Activity-based modelling: Research directions and possibilities


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ABSTRACT

This note discusses the expected contributions of the activity-based research approach to the general development of transport planning. Against a brief review of the development of the approach and its central tenets it discusses four areas in turn: data collection, models of household interactions, choice models incorporating the whole daily activity chain and finally explicit micro-simulation models of activity scheduling. The final section highlights the expected contributions and the possible difficulties of their acceptance into the planning process.

KEYWORDS

Activity-based modelling – Expected contributions - Research directions - Planning practise

Figure on title page:

Share of working day activities for each respondents during six week reporting period of the Mobi drive survey (excluding immobile days and days outside the study area). Compulsory: work, school, work related; Household related: shopping, personal business, service trips, pick up and drop off; Leisure: all other (See König, Schlich and Axhausen, 2000).
1 STARTING POINT

Activity-based analysis of travel and activity participation is the attempt to address the complexity of the travellers’ daily and long-term scheduling of their activity demands. It sees travel not only as a demand - mostly – derived from the need to change location between two successive activities, but increasingly and more importantly as part of longer term and larger on-going personal projects and socially negotiated and enforced commitments (see below).

The activity-based approach as a research practise and as a network of researchers developed in the late 1970’s and early 1980’s as a response to the obvious behavioural short-comings of the four-stage approaches, as then implemented (see for example Hutchinson, 1974 for a contemporary textbook). Work in Germany (for a review see Axhausen and Herz, 1989), but in particular the UK (Jones, Dix, Clarke and Heggie, 1983) highlighted the need to understand travel as part of the more complex pattern of activity performance. It responded to the challenges and insights of Chapin’s (1974, 1978) and Hägerstrand’s (1970) work on activity participation as driven by choices and constraints.

While definitions differ between different writers, the following elements can be considered as the core of the approach:

- Travel is derived from the need to change locations between two successive activities. It is a means not an end.
- Movements undertaken for their own sake are an exception. These will be considered as activities, not as travel, for example: walking the dog, strolling through the park, cycling through the countryside.
- An activity is a continuous interaction with the physical environment, a service or person, within the same socio-spatial environment, which is of importance to the person.
- Individual activities contribute to larger personal projects, such as e.g. shopping for plants contributes to the remodelling of the garden, reflect longer-term commitments, such as work, or satisfy basic physiological or emotional demands, such as eating or sleeping.
- Individuals operate within their budgets of time, resources (in particular money) and of social capital.
- Individuals will schedule their activities in co-ordination with the members of their household or of their social network, so as to optimise their satisfaction balancing short- and long-term considerations.
- Scheduling encompasses the choice of time, duration, location and access mode for the activities selected.
- Individuals are constraint in their scheduling because of the resources available to them, in particular vehicles.
- Individuals are constraint in their scheduling due to the need to be available to others at particular times or locations, either in person or at a distance (phone, chat room or email).
Individuals are constraint because of their longer-term commitments to their household members, to their residential location(s) and to their work place(s).

These elements translate into a research programme and modelling framework, which even today cannot be realised in its totality. The number of endogenous variables, the long timeframes of analysis and the social context are just too complex for today’s analytic modelling tools; even the descriptive work does not fully live up to the demands, but for a large part because of the lack of suitable data sets.

The work influenced by the activity-based approach has been reviewed repeatedly during the last twenty years (e.g. Damm, 1983; Kitamura, 1988; Jones, Koppelman and Orfeuil, 1990; Pas, 1990; Bhat and Koppelman, 1999 or Timmermans, 2000). The conferences of the International Association of Travel Behaviour Research (IATBR) have provided a forum for many of the researchers influenced by the approach (see TRB, 1974; Stopher and Meyburg, 1976; Hensher and Stopher, 1979; Stopher, Meyburg and Brög, 1981; TRB, 1983; Rijkswaterstaat, 1986; IATB, 1989; Stopher and Lee-Gosselin, 1997; Ortuzar, Hensher and Jara-Diaz, 1998 for their proceedings; for the two most recent conferences at Austin, 1997 and Golderast, 2000 see the relevant web sites at www.ce.utexas.edu/org/iatbr97 and www.its.usyd.edu.au (Conferences); see also Carpenter and Jones, 1983 and Jones, 1990 for related conferences).

It is noticeable that the research so far, has not been able to address the research programme fully. The work reported is more open to qualitative and social science research approaches, but it generally still belongs into the mainstream of the development and application of choice modelling, which has dominated transport planning since the 1970’s. This is not surprising given the personal overlaps between these research communities. It is the recent progress in choice modelling (see for example Bhat, 1997), in the modelling of systems of simultaneous equations (e.g. SEM) and in gaming- and computer-based surveys, which is slowly allowing the activity-based researchers to address their original research programme head on.

At the same time, transport policy has at least partially shifted from an exclusive reliance on capacity expansion to a mixtures of policies, including demand management through pricing and information. These policies clearly require a better understanding of travel in its activity context for a proper evaluation and for the forecasting of their effects. ISTEA in the USA or the multi-modal modelling initiatives in the UK are therefore providing the backdrop for the current work in the activity-based mold.
Four areas will be the focus of this work: data collection, models of household interactions, choice models incorporating the whole daily activity chain and finally explicit micro-simulation models of activity scheduling. The next sections will discuss these areas in turn, while the final section will assess the possible contribution of this research to general practice and the hurdles it has to overcome before having an impact.

2 DATA COLLECTION

The description and modelling of travel behaviour relies traditionally on travel diary surveys (see for example Richardson, Ampt and Meyburg, 1995 or Axhausen, 1995a), which focus on the movements of respondents. Travel diaries have always had an interest in episodes, i.e. clearly delineated blocks of time: the movement and less so the associated “activity” following it. The parallel tradition of time use research (Szalai, 1972; Ås, 1978 or Pas and Harvey, 1997) has put its emphasis on the stream of activities and the total amount of time spent on each activity type. Here, the number of episodes was traditionally secondary.

Recently both groups have tried to integrate these experiences: travel-behaviour researchers by using activity-based diaries, in which travel is secondarily established in association with an activity and time-use researchers by using activity episode-based survey formats. The motivation of the shift to activity-based surveys by travel behaviour researchers is a) the wish to understand the in-home and out-of-activity trade-off better and b) the suggestion, that respondents find this format easier to answer and will therefore answer it more willingly and more completely. Recent examples are the 1994 Portland, Oregon survey and similar exercises in Dallas-Fort Worth, Texas and the Research Triangle, North Carolina.

This research has highlighted the need for common and consistent definitions of activity and trip, which in the past were not fully spelled out. Professional practice substituted for it. While recent attempts such as Axhausen (Forthcoming) are helpful in understanding the issues, they will not be professionally accepted any time soon:

“A stage is a movement with one vehicle (as driver/rider or passenger), respectively on foot\(^1\). It includes any pure waiting (idle) times immediately before or during that movement.

A trip is a continuous sequence of stages between two activities.

A tour is a sequence of trips starting and ending at the same location.

\(^1\) Ignoring animal carriage, such as horse riding for the moment.
A *journey* is a tour starting and ending at the relevant base location of the person.

An *activity* is a continuous interaction with the physical environment, a service or person, within the same socio-spatial environment, which is important to the respondent. It includes any pure waiting (idle) times before or during the activity.” (adapted from Axhausen, Forthcoming)

Still, they highlight the need to come to an agreement to allow more standardisation of data collection with the attendant gains in efficiency and data exchange. Activity based researchers will for obvious reasons make a substantial contribution to this work, as they have to be able to observe and describe their research object clearly.

Related to the effort of standardising the definitions of travels and activity is the need to characterise the activities in more detail. Axhausen (Forthcoming) suggests, for example, the following partial list:

- **“Kind of activity**: what the person is doing: gardening, talking with someone, operating a machine, walking through a park
- **Purpose**: what the person hopes to achieve in an instrumental sense: earning money, relaxing, getting fit, growing food, satisfying the demand for sleep etc.
- **Meaning**: what the person hopes to achieve in a moral sense or say about himself/herself: helping someone, fulfilling a promise, taking care of himself/herself etc.
- **Project**: the greater context of the activity, the framework under which it is undertaken, e.g. preparing dinner, obtaining a degree, working towards promotion, building a house etc.
- **Duration**
- **Effort** accepted to be able to undertake the activity, in particular the detour required to get to the activity location
- **Expenditure for/income from** the activity participation and the associated additional travel
- **Urgency** of the activity in terms of the possibility of (further) delay.” (Axhausen, Forthcoming)

The progress made in capturing these items will be felt indirectly through development of scheduling models (See below). Activity-based research will also have to develop models, which allow to describe the distributions of the attribute values of these items in the population.

These specific contributions will obviously be part of the more general work directed at improving the quality of behavioural data with respect to response rates, weighting and imputation, completeness and enrichment from external sources (see for example TEST Consortium, 1999 or the current UK NTS review).
3 MODELS OF HOUSEHOLD INTERACTIONS

The activity-based approach has always highlighted the interactions between the members of a household and the impact of this household co-ordination on travel behaviour. This insight was in the past rarely backed up by empirical data. For example, the number of joint household activities or trips are normally not given in description of household behaviour. One finds only statistics on the person trips. Car occupancy statistics are not the same thing, as they are limited to car movements and as they include non-household members. Even the recent work by Golob and his collaborators does not distinguish between individual and joint activities (e.g. Golob, 1998, 1999; Golob and McNally, 1997 or Golob and van Wissen, 1989 or similarly Simma and Axhausen, 2000). Exceptions are Wen and Koppelman, 1999 or Gliebe and Koppelman, 2000 using choice-based approaches and Goulias, 2000 using a multi-level modelling framework.

The paper by Goulias (2000) shows that proper accounting for the interaction between the household members, but also of within-person correlations over time is necessary to obtain more consistent estimates of trip generation and of activity participation (see also Scott, 2000).

The greater availability of multi-day household surveys will enable researchers to address these issues in more depth in the future. The UK National Travel Survey is an obvious candidate for such work with its weekly diary, in particular as the modelling tools can also account for between-location and between-year co-variances. This research will not only improve our estimates of trip generation, but will also guide the research into activity scheduling by identifying the patterns of within-household and between-day interactions.

4 MODELS OF ACTIVITY CHAINS

The development paths of choice modelling and of the activity-based approach overlap in their interest in modelling whole daily activity chains. The resulting nested-logit structures incorporate activity-generation, destination and mode choice in combination with other elements, either lower level decisions, such as parking choices or higher level decisions, such as residential location or car ownership. Examples are Bates, Skinner, Scholefield and Bradley, 1997; Ben-Akiva and Bowman, 1998; Ben-Akiva, Bowman and Gopinath, 1996; Kitamura, Chen and Pendyala, 1997). Alternatively, the model structures include rule-based elements such as those approaches described in Spear, 1996 or
the AMOS system implemented by Kitamura and collaborators (see for example Pendyala, Kitamura and Prasuna, 1995).

The recent work in Portland, Oregon (Bowman, Bradley, Shiftan, Lawton and Ben-Akiva, 1998; Shiftan, 1999) as well as the work in the UK by Bates, Skinner, Scholefield and Bradley, 1997 has shown that these approaches can be implemented for practical policy analysis. They will merge with approaches such as the VISEM model (Fellendorf, Haupt, Heidl and Scherr, 1997) or TRANSFER (Ruppert, 1998), which derive directly from the early German work on activity-chain based simulation mentioned above.

The fruitful interaction between choice-modelling and the activity-based approach will continue in development of these models, with activity-based research continuing to highlight behavioural omissions in the choice-models. One important direction will be the incorporation of household interactions, already mentioned above.

5 ACTIVITY SCHEDULING

At the core of the activity-based approach is the idea of persons actively scheduling their time, their day or week. Since the early work by McNally on STARCHILD (see Recker, McNally and Root, 1986) and by Clarke on CARLA (see Jones, Dix, Clarke and Heggie, 1983) very little has been achieved, as the true complexity of the issues became clear and as it became clear, that choice-based approaches might be inappropriate for the task. The now-available modelling and computing possibilities have revived the interest (see for example Ettema and Timmermans, 1997 for a recent conference)

Gärling has proposed conceptual structures for the problem and matching simulation models (for his latest thinking see Gärling, Kalen, Romanus and Selart, 1998; earlier work is reviewed in Axhausen and Gärling, 1992). The current thinking (see also Axhausen, 1995b) considers the following elements:

- **Long-term commitments** of the household and its members to their life-style and to each other, including amount and location of work, residential location relative to work and relatives and friends, car ownership and season ticket ownership, preferred types and locations of shopping and leisure
- **Medium-term calendar** of each person, which reflects the household tasks allocated to them, their projects and their specific activity demands.
Daily calendar, which includes the activities which the person has formulated as discrete scheduled events, although the level of detail of the schedule might vary for different activities at the start of the day.

The scheduling process works on the daily calendar, but is able to shift events to and obtain events from the medium-term calendar. The scheduling process allows for modifications to the long-term commitments on a one-off basis, e.g. a late arrival for work. It also gives the physiological and emotional needs their concrete formulation as activities.

The little empirical work conducted so far has looked at the concrete choices involved in managing the daily calendar, at the amount of scheduling and rescheduling undertaken by travellers and at the long-term flow of activities. Ettema (see Ettema, Borgers and Timmermans, 1993) used a computer-based game to observe how students planned a day for a given set of well defined activities. He then estimated choice-models to analyse the trade-offs made by his respondents during the process.

Doherty (see Doherty and Axhausen, 1998) used a computer-based seven-day diary approach to observe, when respondents plan a particular well defined activity, how often they change attributes of planned activities and how many get dropped. His results, obtained from a small sample of households drawn from a university environment, show a substantial amount of each of these steps and highlight the amount of time people leave unscheduled until relatively late. His approach has been adopted elsewhere and further studies using survey instruments refining Doherty’s original tool are planned for or are in the field in Germany, California and Toronto.

Travel diary work is, in the main, based on one-day cross-sections. While multiple-day and one-week diaries have become more common in recent years, they do not really allow the analyst to observe how the scheduling process works over longer periods. The 1971 five-week Uppsala survey analysed by Hanson and her collaborator was never studied from this point of view (see for example Hanson and Hanson, 1981 or Hanson and Huff, 1982, 1986 and 1988). A new German study, the six week Mobidrive-diary survey undertaken in Halle and Karlsruhe opens up this opportunity (see Schönfelder and Axhausen, 2000; Schlich, König and Axhausen, 2000 or Axhausen, Zimmermann, Schönfelder, Rindsfüser and Haupt, 2000). This data, and hopefully data from other exercises based on either diaries or passive tracking technologies, such as GPS or modified GSM-mobiles, allow the estimation of models of activity generation, which account for both the household interactions, the temporal dependencies and the competition between activity types.

While Gärling et al., 1998 demonstrates the concepts of activity scheduling, only the simulation system ALBATROSS (Arentze and Timmermans, 2000) can currently be considered as fully
operational and ready to tackle questions at a practical scale. ALBATROSS was developed for the Dutch Ministry of Public Works and is currently being used for various policy tests. It is based on the idea of activity scheduling and implements the various choices using rule-based systems, which include learning. As a micro-simulation it is in the wider tradition of such models in transport (see for example Axhausen and Herz, 1985; Axhausen, or Pendyala et al., 1995 or Ruppert, 1998). Based on the strong interest in the micro-simulation of flows and route choice, exemplified by the systems TRANSIMS, DYNASMART or ADVANCE (Esser and Nagel, 2000; Mahmassani, 1997; Hawas, 1997; Fellendorf and Vortisch, 2000) a merger of these two streams of work is currently ongoing.

The next generation of research tools will integrate models of day-by-day activity generation, of daily activity scheduling with models of activity execution and of traffic flow and route choice. They will also incorporate day-to-day learning to generate the paths of systems through time. The practical tools will integrate models of activity chain execution within detailed micro-simulations of flow and route choice, such as TRANSIMS, DYNASMART or ADVANCE (See Axhausen, 1990 for an early example or Mahmassani and Abdelghany, 2000 for a current partial implementation). Both types of systems will be built on artificial sample generators, as long implemented in the Dutch National Model (Gunn, 1994) or in systems, such as TRANSIMS.

These developments will depend on suitable data collection on the scheduling process itself and its outcomes over time, but they will also depend on work on spatial learning – an area, which has been neglected in transport, but also environmental psychology and geography, which have been interested in the learning of topologies, but not in the learning of the performance of networks.

The scheduling models, as all simulation models, will have to be integrated in appropriate user environments, which help the analyst in the application of the tools by specifying the required experimental designs, by collating the relevant measures-of-effectiveness from the outputs and by estimating correct summary statistics and response models from the simulation runs.

The parallel development of dynamic equilibrium models of travel demand and assignment and of comprehensive path-dependent scheduling models should be seen a chance for collaboration and not as a choice of either/or. While equilibrium models will be the preferred tools for social cost-benefit project evaluation for the medium term, scheduling models will allow analysts to explore the development paths of systems and to incorporate a behaviourally richer description of human behaviour.
6 POSSIBLE CONTRIBUTIONS

The brief discussions above have suggested the priority areas for the work within the activity-based approach. They have also identified the main contributions, which this work will make to the general practice. In the short to medium term (3-5 years):

- Improved data on travel behaviour: better definitions, more insight into the trade-offs between in-home and out-of-home activities and between physical and remote presence, longer reporting periods
- Improved models of activity generation accounting for within-in household and within-person correlations over time
- Choice models, which properly account for habits across days and temporal and social dependencies and constraints within the day
- Clarification of the long-term optimised parts of activity performance and those optimised under the constraints of the current schedule (Doherty’s impulsive category)
- Improved understandings of the evaluations people put on time, reliability and safety due to a clearer division between the different temporal horizons of decision making (see last two points)
- Operational combined activity chain execution – route choice – traffic flow models accounting for within-day dependencies and demand management via information and pricing. It is likely that the current choice-based activity chain models will be integrated into this class of models systems.

In the longer term:

- Operational activity scheduling models accounting for spatial learning and the across time processes of activity generation and competition.

The model development mentioned in the last two points is predicated on the increasing availability of high quality geo-coded data (network, locations, land usage) from non-transport uses, such as logistics, environmental assessment, taxation, land use planning and property development.

The bottlenecks for these developments are intertwined: a) the willingness of the research councils and planning agencies to invest into data of suitable quality to support the model development; b) the dissemination of the research results to the practitioners and their professional development and c) the necessary time for the practitioners to become familiar with the approaches and models. Depending on the direction of the dynamics both a virtuous circle of progress or a vicious circle of stagnation is a possibility for the future.
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9 See Footnote 2 above.