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CHAPTER 3

FRAMEWORK FOR EMPIRICAL INVESTIGATION

3.1 Introductory note

This chapter is dedicated to formalizing the conceptual framework used for empirical investigations. After considering the methods most popular in the transportation sciences, Section 3.2 describes the “activity-based framework” in which most research has been carried out in the past. Section 3.3 is dedicated to explaining the main features of our three case studies, together with the main criteria used to operationalize the variables under investigation. A brief explanation of the main tools used for data collection is provided in Section 3.4.

3.2 Methodological framework: activity-based travel and time-use research

The field of travel behaviour encompasses different types of research, the most popular of which are (Buliung, 2005):

- travel forecasting models, based on discrete and discrete-continuous choice modelling;
- econometric travel process modelling;
- travel behaviour studies.

In the last ten years, the last of these has been rapidly expanding (Kwan et al., 2007), due to a growing awareness that predictive models need to be based on a deeper understanding of travel behaviour and ultimately on more reliable data. At the same time, a further understanding of trip chaining, activity sequencing and route choice is warranted (Levinson and Kamar, 1995; Vande Walle and Steenberghen, 2006).

Nowadays, most travel behaviour research is conducted within the activity-based framework. This is a new paradigmatic approach according to which the demand for travel
is inferred from the demand for activities: since individuals travel to become involved in activities, the demand for activities needs to be estimated in order to forecast the demand for travel (McNally, 2000).

Understanding patterns of participation in activities becomes pivotal, and these patterns result from complex individual decision-making processes (Clark and Doherty, 2009) as well as from individual motives and social constraints (Chapin, 1974, Stauffacher et al., 2005). Hagerstrand (1970) distinguished spatial from temporal constraints regarding participation in activities, and - based on empirical evidence - suggested that temporal constraints are more rigid than spatial ones, especially where work-related activities are concerned (Cullen and Phelps, 1975). Such findings have been revisited more recently in light of the advent of the Internet and mobile phones (Schwanen and Kwan, 2008).

The activity-based paradigm prompts the use of new research and data collection methods. Most importantly, time-use surveys are replacing traditional travel diaries (Axhausen et al., 2007): the latter are typically administered on a one-day level and solicit information on the origin and destination of each trip undertaken, as well as the time it took and the means of transport used. In time-use surveys, on the other hand, people report on their activities during the day, both at home and away from home; each discrete participation in an activity is defined as a separate “activity episode”, defined by the type of activity, its timing, duration and location in space (Axhausen, 2003). Time-use analysis aims to clarify how time is allotted to different activities, whereas “episode analysis” looks at the generation of activity episodes and their temporal, spatial and personal aspects, as well as their sequence and travel contexts (Bhat and Misra, 1999). Unlike time management (a managerial method finalized to increasing the efficiency or effectiveness of economic processes), the main goal of time-use research is to understand human time allocation behaviour (Bhat and Koppelman, 1999).

Questions relating to time-use research arise in several professional and academic domains, e.g.:

- town planning and urban design (how do they affect how people spend their time?);
- transportation planning (which groups use public transport?);
- sociology (how do people maintain social relationships and who is more likely to spend time alone?);
- recreation and active living (which groups are more physically active?);
• information technology (what part does IT play in peoples’ daily lives? This is the subject of our investigation);
• feminist economics (how does non-market work affect gender inequality and economic well-being in society?).

In the transportation sciences, the results of time-use surveys are often used to devise and calibrate travel forecasting models, but in the present study they will be used solely to explore the impact of mobile information technology on the activity patterns of individuals and their travel behaviour. Here, interpersonal and intrapersonal variations in travel behaviour will be explained in terms of the individuals’ characteristics, their agendas and their environment (Pas and Koppelman, 1987; Buliung, 2005). We shall strive to identify the basic forces that prompt travel, by surveying how people allocate their time to different activities (Burnett and Thrift, 1979). At the heart of our research lies the time budgeting method defined by Anderson (1971) as “a systematic record of a person’s use of time over a given period. It describes the sequence, timing and duration of a person’s activities, typically for a short period ranging from a single day to a week”. Time budgets trace what Kutter (1973) defined as individual activity patterns, i.e. the sum of all activities undertaken by a given person in the course of a given period, plus the trips required to do so (Fox, 1995). This approach is also called situational, since it strongly emphasises the role of environmental constraints on travel: the simplistic assumption that people always make rational choices to maximize their time is replaced by the acknowledgement of the many factors influencing travel decision making, which also include routine and habits (Garling and Axhausen, 2003; Verplanken et al., 2008).

The ultimate aim of our study is to understand whether and how an environmental modifier (i.e. the availability of mobile technologies) restricts or expands the range of choices available when people decide what to do and where to go. For this purpose, a definition of “trip” has to be derived from a definition of “activity”. The one that we considered most appropriate is as follows (Axhausen, 2003): “an activity is a continuous interaction with the physical environment (or a service/person within the same socio-spatial environment), which is relevant to the sample/observation unit. It includes any pure waiting (idle) times before or during the activity”. As a consequence, a “trip” can be defined as any transfer between two activities.

All the above-described methodological constructs related to the activity-based travel and time use frameworks applied to the individualised analysis of travel behaviour,
so they were not used to analyze the collective spatial and travel behaviour dynamics considered in our third case study, based on the aggregate analysis of mobile phone data (see Chapter 6). The next section gives a brief description of the research tools used to collect empirical data on mobility and emphasises how the research was operationalized differently in the third case study.

### 3.3 Selection of case studies and operationalization of research

Having defined the overall methodological framework within which to conduct our research, we needed to select case studies from which to obtain empirical data for our analysis. If the studies were to be based on primary data, they needed to comply with a few preliminary requirements in order to be more readily manageable and observable using a scientific method. In particular, they had to:

- be homogeneous, in terms of the work activities of the population investigated;
- involve forms of travel behaviour implemented within a bounded space and comparable within the population considered;
- have clearly defined forms of ubiquitous connectivity, enabled by new mobile technologies.

The two case studies from which primary data were generated (discussed in Chapters 4 and 5) had favourable features on these dimensions. Indeed, the Groningen police officers’ PDA use and travel behaviour met all three requirements, in that:

- the population under investigation was homogeneous;
- activities were spatially bounded, since most officers travelled exclusively within the perimeter of the Groningen North police district;
- ubiquitous connectivity was clearly defined, given the constant accessibility of the new PDA applications, whose impacts we aimed to explore.

Our observation of the travel behaviour of MIT students likewise complied with all three requirements, since:
• the population under investigation was homogeneous;
• activities were spatially bounded, since almost half of the MIT students live in dormitories on campus and rarely travel beyond its boundaries during the working week;
• ubiquitous connectivity was clearly defined, the Internet being accessible via a laptop everywhere on campus, indoors and out.

Unlike the previous two, our third case study (presented in Chapter 6) concerned a large secondary dataset containing records of all the cell phone traffic in the Amsterdam Metropolitan Region over the “KPN Mobile” GSM network. This case study did not meet the above three requirements because, although it was used to monitor human travel behaviour within a spatially-bounded area where connectivity (i.e. network reception) was ubiquitous, it concerned a heterogeneous population of network subscribers and roamers of all ages, social classes and occupations.

Another aspect to consider when assessing the suitability of case studies regarded the operationalization of the variables involved. Since we aimed to investigate a possible causal relationship between an independent variable and a dependent variable \( [(\text{mobile technologies}) \rightarrow (\text{travel behaviour})] \), we had to find a suitable way to measure these two variables, as well as other independent variables which had to be controlled. In our first and second case studies (presented in chapters 4 and 5), we measured:

a) the number and types of activities carried out;
b) the number of trips between activities;
c) the availability of mobile technologies.

The two very different research settings posed different challenges when it came to choosing operational definitions. First of all, we had to decide what to consider as activities, exactly how to define an activity. Different tasks completed in the same place (i.e. using a computer and reading a document) are two different activities, but since we wished to research travel behaviour, we needed to treat them as only one (i.e. working in the office). Using Auxhausen’s definition (2003, “activities as continuous interaction with the physical environment”), activities would coincide with the workspaces used for them, so the MIT students were given a list of 10 classes of workspace, from offices to libraries, whereas the Groningen police officers were given a list of the 12 most typical physically
contiguous tasks carried out in the field (e.g. attending to traffic accidents or dealing with cases of annoyance/abuse). In both cases, a trip would be counted as any movement from one workspace (or task-space) to the next.

Operationalizing the main independent variable (i.e. the availability of mobile technologies) proved more straightforward. In fact, we did not need to record every interaction with the technologies, but only their availability, i.e. the fact that people carried the device on a daily basis (in the case of MIT students) or during shifts (in the case of the Groningen police force). We originally intended to assess the causal relationship between “ubiquitous connectivity” and travel behaviour. Rather than monitoring a generic availability of portable devices, we aimed at understanding the role of ubiquitous access to information, assuming that it would be the information, rather than the technology per se, that might lead to behavioural changes. But how could we operationalize ubiquitous connectivity in the cases of the Groningen police and the MIT students? The simple fact that connectivity was available does not necessarily mean that it was used, since the mobile devices might be used only for applications running locally (e.g. Microsoft Office applications)\(^1\).

Although MIT students were asked when and where they used web applications via Wi-Fi, in the first two case studies we preferred to observe the generic availability of the technology. In operational terms, the original research question on behaviour change (see Section 1.2) was posed as follows:

1. All other things being equal, do people who carry mobile devices get involved in a different number of spatially diversified activities by comparison with people who do not?
2. All other things being equal, do people who carry mobile devices take a different number of trips a day by comparison with those who do not?

Such questions could then be rephrased in terms of causality:

1. All other things being equal, do mobile technologies lead to a reorganization of spatial activities?

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\(^1\) In our third case study, on the other hand, ubiquitous connectivity to the GSM network was a prerequisite for the mobile phone to be of any use.
2. All other things being equal, do mobile technologies lead to a different travel behaviour?

Our third case study offered a more unequivocal way to operationalize mobile communication and travel behaviour, since we could count on direct measurements of the number of calls initiated and received, the number of SMS sent and received, the overall bandwidth consumption for cell phone activities (i.e. “Erlang”) and the number of calls “handed-over” within the network (i.e. calls made while on the move - this was used as a proxy for travel behaviour). In this case, the original research questions on behavioural change and new observational capabilities (see Section 1.2) could be stated as follows:

1. What is the correlation over time between the number of SMS sent over the network (as a proxy for mobile communication) and the number of calls handed-over (as a proxy for travel behaviour)?
2. What information can we extrapolate from the variance over time in the number of calls initiated, to describe people’s presence and travel behaviour in different areas of Amsterdam?
3. What is the relationship between mobile phone activities and land use in the location from where they originate?

3.4 Data collection methods and tools

After selecting which case studies to consider and how to analyse them, in order to obtain suitable sample and control groups, we had to decide how to select our sample of subjects, how many subjects to sample, and how to manage the data they provided. In our first case study, the whole population of 30 police officers - who had volunteered to test the new PDA applications under investigation - was approached. As a control group, we considered the data they provided before and after the technology had been introduced, so the sample was surveyed in early March 2007 (before the adoption of the PDAs) and in late January 2008 (after the adoption).

In our second case study, on the other hand, our sample was drawn from a population of approximately 10,000 students: 50 students were selected from the
population in the academic year 2005-2006 and interviewed in the first week of May 2006. Another 50 students were selected in the academic year 2006-2007 and surveyed during the first week of May 2007. Since Wi-Fi had been introduced before 2006, a longitudinal study (before/after adoption) could not be adopted as a control, so we used data provided by individuals who reported using a laptop only occasionally or not at all for control purposes.

In our third case study, there was no question of sampling, since the secondary data that we considered concerned all KPN Mobile subscribers and roamers using their cell phones in the Amsterdam Metropolitan Region. Several methods were used to generate primary data. For our first case study, these were:

Table 3.1: Methods used to generate primary data in Groningen

| • closed-item questionnaires; |
| • mobility & activity diaries; |
| • GPS tracking applications; |
| • face-to-face interviews; |
| • participant observations (non-systematic). |

For our second case study, they were:

Table 3.2: Methods used to generate primary data at the MIT

| • closed-item questionnaires; |
| • time-budget & activity diaries; |
| • online tracking applications; |
| • on-site observations (non-systematic). |

In both cases, the purpose of the closed-item questionnaires was two-fold, i.e. to collect the subjects’ socio-demographic details, and to check for competing variables at the time of assessing the impact of mobile technologies on these individuals’ travel behaviour. Diaries and tracking technologies were used to collect spatial data. Considering the activity-travel framework chosen for the investigation, spatial data had to be supplemented with data on the respondents’ daily activities.

At the MIT, we faced the question of how to administer time-budget/activity diaries, i.e. whether our subjects had to fill them in on paper or using online forms. The
former option was preferred because it afforded greater design flexibility, although the subsequent data entry would be more time-consuming. Two assistants (i.e. one Master student and one undergraduate student) were recruited for the first round of data collection at the MIT, and two undergraduate students in the following year. These students were involved in the sampling process, in recruiting subjects and holding explanatory sessions, and in entering data and performing descriptive statistics. In Groningen we had no assistants, but we did have the full support of the head of innovation at the local police department, and of the chief police officer for the Groningen North district.

Qualitative observations were carried out both in Groningen and at the MIT, but not systematically. At the MIT, a list of functional locations to observe was compiled (i.e. libraries, cafes, student centres, and corridors) and these sites were visited during a 1-hour round of on-site observations. Equipped with cameras and exercise books, we took photos of people using their laptops individually or in small workgroups. We also approached a few of them and asked why they had chosen that particular place to use their laptops. In Groningen, observations were participative (i.e. the researcher was involved in the situation under observation): before the new technology was introduced, we joined two field officers on one of their evening rounds in their patrol car; then, after the new PDA services had been introduced, we joined a neighbourhood officer on his street-patrolling of a small section of the Groningen North district.

Face-to-face interviews were conducted in Groningen to get a better understanding of individuals’ reasons for accepting (or rejecting) the new technology. The interviews provided insight at exploratory level, helping to clarify the quantitative findings emerging from the questionnaires. While the questionnaires were designed to measure to what degree the new technology had been adopted and according to which general principles, the interviews were useful for recognising all the variables behind the acceptance or rejection of the PDAs. Indeed, in Groningen we needed to deal with unknown work practices as well as with a technology that was still in its experimental phase, whereas the academic environment of the MIT was a familiar one, as was its highly institutionalised wireless technology (as further described in the next section).

Generating all the primary data demanded a great deal of effort. The only secondary data accessed at MIT were provided by the MIT Office of the Provost and the MIT Property Office (see Chapter 5): from the former we obtained the results of the 2002 and 2004 transportation surveys on the commuting habits of MIT students; from the latter, we obtained statistics on the use of fixed computer equipment on campus from 1996
through 2006. Such secondary data were helpful for placing the primary data in a broader context and providing a more comprehensive explanation of their results.

Finally, the following analyses were performed on the secondary data received from the KPN Mobile network, for our third case study (presented in Chapter 6):

- an index of correlation was calculated for two indicators (i.e. number of SMS and number of calls performed on the move);
- several “spatio-temporal network signatures” were derived, presenting the variance in cell phone activities over time for a few selected areas of Amsterdam;
- a regression analysis was performed to quantify the relationship between mobile phone activities and land use typologies at the locations from where the activities originated.

Following each of these 3 analyses, an interpretation has been provided with a view to trying to disambiguate the findings and pave the way to future research on the topic

### 3.5 How the three case studies complement each other

Using three case studies for the collection and analysis of empirical data was considered necessary to expand the scientific relevance of the overall research. Being aware of the novelty of the technologies under investigation and of the possible limitations at the time of generating the data needed, we designed a research strategy in which each subsequent case study would compensate for the limits of the previous one.

The first case study (presented in Chapter 4) was meant as a test ground for our first two research questions (see Section 1.2) on (1) the drivers of ICT adoption and (2) the travel behavioral changes induced by mobile ICTs. By accessing a relatively small group of users operating in a geographically confined environment (i.e. police officers in Groningen North), we aimed at identifying which independent variables would play a prominent role for mobile ICT adoption and could be further operationalized and investigated in the subsequent case studies. Such exploratory work would be facilitated by the fact that we would assess a very specific set of mobile ICT applications, to be used within a professional community driven by clear performance goals: this narrow range of
potential usage patterns would presumably lead to a more clearly definable set of adoption practices and behavioral impacts.

Going on to the second case study (presented in Chapter 5) would mean, on one hand, broadening our focus from a specific set of mobile ICT applications to a more transversal one (i.e. all work-related computer applications used by students) and, on the other, moving to a more familiar research environment over which we could have more control. While in Groningen our subjects were involved in a relatively fluid spatial behaviour that was more difficult to keep track of (i.e. patrolling the streets while stopping for activities from time to time), at MIT we would have the opportunity to observe more clearly definable travel patterns, coinciding with the utilization of different campus spaces by students. Leveraging on our research affiliation with MIT, we would face smaller constraints at the time of obtaining the necessary authorization to track their spatial behaviour and technology usage patterns.

With two case studies focusing on relatively small and deeply characterized samples of subjects, our third case study (presented in chapter 6) was seen as a unique opportunity to analyze a truly quantitative data sample to reveal the spatial behaviour of an entire urban population, as socio-demographically and professionally diverse as possible. This dataset would offer us the opportunity to reconsider the issues under investigation from an urban perspective: this time, in order to understand travel behavioural change, we would not start from the behaviour of individuals, but from the behaviour of masses of individuals populating different urban spaces and areas of land at different times. We would step from a micro to a macro-view of mobility and technology usage.

A final complementary element shared by the 3 case studies has to do with the type of technology under investigation: moving from Groningen North, to the MIT Campus and from there to the Amsterdam metropolitan area, our research focus was shifted from a highly technical and professional device (i.e. the PDA used by police officers), to a mainstream one but still professional one (i.e. the laptop used by MIT students), to the most ubiquitously diffuse one (i.e. mobile phones used by Amsterdam residents and visitors). By considering different mobile devices, our research might detect possible common denominators of behavioural change. In this respect, the explanatory model presented in section 7.3 is a first attempt to build a common theoretical framework which can encompass the behavioural impacts of all kinds of mobile technologies.