determined home, work and secondary anchor points and movement between them allows also distinguishing between different movement types (Table 3). We separated 3 categories: a) everyday movement between home and work anchor points, in Ardu profile was 8% of total movements; b) regular movements between one anchor point and secondary anchor point (2-15 trips every month)- 31% of total movements in Ardu; c)Irregular movements which are not connected with home and work locations - 61% of total movements in Ardu.

## 4. Conclusions

The preliminary results of our study showed that passive mobile positioning data has high potential for traffic studies and modelling. Our method for modelling call activity database to movement vector; for downscale it into highway canyon and to determine anchor points is primitive but high number of respondents (more than 50% of Estonians) and cost-effectiveness of method have expositive aspects. As our results showed, the traffic frequency of modelled data from mobile positioning and traditional traffic counters has very high correlation. Another strength is possibility to find geographical distribution of traffic, to determine anchor points and to distinguish between purposes of trips. This may be aspects where passive mobile positioning can contribute to current methodology in travel behaviour research. Problems of mobile positioning data are privacy, access to data and need to run huge databases with geographical extensions. Our Estonian experiences with cooperation of Positium LBS and Department of University of Tartu with 2 major mobile operators in Estonia are positive and we see possibilities to start similar studies in neighbouring countries.

## References


Adams, P.M., G.W.B. Ashwell, and R. Baxter. 2003. Location-based services—an overview of the standards. BT Technology Journal 21(1): 34-43.

Ahas, R. Aasa, A., Roose, A., Mark, Ü., Silm, S. 2007a. Evaluating passive mobile positioning data for tourism surveys: An Estonian case study. Tourism Management (Published online June 2007). http://www.sciencedirect.com/science/journal/02615177

Ahas, R., Aasa, A., Mark, Ü., Pae, T., Kull, T. 2007b. Seasonal tourism spaces in Estonia: case study with mobile positioning data. Tourism Management 28(3): 898–910.

Ahas, R., Aasa, A., Silm, S., Aunap, R., Kalle, H., Mark, Ü. 2007c. Mobile positioning in space-time behaviour studies: Social Positioning Method experiments in Estonia. CaGIS 34(4): 259-273.

Ahas, R. and Mark, Ü. 2005. Location based services - new challenges for planning and public administration? Futures, 37(6), 547-561.

EMT 2008. Web site of Estonian operator EMT, www.emt.ee. Last visted 7.01.2008.

Kwan, M.-P. (2000) Interactive geovisualization of activity-travel patterns using three-dimensional geographical information systems: a methodological exploration with a large data set. Transportation Research C, 8, pp 185-203.

Mountain, D. and Raper, J. (2001). Modelling human spatio-temporal behaviour: a challenge for location-based services. In Proc. of the 6th Internat. Conference on GeoComputation. University of Queensland, Brisbane, Australia, 24-26.

Positium 2008. Internet homepage of Positium LBS. www.positium.com. Last visited 7.01.2008

Ratti, C., Frenchman, D., Pulselli, R.M. & Williams, S. (2006). Mobile landscapes: Using location data from cell phones for urban analysis. Environment And Planning B-Planning & Design 33(5): 727-748.

Reades J, Calabrese F, Sevtsuk A, Ratti C, 2007. Cellular census: Explorations in urban data collection. IEEE Pervasive Computing 6(3): 30-38.

Spinney, J. E. (2003) Mobile positioning and LBS applications. Geography, 88, 256-265.

Timmermans, H., Arentze, T.,Joh, C.-H. (2002). Analysing space-time behaviour: new approaches to old problems. Progress in Human Geography, 26(2): 175-190.