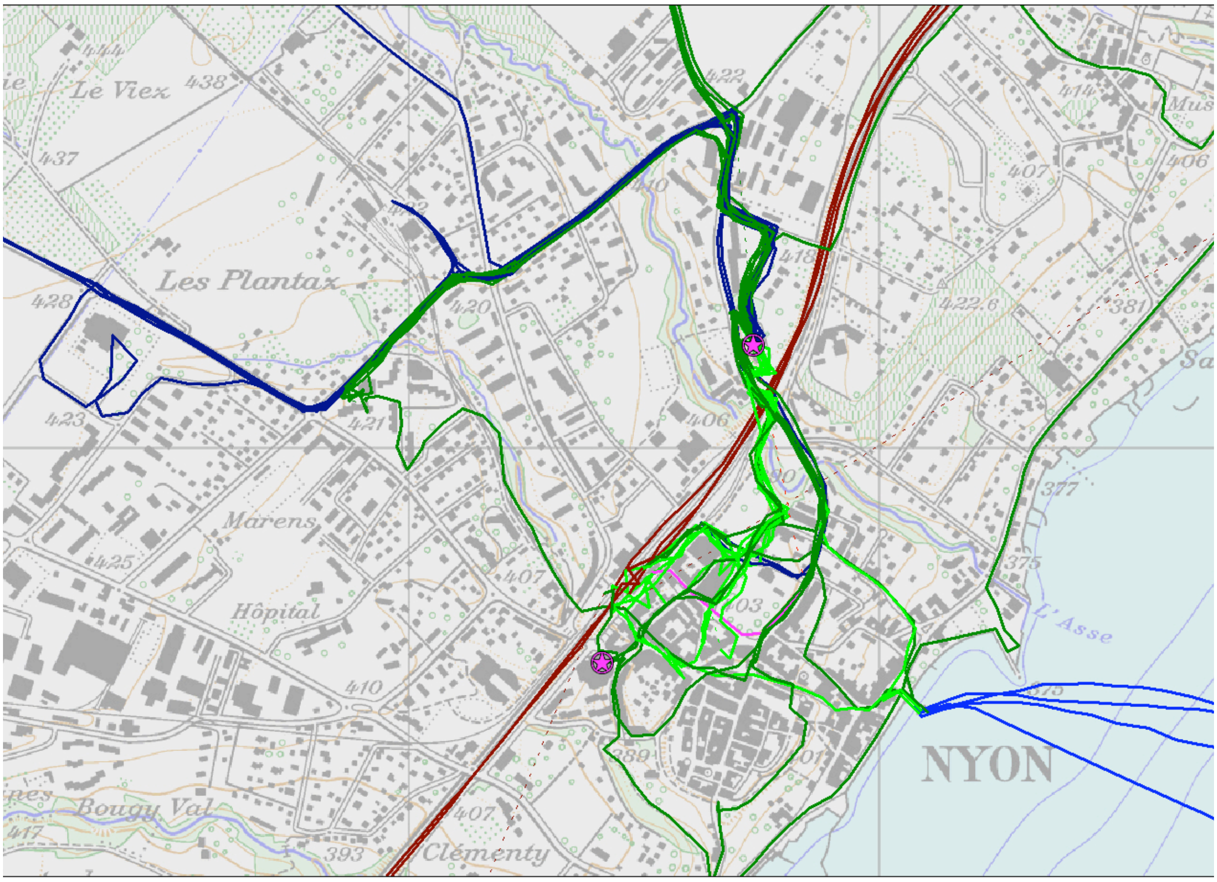

Combining person based GPS tracking and prompted recall interviews for a comprehensive investigation of travel behaviour adaptation processes during life course transitions

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Abstract

In order to comprehensively understand behavioural changes occurring during life course transitions, surveys must be conducted over a relatively long period. Indeed, changes in behaviour and in attitudes do not take place instantly, at time t of the transition (the day of the residential move, the day when starting a new job, the birth of a child, etc.). Rather, people go through complex adaptation processes which can involve phases of preparation, of experimentation and of consolidation of new practices. At the same time, surveying people going through notable life course transitions sets very high demands with respect to minimizing respondent burden: typically, individuals will not be ready to dedicate much time for surveys during these life phases as they are already rather busy with adapting their conduct of life to their new situation.

In this paper, we present an innovative survey design combining GPS-based person tracking and qualitative interviews. . In practice, we hand out GPS tracking units to respondents, collect extensive data about their travel behaviour and subsequently use this data as an input for qualitative, prompted recall interviews. Survey participants are asked to comment on their travel behaviour, the location choices underlying their activity space and their new mobility experiences, with a reporting period of 5-6 weeks after the life course transition. In total, we intend to survey 30 persons going through three different types of life course transitions: (1) residential moves, (2) changes of workplace and (3) retirement.

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1. Introduction

Modern society has to deal with a major dilemma: mobility plays an ever more central role in its inner functioning, but the means by which this mobility is effected cause pollution and congestion problems that are less and less tolerated by the population. Redirecting mobility towards more sustainable means of transport is thus a priority for transport policies. However, in this respect past policy implementation experiences have shown only limited results and the general trend still shows a growth of the negative externalities of travel. This pinpoints the problem: How can mobility successfully be redirected towards more sustainability, without putting it fundamentally into question?

To answer this question, it is essential (a) to understand the determinants of individual travel and transport decisions, (b) to assess how these could be influenced in various time perspectives and (c) to monitor in an accurate and timely fashion the effects of specific policies, so that an optimal policy mix can be assured. This requires the development and implementation of new observational and analytical tools which enable the investigation of changes in travel behaviour and the conditions necessary to promote these changes.

Generally speaking, it appears that it is rather difficult to influence travel practices, especially those of car drivers. A major reason is that spatial practices and travel mode preferences are firmly integrated in lifestyles and in daily life practices and thus are usually consolidated during life course transitions like a residential move, starting a family, birth of an additional child, a divorce, change of workplace, retirement, etc. In other words, individuals are rather reluctant to change their habits when they are not confronted with such a transition and voluntary behavioural changes do therefore mainly occur during these very specific (and rare) temporal intervals.

This observation is central for policy intervention: life course transitions must be considered as “windows of opportunity” for influencing individual behaviour, for example by way of individualised marketing and travel blending. However, even though social science and transport researchers have already investigated these transitions, there still remain numerous open questions regarding the role of transport supply and travel mode preferences in the adaptation and new habit formation processes occurring during these transitions.

2. Travel habits: a short review of existing research results

The topic of habitual travel choice is not really new, but it has recently gained a revitalised interest (Gärling & Axhausen, 2003). A particular reason is that travel demand strategies are confronted with the problem of breaking travel habits in order to succeed in redirecting individual behaviour towards more sustainable modes of transport and smaller activity spaces. More generally, travel habits can be understood as a stable component in individual behaviour, for which it is essential to understand under which circumstances and foremost how they are formed and reformed. Up to today, this issue has been investigated only incompletely.

In order to improve our understanding of the formation of travel habits, individual travel behaviour must be analysed in its continuity over the life course, with a specific focus on the moments in which behavioural change occurs. Past research points out the role of life course transitions as triggers for the rearrangement of daily habits. Building on this observation, a growing number of authors suggests that travel behaviour research should take a closer look at the interactions between travel habits and the biographical stages of an individual's life course. Lanzendorf (2003) has proposed a theoretical framework for the empirical analysis of these interactions, based on qualitative retrospective data (life course approach). Van Der Waerden et al. (2003) suggest a more quantitative approach looking at the influence of key events and critical incidents on transport mode switching behaviour. All in all, the existing literature shows that the idea of analysing the evolution of travel habits with respect to life course transitions is highly pertinent. However, the existing empirical evidence is still too superficial to draw conclusions about the decisions processes that underlie travel behaviour change and about their interactions with the long term decisions that are related to the life course transitions.

Indeed, several aspects must be considered in order to grasp the rationales of individual travel habits, as travel behaviour derives from a complex set of intertwined determinants, comprising in particular personal attitudes with regard to travel modes, personal competences for their usage, mobility tool ownership as well as personal activity space structure (Flamm, 2004). Location choices deserve a particularly detailed interest, because they are strongly interrelated with travel mode preferences. Thus, when studying the processes underlying a change of travel mode habits, it is essential to keep track of the evolution of personal activity space. Last but not least, personal social networks must also be taken into account, because the geography of personal travel is substantially determined by the fact that persons want to meet up for joint activities, as such face-to-face contact is crucial for the maintenance of personal relations (Axhausen, 2004; Larsen et al., 2006). In other words, travel behaviour change after life course transitions is not only concerned with new stores, travel modes, or other leisure facilities, but also with new friends, new colleagues, or simply new contacts; in consequence, the distribution of the residences, workplaces and preferred leisure facilities of new and previous contacts in space (and time) must also be analysed.

With regard to the question of how travel habits are formed, empirical evidence is to our knowledge almost solely based on experiments in social and cognitive psychology. Very little is known about individual travel behaviour adaptation processes in the real world, in particular with respect to the influences of social factors. In order to grasp the learning processes that people go through when they change their travel habits, surveys must rely on a comprehensive approach and must be conducted over a relatively long period. Indeed, changes in behaviour and in attitudes do not take place instantly, at time t of the transition (the day of the residential move, the day when starting a new job, the birth of a child, etc.). Rather, people go through complex adaptation processes which can involve phases of preparation, of experimentation and of consolidation of new practices. At the same time, surveying people going through notable life course transitions sets very high demands with respect to minimizing respondent burden: typically, individuals will not be ready to dedicate much time for surveys during these life phases as they are already rather busy with adapting their conduct of life to their new situation.

In this context, newly available positioning technologies offer a real opportunity for innovative research approaches. The feasibility of integrating technologies like GPS or GSM-based positioning in travel behaviour surveys has already been demonstrated in numerous experiments including real-time interactive activity diary and travel surveys, passive monitoring and automatic trip data processing as well as hybrid approaches combining passive monitoring and prompted recall interviews (Lee-Gosselin, 2002; Wolf, 2004). We thus decided to explore which benefits can be expected from using automatic tracking of space-time paths to address the issues related to habit formation and adaptation processes during life course transitions.

3. Introducing a new research approach

We propose to combine qualitative interviews and person-based tracking units allowing the precise and complete reconstruction of individuals' travel behaviour and activity spaces. This innovative survey approach is needed, because our investigation must analyse the interdependencies between actual spatial practices and travel mode use on one hand, and subjective attitudes, reasoning and competences on the other hand. By surveying people throughout the whole period of one of their life course transitions, it is possible to precisely observe behavioural change and to comprehensively understand the underlying adaptation processes.

In practice, we hand out GPS tracking units to respondents, collect extensive data about their travel behaviour and subsequently use this data as an input for qualitative, prompted recall interviews. Survey participants are asked to comment on their travel behaviour, the location choices underlying their activity space and their new mobility experiences, both during the observation period and at the end of the observation period. The GPS observation period will encompass 6 weeks, beginning shortly after the studied life course transition.

The main research questions are:

- To which extent do past travel mode practices and spatial habits influence the constitution of new daily life routines during life course transitions?
- What is the importance of past mobility biography? Do people assess formerly unused means of transport and, if so, how do they proceed?
- To which extent do changes of travel mode habits imply the acquisition of new mobility competences and how do people value such learning processes?
- More generally speaking, what are the interactions between life course transitions, mobility biographies, social networks and travel behaviour?

After having conducted tests of available GPS tracking devices as well as a single pre-test case study in October 2006, the main survey has started in January 2007. In total, we intend to survey 30 persons going through three different types of life course transitions: (1) residential moves within an urban area, (2) changes of workplace and (3) retirement. This set of situational contexts should allow to test the proposed survey design with a varied sample of individuals (younger and older people, singles and family parents, people showing very varied travel behaviours and involving diverse travel modes, etc.) and nevertheless provide relevant observations about behavioural adaptation processes in three different situational contexts. In order to facilitate the search for participants, we will survey only individuals and not whole households.

The survey design includes three distinct phases:

1) Initial interview: At the beginning of the observation period, a face-to-face contact is needed to deliver the survey instruments and to properly instruct participants on how to wear the tracking devices. We will take advantage of this initial contact to gather comprehensive information about the respondent's biography (past residences, past working places, past experiences with travel modes), current life context (usual activity locations, personal set of mobility tools, distribution of roles within the household, current priorities for life conduct, social network), attitudes towards different travel modes and appraisal of the oncoming life course transition (level of preparation, resolutions regarding future behaviour).

2) Short prompted recall interviews during the observation period (6 weeks after the life course transition): During the whole observation period, respondents are contacted by telephone on a regular basis (about once a week) in order to get indications such as: description of activities, type of activity sequencing (part of a routine, planned or improvised), travelling parties, etc. In addition, problems encountered while travelling (congestion, late arrivals, etc.) as well as learning experiences are discussed. Automatically collected data is used as an input for the interview, after a pre-analysis by the interviewer using a specifically designed software (presented later on).

3) Final assessment: At the end of the observation period, a final assessment interview allows to get the respondent's evaluation of the life course transition, of the degree of consolidation of new behavioural routines and of possible changes in attitudes towards travel modes, in the personal set of mobility tools as well as in their social networks. Moreover, we will ask the respondent to assess the survey design and instrumentation.

Originally, two GPS observation periods of 4-6 weeks (one before and one after the life course transition) had been envisaged. However, project funding and planning limitations have obliged us to reduce the GPS reporting period to 6 weeks. Given this restriction, only the period shortly after the life course transition is studied on basis of GPS tracking data (it is obviously the most interesting period for investigating the formation of new travel habits).

Survey participants are gained through various means (snowball-search in personal social networks, contacts with employers or associations, etc.). For participant motivation, a small reward has been advertised (100 Swiss francs). Individual surveys will be spread out over 2007.

4. The choice of a suitable tracking device

An initial task of our research has been to identify commercially available solutions which best fulfil the needs of our survey. The characteristics that we were looking for were:

- The technological survey system should allow to reconstruct automatically the space-time path of one person, through identification of activity locations and routes. An automatic recognition of travel modes would be a bonus.
- The wearable survey device must be small and light-weight (about the size and the weight of a cellular phone). It should be functional in various configurations of wear, appropriate for both men's and women's clothing.
- The wearable survey device must be able to function autonomously for at least a day and battery recharging must be user-friendly.
- Ideally, collected data should automatically be transferred to a central database, in order to allow parallel offline data analysis and prompted recall interviews with a short time lag.
- The effectiveness of automatic data processing (proper identification of activity locations and of the time spent at each one) must be good enough that verifications are only needed rarely during prompted recall interviews.

After having checked the development status of different positioning technologies (GPS devices, GSM monitoring services, devices combining GSM and GPS for tracking animal spatial behaviour, dead reckoning devices), we came to the conclusion that the GPS technology currently is the most appropriate solution for our research plan. New, highly sensitive GPS receivers are available since November 2005 and allow for weak signal tracking, providing uninterrupted operation in locations with obstructed views to the sky. Also, very fast start-up times ensure that almost every trip is recorded.

We have tested two products making use of this new technology: the MobilityMeter, produced by GeoSat in Switzerland, and the StepLogger, produced by NEVE in Australia (see pictures in Figure 1). The MobilityMeter has originally been developed for purposes of billboard audience measurements, building on large scale surveys of one-week individual tracks (Swiss Poster Research Plus). The StepLogger has more specifically been developed for travel behaviour research (Stopher et al., 2005a). Both devices produced very promising results with regard to their tracking capability. However, during the tests in January 2006, the battery autonomy of the StepLogger was insufficient with a maximum of 8-9 hours of continuous operation (which implies recharging during the day). In comparison, the MobilityMeter provides about 20-22 hours of effective continuous operation (one second sampling rate, no sleep mode).

Figure 1 Pictures of the MobilityMeter (above) and the StepLogger (below), besides a standard mobile phone

Source: own pictures

In early 2006, there was no economically practicable commercial solution for an automatic telecommunication of the tracking data and the development of this functionality for the StepLogger was not yet finalized. As our research plan did not allow to wait any longer, we decided to use MobilityMeters. For collecting the tracking data, we can work either by way of postal exchanges of the tracking devices (with the disadvantage of extending the time lag between data recording and the prompted recall interviews), or by asking survey participants to download the tracking data on a computer of their own and to email us the data files (which increases the respondent burden). Pre-tests have shown that both ways of doing are practicable.

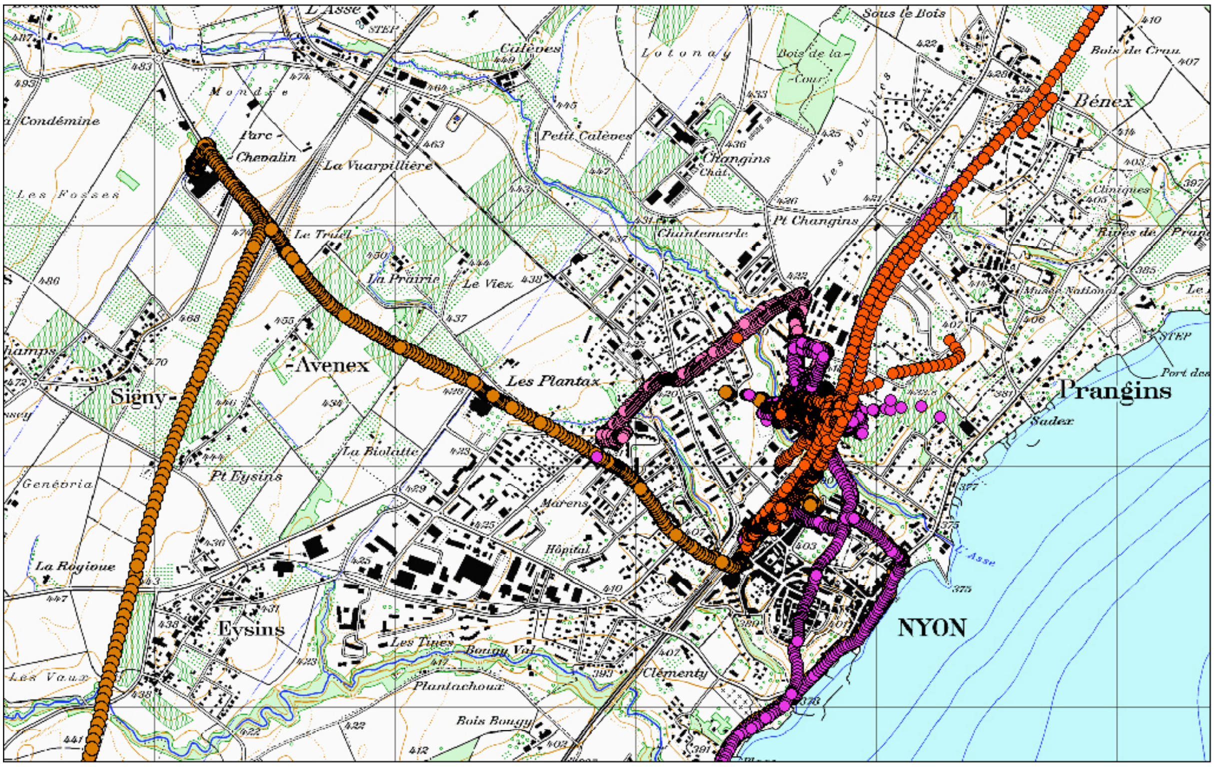
The MobilityMeter's memory is able to record about 450 000 data points. In the current version of the firmware, data that is recorded includes only the most important parameters, that is: latitude, longitude, altitude, date and time. Data is stored with a one second sampling rate, as long as the GPS module is able to calculate a position on basis of 4 satellite signals.

Tests conducted so far show that the tracking capability of the MobilityMeter is quite effective, especially when considering that we had advised test respondents to carry the device in a practical way for them (that is: in a coat's pocket, in a backpack or a handbag) and without giving specific attention to its functioning. Indeed, in past GPS based surveys, respondents often have been asked to wear the device in a way that the GPS antenna would have a direct view to the sky, resulting in somewhat artificial conditions of wear, and sometimes they have been asked to wait the device to perform a warm start when leaving a building. For our own survey, this kind of instructions has been considered unrealistic, given the duration of the observation period.

Generally speaking, the MobilityMeter has proved to perform warm starts in rather difficult conditions like travelling in a car or riding a bus (with tracking data missing for not more than 2-3 minutes). However, the warm start issue still is problematic when trips begin in dense urban environments and when they are of short distance (for example, when the respondent is shopping in the central business district and stays most of the time inside buildings). Under those circumstances, cases where data is missing for several consecutive trips have been observed. With regard to this problem, a very positive point is that the MobilityMeter sometimes is able to keep receiving satellite signals inside buildings, especially when being placed near windows. We thus have instructed test persons to keep the device always on and to look in their homes for a place where the MobilityMeter continues to calculate positions while recharging its battery. When this was the case, tracking usually started only few seconds after they left home, as the GPS module only performed a hot start.

A negative side effect of the weak signal detection capability is that the MobilityMeter calculates quite imprecise positions when there is no direct view to at least 4 GPS satellites. In fact, in this case, the device uses signals that have been reflected against buildings and these signals generate positioning errors of about 50–250 meters (multipath errors). Moreover, when the MobilityMeter keeps receiving signals within a building, it generates "virtual space-time paths" which more or less correspond to walking strolls around a given place, whereas the device is in fact staying still on a desk, for example. This error generation sets very high demands with regard to the data analysis, when it comes to breaking down the tracking (dot) data into trip segments and into stays at activity places. Figure 2 shows an example of raw data generated by a personal GPS tracking unit.

Figure 2 Screen shot of raw tracking data



Tracking data includes trips by car (brown and cyan), by train (red) and by bicycle (pink). The large bulk of points in the centre-right results from positioning errors generated while the device was inside my home; a few “one way trips” going out of that bulk are in fact additional measurement errors.

5. GPS tracking data processing issues

Tracking individuals with a one second sampling rate produces a very large amount of data, in the order of magnitude of about 10 000 to 30 000 data points per day. In this context, data reduction algorithms are essential in order to make the tracking data usable as an input for prompted recall interviews. For this purpose, the essential task is to automatically identify activity places and trip segments (i.e. trip parts made with a specific travel mode), with a high probability of effective occurrence.

The issues related to processing GPS data from travel surveys have already been tackled in several publications (Chung et al., 2005; Legendre et al., 2005; Stopher et al., 2005b; Tsui et al., 2006):

1) Data Filtering: In a first step, it is wise to eliminate redundant and poor quality data points, in order to minimize further data processing time. Obviously, data filters must be matched with the characteristics of the GPS tracking units, depending on data recording settings (min. number of satellites, amount of parameters stored in memory, etc.). Given that the MobilityMeter is configured to record only positions calculated with at least 4 satellites, the number of poor quality data points is in our case rather limited. Our own experience shows that a simple spatial filtering (i.e. eliminating all points which are not at least 5 meters away of the preceding valid position) is very effective, reducing data quantity by half or more.

2) Activity / Trip Identification: Identifying activity locations can be based either on speed or spatial density analysis algorithms. In both cases, a minimum dwell time defines if a portion of the data stream is to be considered as an activity (no movement for a given time). Trips are consequently defined as data stream portions which connect two activities. Cases where the tracking data displays a GPS signal loss need a special treatment, as the signal loss can be induced either by an indoor activity or by underground travelling. Tsui et al. (2006) have outlined a set of rules to handle such cases, with imputations depending on the duration of signal loss and the (Euclidian) distance travelled during this period of time. For our own research, we have implemented a spatial density algorithm with a dwell time of 90 seconds and a maximum spatial divergence of 40 meters, completed by a set of rules similar to Tsui et al. (2006) for dealing with signal losses. This algorithm often generates excess activity locations, for example when an outdoor activity is performed with some movement or even more when the GPS unit is still "tracking" when inside a building (with this regard, the multipath error induced recordings mentioned above have proven to be quite tricky to deal with). In a second step, an activity merging algorithm reduces the number of detected activity stops. With this combination of algorithms, experience has shown that only very few

effective activities are missed, while the number of “redundant activity stops” is still manageable.

3) Mode Transfer Point Identification: When GPS tracking data is to be used for reconstructing individual travel diaries, it is crucial to differentiate trip segments travelled with separate travel modes and to identify the places where transfers occur (mode transfer points). This is done by way of a speed variation analysis. Our own algorithm compares mean speeds in three time windows (at time t, about 15 seconds earlier and 15 seconds later) and marks data points which display a significant speed variation. In fact, this analysis detects all pauses within trips travelled otherwise than by walking (stops at red lights, bus stops, pick up or drop off of passengers, etc.), thus signalising a potential mode transfer point. These trip pauses are used to further break down trip data into trip segments.

4) Mode Identification: The research teams cited above have developed a variety of algorithms to identify the most probable travel mode for a given trip segment, using speed and acceleration rule sets, fuzzy logic inference or applying link matching with transport network models. For our own research, we have not developed any automatic travel mode identification and rather rely on “manual” analysis by the interviewer, while preparing the prompted recall interview. Indeed, with the knowledge gained during the initial survey interview and with the help of a trip segment display against a map, the interviewer can fairly easily determine the most probable travel mode.

5) Treatment of Trip Segments without tracking data: Usually, trip data includes gaps due to temporary GPS signal absence (underground travel, poor satellite reception in vehicle) or due to warm / cold starting of the GPS module. These periods of missing data may last a few seconds up to several minutes, and the question arises on how to deal with these missing routes. Tsui et al. (2006) have presented an algorithm based on link matching. We have not yet developed any solution for this problem, but we are considering to include a manual editing function within the trip diary editor application that we have developed.

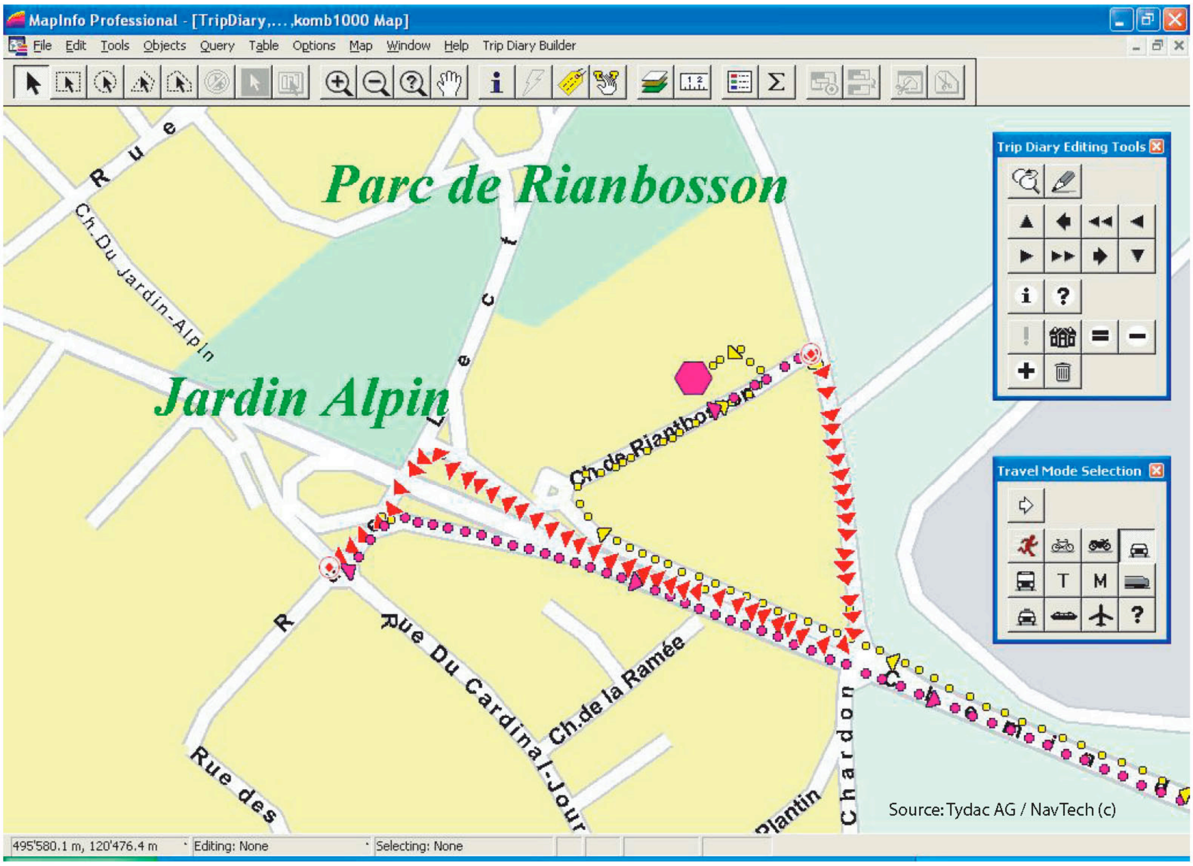
6. A Trip Diary Editor application for supporting prompted recall interviews

For our research project, we have developed a specific application within the MapInfo / MapBasic programming environment to support qualitative prompted recall interviewing. This Trip Diary Editor application is used by the interviewer to import raw tracking data and break it down into trip segments and place delimiters. Subsequently, the interviewer can interactively re-enact the trip segments that are displayed on maps of different scales, depending on zoom level. The application allows to navigate in the trip diary by moving back or forth segment by segment or to directly move to a trip start (when leaving an activity place), a tour start (when leaving home) or a day start (first trip of a survey day). Figure 3 shows a screen shot of the application user interface.

A first editing environment is used for preparing prompted recall interviews. In this phase, the interviewer by-hand eliminates obvious data artefacts (excess activity places or trip pauses, erroneous data points) and assigns the most probable travel mode for each trip segment. A second editing environment is used for additional corrections (correcting departure or arrival times, for activity places that have been imputed from GPS signal loss situations) and for completing the trip diary with trip attributes gathered during the prompted recall interview, as for example: identification of activity places and mode transfer points (place names), trip purpose (activity type), driver / passenger status, size of travelling party, type of activity sequencing (routine, planned, improvised), etc. A third editing environment is planned for activity space analysis, but not yet implemented.

This trip diary editing approach might seem somewhat burdening for the interviewer. Indeed, alternative approaches exist, like Doherty et al. (2006) have demonstrated it with the development of an internet-based automated prompted recall system. However, we believe that for our own research, no true alternative survey approach is realistic, given the long observation period and the need to minimize respondent burden as much as possible in order to find willing survey participants (especially for those people who are in the process of moving homes).

Figure 3 Screen shot of the MapInfo / MapBasic trip diary editing environment



The Trip Diary Editor breaks down raw tracking data into trip segments, delimited either by activity places (stays longer than 90 seconds) or by trip pauses (shorter stops, identified by way of speed variations). In editing mode, trip segments can be displayed one by one, allowing the interviewer to re-enact the respondent's travel diary for primary analysis (verifications, travel mode imputation) and as an input for prompted recall interviews.

7. Future perspectives

The first case studies realised so far have shown that, with the survey tools presented above, it is possible to thoroughly investigate travel behaviour and especially mobility “incidents” or “hesitations” (for example, when a driver is stuck in traffic, when a trip was unexpectedly interrupted or when the route travelled shows apparent detours). The detection of such ‘incidents’ or ‘hesitations’ provides indispensable elements for interviewing survey participants about their (small) learning experiences in everyday mobility. Indeed, with the help of the tracking data, respondents have been able to comprehensively comment those experiences, even several days after happening. This obviously is an essential advance in order to fulfil our research objectives of investigating the formation of travel habits.

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