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On the GPS track of 169 young Danes in the urban landscape:

The Aalborg case – GPS-tracking of young adults in the central city

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Recent developments in the global positioning system (GPS) and the global system for mobile communications, or third generation technology (GSM/3G), have enabled an increasingly simple and cost-effective tracking of human activity in urban areas through the use of mobile telephony for the collection of vast amounts of location-based data.

From a planning perspective, location-based datasets on collective or individual spatial behaviour in urban areas are highly interesting. Combining this data with existing information on urban elements such as plazas, shops, etc., to yield infinitely detailed information on the interplay between users' individual behaviours and the mentioned urban elements require complex, yet accessible ways of representation. Further questions must address other, value-based choices concerning urban design and planning.

We demonstrate a number of ways in which the collected data enable statistical analysis of urban activity such as citizens' time spent in plazas, parks, or window-shopping, etc. More complex analyses are also undertaken by breaking down the data into male and female cohorts, geographical areas, and activities at several places of interest.

The study was based on a unique sample of movement data gleaned from 169 young adults aged 16 to 20 years. Each person was GPS-tracked over a period of seven days in 2008-2009 to record their movements in and uses of spaces in the central city area of Aalborg, which is Denmark's fourth-largest city, with 122 461 inhabitants (2009).

Background – The Aalborg case 2009

This paper is the result of a study that combined data from the GPS-tracking of respondents' outdoor activities and their self-reported movements in urban spaces. The research group has also employed radio-frequency identification (RFID) based activity tracking in both indoor and outdoor spaces. For the present study, an online and real-time collection of quantitative data was carried out employing a GPS unit. For the respondents' daily reporting of their activities, a programme was installed on their home computer, which was connected to a central server/database. Additional qualitative data were collected by a combination of web-based questionnaires and interviews after the GPS data was collected.

The paper presents a minor, but important selection of results from the Aalborg Case 2009, one of our group's large-scale surveys. The respondents in this study were defined as young adults living in Aalborg municipality who attended one of urban Aalborg's upper secondary schools directed at academically gifted students. The schools all required daily attendance. The study thus recruited not only a group of very active users but also one that represents the future users of Aalborg's urban spaces. The group was also chosen because of its easy accessibility through school administrations, a circumstance that has made the survey logistically and economically feasible while also allowing for the reproduction of relevant empirical data at a later date.

The present study is based on three surveys, only two of which are partly reported here, e.g. results from a bigger web based survey (first survey) and results from the combined web and GPS survey (second survey). For the second survey the respondents were required to enter a report of their day-to-day activities into a web database while based on GPS-generated data and web sources. The purely qualitative survey based on 16 face-to-face interviews is reported elsewhere. The shared point of departure for all three surveys was an interest in how young adults spend time in urban areas and the possibility of working with "urban living" on the basis of GPS-generated data. The objective of the three surveys was twofold, its primary aim being to supply a detailed illustration of a number of themes concerning young adults' attitudes and priorities in relation to Aalborg's central city areas. Secondly an additional aim was to collect data for a survey of the group's spatial behaviour at three levels, i.e. for the central city, the larger urban area of Aalborg and fort the municipality as a whole. Thirdly supplementary data was collected from web-based questionnaires and interviews after the GPS data was collected and this data was is referred to as the third and last survey

The web survey – The first part of the Aalborg study

The first part of the survey was conducted between 2007 and 2008 using a web based survey. In what represents a unique effort to survey the movements and activities of a whole population segment through detailed, second-by-second electronic tracking, the entire population of students attending youth education programmes was contacted by email. The 7.277 young adults thus comprised the whole spectrum of students from both academically and vocationally oriented programmes (dst 2006).
Positive responses to the call for participants were received from 1 073 persons (463 men and 610 women), who expressed their interest in participating in the survey. However, the differences in the individual groups' response frequency indicated that it would be meaningful to include only students' attending the academically oriented schools. As a result, the sample was fully representative of Aalborg's population of

upper secondary students between 16 and 20 years while it was only partly representative in respect to the following parameters: gender distribution, home address in the municipality, and the type of school that the respondents attended (Denmark's upper secondary schools are comparable in terms of their academic level, but for historical reasons, separate institutions cater for traditional academic studies, technical studies, and commercial studies), respectively. One of the survey's central questions is quoted here:

> *"What do you think will be important to you in the future as you move around the central city and park spaces of Aalborg?*

Participants were asked to give their response by indicating their rating of the significance of a number of parameters. Their answer options were: "very significant", "significant", "less significant" and "slightly significant". Only response rates for "very significant" are given here: 858 responses. Response percentage 80% for "very significant") (test of Gehl's 12 key quality criteria, (Gehl 2006) + "Being able to walk through a green area, e.g. a park")".:

	Men	**Women**	**Total**	**Diff.**
1. Feeling protected from crime and violence	39%	65%	54%	25%
Being able to walk through a green area, e.g. a park	**33%**	**38%**	**36%**	**4%**
2. Being able to watch other people and go window-shopping, etc.	26%	43%	35%	17%
3. Being able to enjoy the weather, e.g. the sun, or stand in the shade	29%	34%	32%	5%
4. Having the opportunity to talk to others or listen to what they are saying / low noise level	28%	32%	30%	4%
5. Feeling safe in the traffic, e.g. from cars, etc.	24%	34%	30%	10%
6. Being able to move freely across roads, pavements and plaza pavements	24%	27%	26%	2%
7. Finding the urban space smartly designed	24%	20%	22%	-4%
8. Having the opportunity to sit down on a bench, etc.	18%	23%	21%	5%
9. Finding the urban space suits me and is not too cold or too big	22%	20%	21%	-2%
10. Having the opportunity to stop and stay in a place	15%	24%	20%	9%
11. That the city and park spaces I move around in do not have strong winds or rain	21%	19%	20%	-2%
12. Being able to jog, play, jump, skate or run	15%	11%	13%	-3%

The GPS/web survey – The second part of the Aalborg survey

This part of the Aalborg study was conducted through a combination of GPS-tracking and web surveying involving students at eight schools, with data collection taking place over four months leading up to and following the summer holidays of 2008 and in April the following year.

The focus was on temporal and spatial behaviours and activities in both physical and virtual environments. By utilizing cross-disciplinary research methods such as surveys based on quantitative and qualitative set-ups, the aim was to allow for a broad discussion of interrelations and interactions between respondents and spaces. Thus, answers were sought for three questions that were intended to chart the respondents' current position, current activity and its duration, and their motivation for undertaking the activity. In other words, they were asked about where they were, what they were doing and for how long they had been doing it.

It should be noted that Aalborg's urban spaces (defined as physical, typically open, spaces with public access) only represent one of several offers for young adults to socialize and communicate with their peers or with people of other ages or backgrounds. The Internet, computers and mobile telecommunication, etc., represent technologies that may be conceived as part of the "urban space" that many young people use for social and other purposes. This takes place for example through www.facebook.com, www.hotmail.com, www.youtube.com, etc., which represent new types of virtual meeting places that compete with the traditional physical urban spaces for respondents' time. It should also be noted that the mappings reproduced here do not directly reflect respondents' actual behaviour, but are the result of several procedures. The collected data were thus processed at three levels and over seven procedures in preparation for the mapping shown here:

A. Data processing at respondent level:

1. Actual behaviour
2. GPS-logged behaviour3. Web survey-logged behavior

B. Data processing at database level:

4. Correction for discrepancies between GPS-logged behaviour and reported behaviour (see 2. and 3. above; priority given to the former)
5. Correction for behaviour in data cleaning processes
6. Analysis of corrected reported behaviour (e.g. for trips/stays)

C. Data processing at map/analysis level:

7. GIS square visualizations of behaviour, as corrected, in maps.

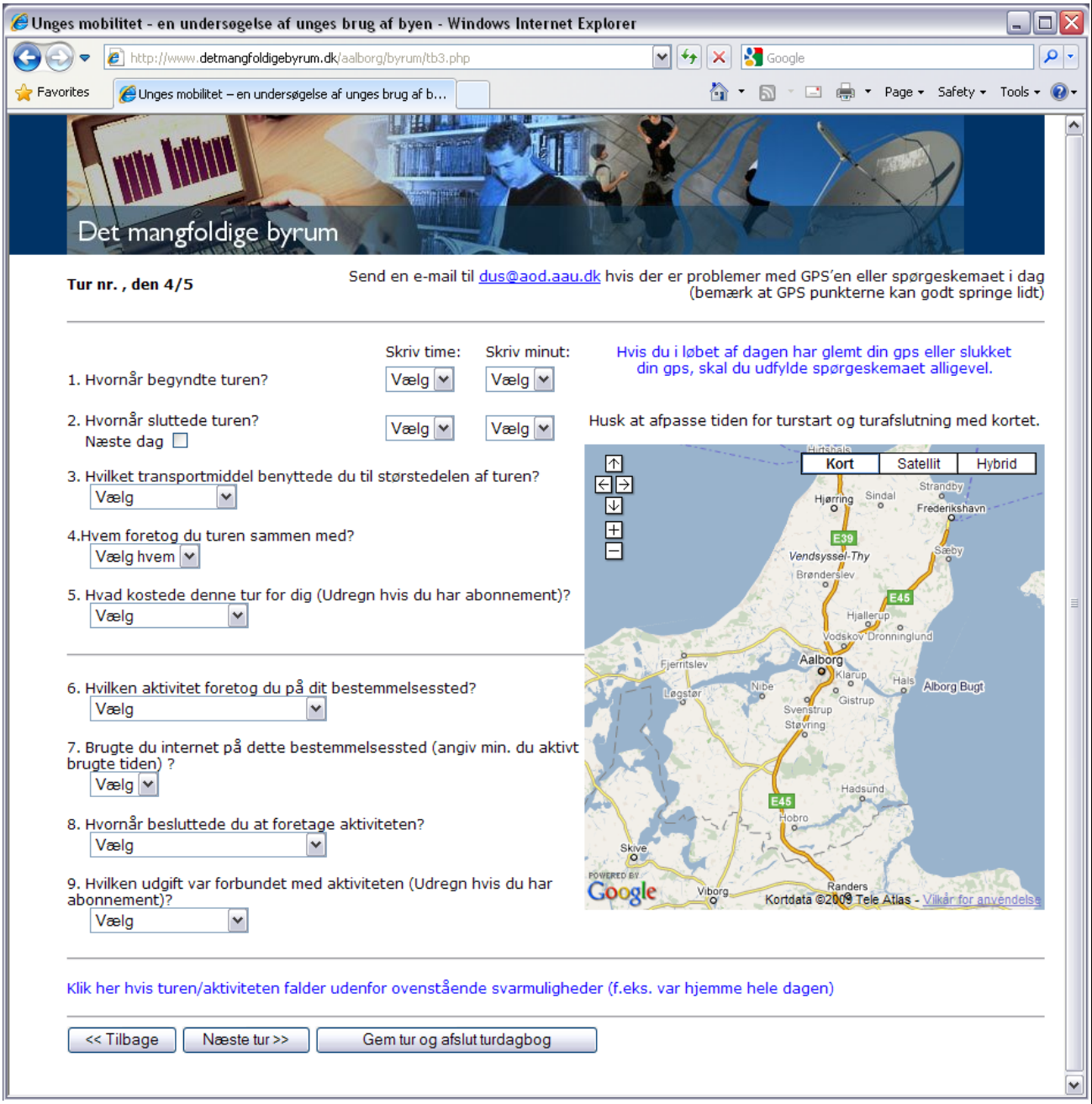

Figure 1: Web travel diary questionnaire, screen dump

The potential number of daily GPS updates for all 169 respondent was, 110 728 800seconds for the seven days, the respondents participated in the GPS while the actual number of recorded GSP updates was no more than 54.694.465.

The GSP datasets were created through updates with 5-second intervals from the GPS unit. In order to simplify the accumulation of time in the GIS maps, the 5-second intervals were afterwards interpolated to 1-second GPS points. Considered in isolation, our relatively simple recording set-up based on GPS updates and the corresponding GPS points contains several potential sources of error, which are described briefly here. Slightly simplified, two types of errors may occur in connection with the collection and the subsequent processing of data, respectively.

Data collection

The great majority of the respondents obliged fully with requirements, but a variety of reason of a social or technical nature may occasionally have caused the loss of data. For instance, if respondents had forgotten to recharge or pick up their GPS unit before going out, or if they deliberately avoided to carry it for certain occasions such as parties or the spring carnival (which was a major event involving over 20.000 young people one day) during the GPS survey period . The tendency to forget or avoid using the device seems to have increased over the seven day period. Other reasons included GPS breakdowns, battery failure or connection failures to the central database. As a result, GPS point updates were incomplete and not fully representative of the individual respondent's behaviour. Such discrepancies are not given further treatment here, but as an example, the number of GPS updates declined during nights, probably due to battery failure.

Data processing

In preparing the maps and data sets for this survey, some of the scatter originating in the raw data GPS-generated was removed. Scatter is defined here as GPS updates showing substantial deviation from what was deemed to be feasible, such as updates that could not be explained by statistical discrepancy or updates that would have presupposed that respondents had moved with improbable speeds. GPS updates were also discarded as scatter on the basis of other considerations, such as weather conditions, satellite positions, signal obstruction from buildings, or because the quality of GPS hardware and software was insufficient.

The respondents

The respondents were asked to carry a pocket-size GPS unit for seven consecutive days. Every evening they were to complete a travel diary using the unit's Google Maps with a log of the GPS waypoints visited by the respondent in the preceding 24 hours. In practical terms, the eight partial surveys were organized on a staggered schedule in which the GPS devices were handed out to respondents at each school for the designated period. The start of each partial survey was designated as "survey day 1", beginning at 12:00 and ending on "survey day 8" at noon, after which the participants were instructed to immediately hand in the GPS units to the school secretariat. They were then collected by the person responsible for the partial survey.

Partial survey periods and names of schools involved

Survey 1: Aalborg Studenterkursus. 2008-03-06 to 2008-03-13 (year-month-day)
Survey 2: Aalborg Katedralskole. 2008-05-07 to 2008-05-14
Survey 3: Aalborg Tekniske Gymnasium, Øster Uttrup Vej. 2008-05-19 to 2008-05-26
Survey 4: Aalborg Tekniske Gymnasium, Sankelmarksgade. 2008-05-28 to 2008-06-04
Survey 5: Hasseris Gymnasium. 2008-08-14 to 2008-09-21
Survey 6: Aalborg Handelsskole. 2008-08-25 to 2008-09-01
Survey 7: Nørresundby Gymnasium. 2008-09-03 to 2008-09-10
Survey 8: Aalborghus Gymnasium. 2009-05-04 to 2009-05-11

Maps

In the visual material shown here gives the results of analyses of accumulated time use for all 169 respondents in the GPS survey.

The collected and processed data serve as basis for the constructions of several maps in three different scales. The central city area is the innermost part of Aalborg and covers an area of approximately 1 x 1 km. The Urban area is the formal city limits of Aalborg which is approximately 10 x 10 km. Finally the municipality of Aalborg is roughly 50 x 40 km. The number of loggings within these boundaries before and after the processing of data are presented in the table below.

Table 1	Before correction for scatter in seconds	After correction for scatter in seconds	Average time spent per respondent in mapped area in seconds
Central city area	3 992 458	3 967 948	3 354
Urban area	34 881 310	34 861 922	29 469
Municipal area	52 829 973	52 818 008	44 648

Table 1 Total and average times for areas (in seconds) by geographical level'. Before and after correction for scatter in seconds

Figures 2, 3 and 4

Figures 2, 3 and 4 show twin images of maps based on data analyses before and after correction for scatter, on municipality, urban and central city level, respectively. In preparing the maps, several challenges had to be overcome, the most important being to secure that our analyses were based on data of adequate quality and quantity. The following analysis concentrates on the central city area.

Calculations on the basis of data as described in table 1 indicate that the average respondent spent approximately 56 minutes per day in the central city area of Aalborg, 491 minutes in the urban area, and 744 minutes in the municipality as a whole (later figures include the former). As all respondents lived in Aalborg municipality, the total time logged on school days should be close to 24 hours, or 1 440 minutes, but in reality no more than approximately 52 % of respondents' time was recorded. In the following the focus is in the city area of Aalborg – and overall 56 minutes per day in the central city area of Aalborg was spent by the 169 respondents. I it is possible to subtract the areas were respondents use time in school and at home areas (26 minutes) and the results is then that the young respondents uses in average approximately 30 minutes per day in the central city area of Aalborg.

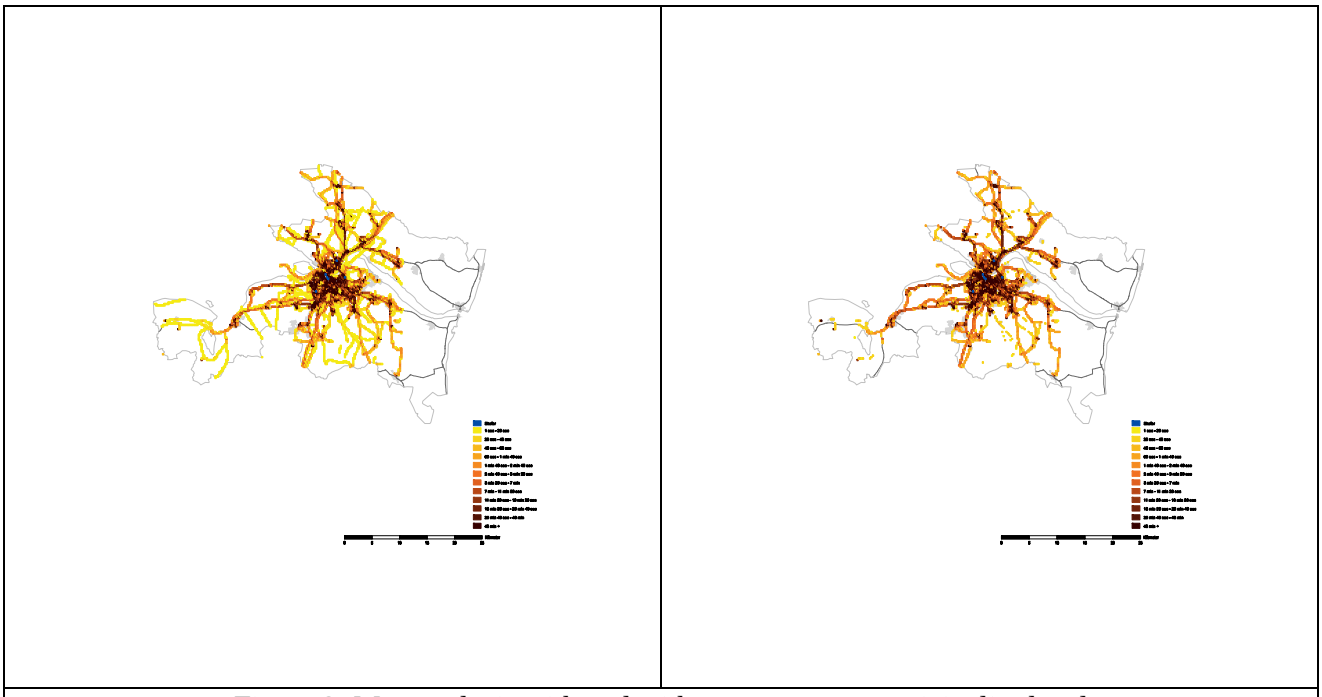

Figure 2: Map analysis with and without scatter on municipality level

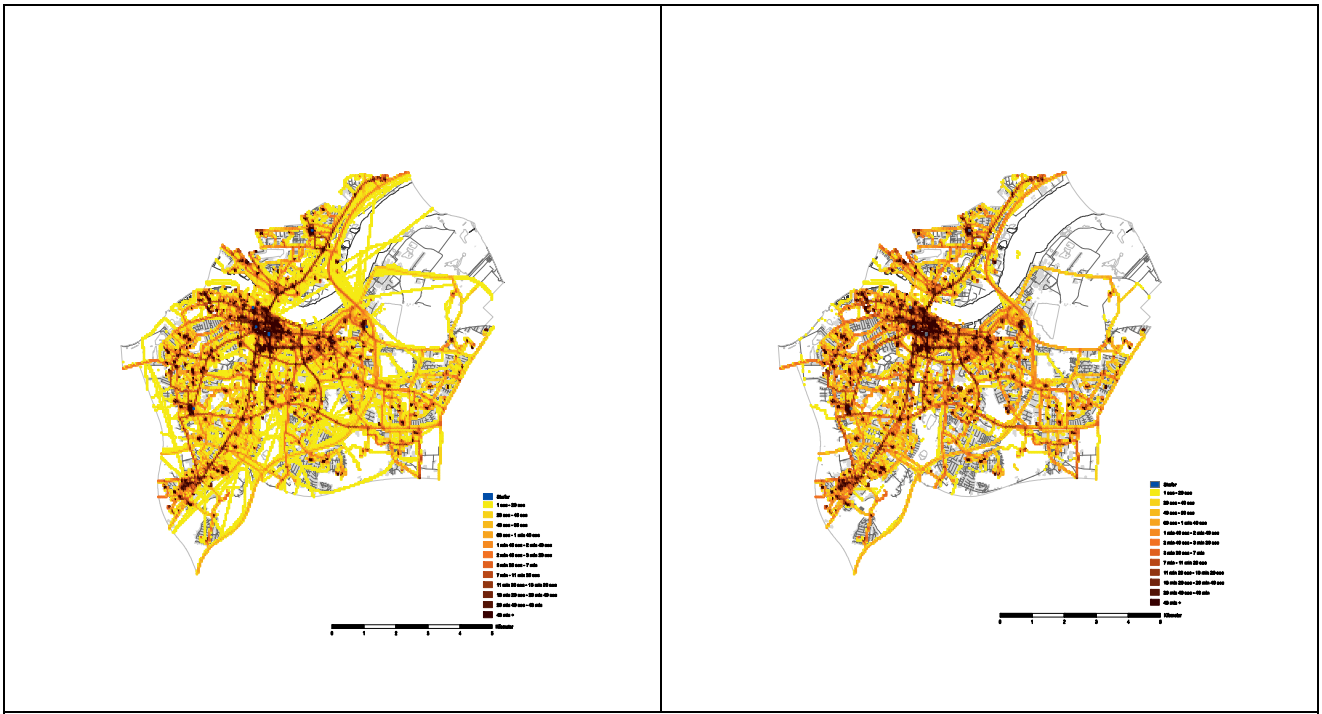

Figure 3: Map analysis with and without scatter on Urban level:

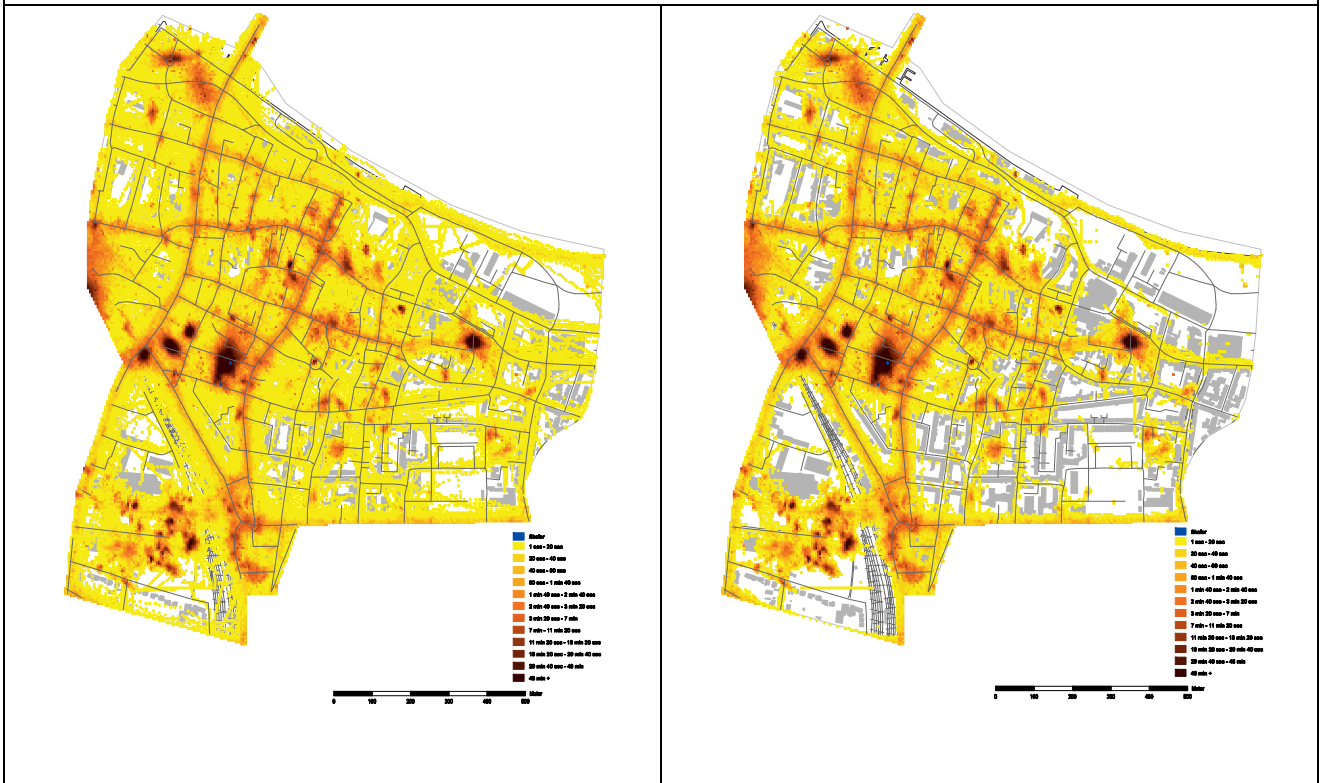

Figure 4: Map analysis with and without scatter on City level:

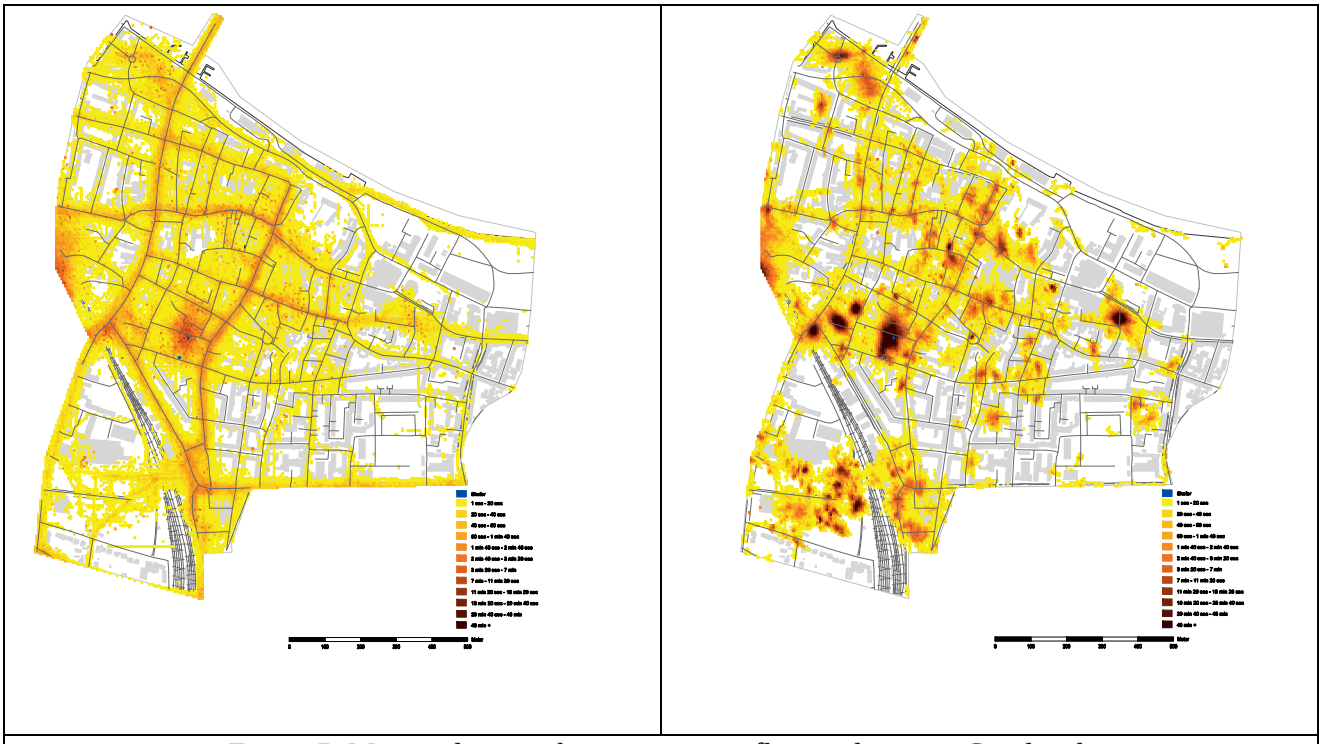

Figure 5: Map analysis with time spent on flow and stay on City level:

Figure 5

The map gives a two-dimensional image of the respondents' time spent in the central city area, divided between time spent in movement and staying at a location, respectively. The two modes are designated as "flow" and "stay". The average amount of time spent in movement or flow was approximately 12 minutes per day per respondent, while approximately 44 minutes were logged as stationary per day. The map thus gives a survey of the location of central Aalborg's typical "flow" and "stay" areas, as indicated by the density of plotting. Unsurprisingly, respondents' homes and school grounds were the areas that scored the highest figures for "stay", followed by parks.

Figure 6: Map analysis showing gender time spent - Men/Women - on City level:

Figure 6

Figure 6 shows the distribution of time as it was spent in central Aalborg by men and women, respectively. The differences between the two sections of the map reflect the fact that, in general, the females spent longer time in central Aalborg, with an average 30 minutes per day compared to the approximately 26 minutes spent by males per day (red circle: location of School – blue circle: location of respondent home). A gender difference was also seen in behaviour patterns with respect to the time spent in different areas, with the women spending more time in the central, east-west oriented pedestrian streets than did the men. Both women and men moved along the central north-west oriented street known as Boulevarden, but the women also stayed for longer there. For the parks, such as Kildeparken close to the central train station, gender differences were negligible. See also the park map in figure 8.

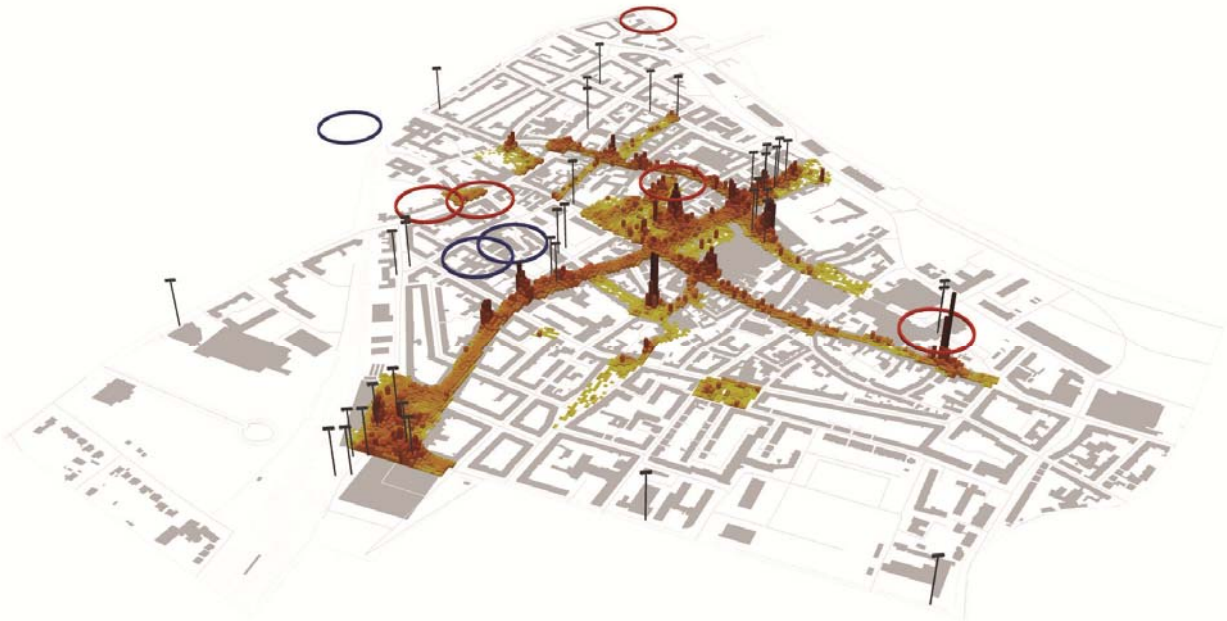

Figure 7: Map analysis of time spent on central plazas - on City level:

Figure 7

The map gives a three-dimensional image of respondents' time as spent in the central plazas, motor vehicle streets and pedestrian streets in central Aalborg (blue circle: location of school – red circle: location of respondent home). It appears that very few of the young respondents stayed in one place for longer periods of time. Two of the longest stays were recorded for the home address of a respondent (indicated by red circles) and the respondents approximately spent 7 minutes in these areas per day. Most of the remaining areas hosting longer stays were close to bus stops. Longer continuous stays were recorded for parks than for plazas, cf. figure 8.

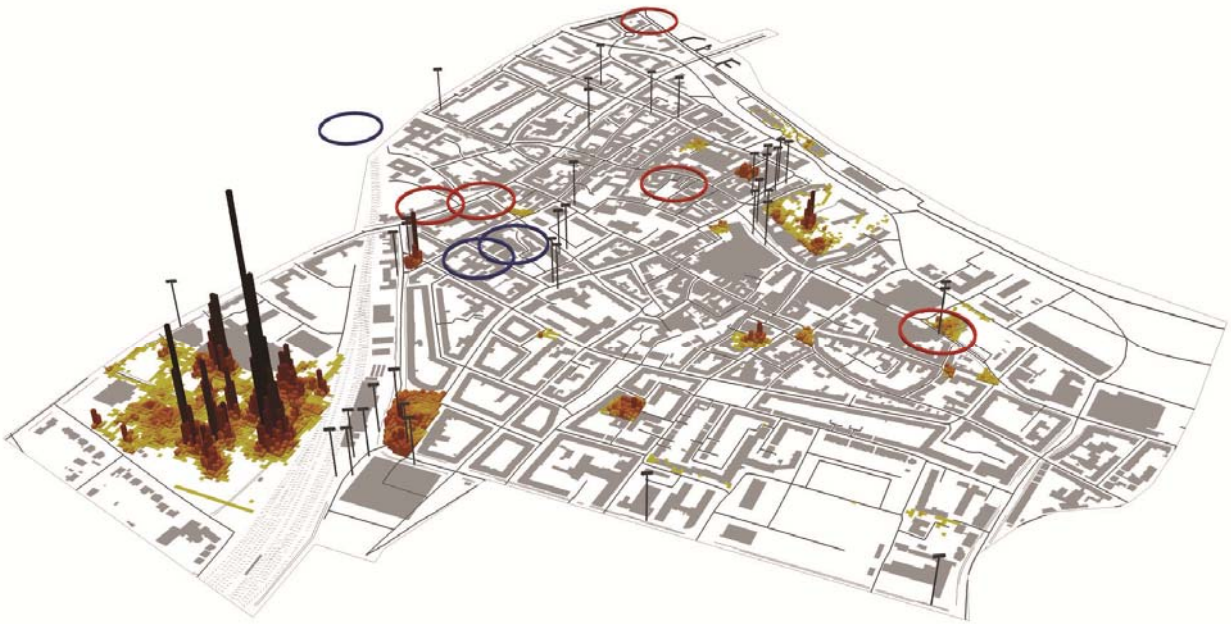

Figure 8: Map analysis of time spent on parks - on City level:

Figure 8

The time spent by respondents' in central Aalborg's park areas is shown in three dimensions in figure 8. The map shows that one park in particular, the Kildeparken, is frequented by the young respondents and the respondents approximately spent 6 minutes in these areas per day Aalborg (blue circle: location of school – red circle: location of respondent home).The other, smaller park areas show a use pattern resembling that of the streets, i.e. primarily as thoroughfares. In the GPS survey period a spring carnival was arranged (which was a major event involving over 20.000 young people one day) - some of the highest dark spots actually can be put down to areas and time corresponding to the time of the carnival.

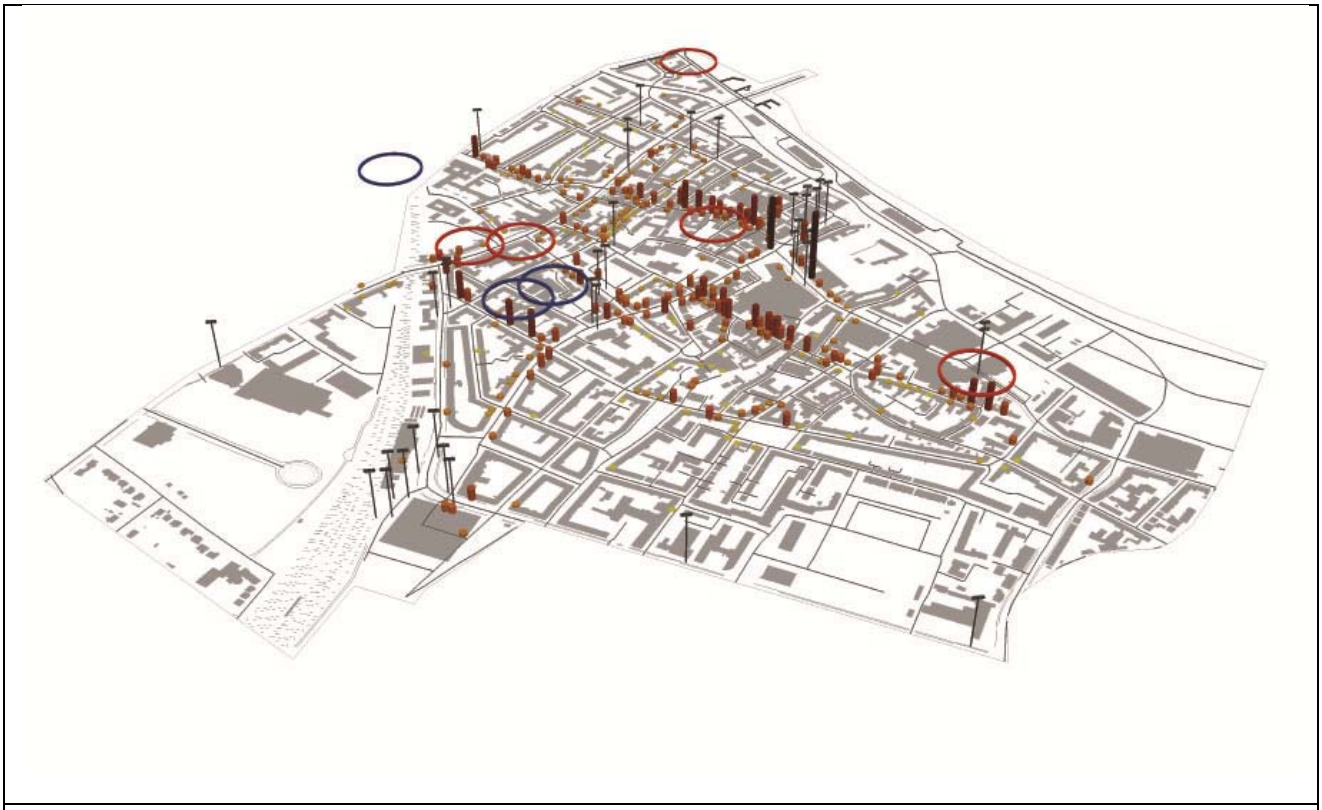

Figure 9: Map analysis of time spent on window-shopping on City level:

Figure 9

The map in figure 9 gives a three-dimensional illustration of the amount of time spent window-shopping by respondents Aalborg (blue circle: location of school – red circle: location of respondent home).The activity was defined as “stays” outside shops and restaurants in a circle with a radius 5 meters, and the respondents approximately spent 4 minutes in these areas per day. The highest figures appear for the broad mosaic pavement outside of a fast-food restaurant. In general, the shops in the pedestrian streets and those situated closest to Aalborg’s commercial centre attracted the respondents for longer times when compared to shops with more peripheral locations.**Conclusions**

This study was based on a unique sample of movement data on 169 partly representative 16 to 20-year-old young adults. Each person was GPS-tracked over a period of seven days in 2008-2009 to plot their use of Aalborg's central city area.

This paper has demonstrated that our data enable statistical analysis of urban activity such as the young respondents' time spent in plazas, parks, window-shopping, etc., and the results illustrate the relevance for city planners of GIS- and location-based datasets on collective and individual spatial behaviour in urban areas. Combining the data with existing information on physical elements in the cityscape, they offer extremely detailed information on the interplay between users' individual behaviour and urban elements. New technologies thus allow easy retrieval and animation of information on urban activity.

While the maps presented here offer much information of quantitative nature, such as the amount of time spent by users, the patterns in which it is spent, etc., we are left with the realization that useful and accessible comparisons among those categories is not simple undertaking.

We therefore propose that analyses of the huge datasets are only part of the answer for essential questions concerning urban users' motivations for their activities. In order to glean such information, planners and researchers continue to rely on for instance the traditional in-depth interview to track the m e.g. needs and reasons for behaviour of city users.

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