Activities and travel behaviour

Modelling and data issues

Author(s):
Ettema, Dick; Axhausen, Kay W.; Polak, John

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Dick Ettema, Urban Planning Group, Eindhoven University of Technology
P.O. Box 513, 5600 MB Eindhoven, The Netherlands
Tel.: +31 40 47 29 33
Fax.: +31 40 45 24 32
E-mail : D.F.Ettema@bwk.tue.nl

Kay Axhausen, Institut für Straßenbau und Verkehrsplanung, Leopold-Franzens-Universität, Technikerstr. 13, A - 6020 Innsbruck, Austria
Tel.: +43 512 507 6902
Fax.: +43 512 507 2906
E-mail: k.w.axhausen@uibk.ac.at

John Polak, Centre for Transport Studies, Imperial College
London SW7 2BU
United Kingdom
E-mail: j.polak@ic.ac.uk

ABSTRACT

The activity based approach emphasises the importance of recognising that the demand stems from the more fundamental demand of individuals to participate in spatially and temporally distinct activities. Therefore, in order to gain insight in how people decide about their travel behaviour, one should focus on the total activity pattern and the interrelationships that exist between different activities and their associated travel behaviour. Model development in the context of this approach has generally taken place with the aim of evaluating policy measures of various kinds that give rise to complex responses at the level of the household activity pattern. However, such policy measures differ widely with respect to the type of behavioural response they aim at, their time horizon, their geographical scope and the durability of their effect. Consequently, models that are developed for evaluation purposes describe different behavioural mechanisms and adopt different model structures, that can vary from utility maximisation choice models to production systems and neural networks. Another main difference between the models is the point in time at which decisions are assumed to be made (before or during the execution of an activity pattern). These differences have a major impact on the data required to calibrate such models.

This paper makes an inventory of a number of modelling approaches in activity based research with respect to the behavioural response they describe, the policy measures they can possibly evaluate and their data requirements. The following categories of models are considered:

- Trip chaining/activity chaining models, describing the choice of the next activity/destination in an activity chain.
- Activity scheduling models describing the choice or planning of a complete activity pattern.
- Models describing adaptations to a planned activity schedule while it is executed.
- Dynamic models describing adaptations to existing activity patterns in response to policy measures.

Based on the review of modelling approaches, data requirements that stem from different modelling exercises and theoretical frameworks will be addressed. Existing data collection techniques will be reviewed in order to determine to what extent they meet the data requirements of the different modelling approaches. Based on the outcome recommendations will be given for the developments of new data collection procedures that might enable calibration of more advanced models of activity pattern generation.

1. INTRODUCTION

Transportation policy in most EC countries is strongly interwoven with other policy areas such as economic, financial, social and environmental policy. Consequently, policy objectives within the field of transportation differ widely in nature. From an economic point of view transportation and communication infrastructure should provide advantageous conditions for economic development by facilitating unconstrained and cheap exchange of persons, information and goods. From a financial perspective, transportation can be regarded as a source of revenue in the form of taxes and tolls, while on the other hand maintenance of infrastructure and supply of public transport will make a demand on state finances. Another objective of transportation policy, which has gained increasing interest in the past decade is sustainability. In order to deal with the problems caused by increased car traffic and to ensure the quality of life in urban areas transportation policy should strive for regulating mobility such that environmental damage is minimized. Finally, transportation policy has social implications. As transportation provides people with the opportunity to participate in activities from which they derive personal satisfaction, the accessibility of private and public transport to socially and spatially diverse groups is an issue of concern if equity is pursued.

It should be noted that, due to societal trends such as individualisation and task combining, technological developments and economic growth, activity and travel patterns have become more complex over the past years. To regulate travel and avoid undesired side effects of mobility, new policy measures have been proposed or introduced. Telematics, information systems and pricing mechanisms play a key role in this respect.

However, from the diversity of policy objectives it is understandable that policy measures will seldom be in accordance with all objectives. For instance, an unrestrained expansion of the road network may to some extent increase personal mobility, but may at the same time lead to undesired side effects as far as sustainability is concerned. Conflicts between environmental and financial goals may occur if providing ecologically sound ways of transportation lay heavy claims on state expenditures. Furthermore, social and financial policy may conflict if the question is whether or not to maintain loss making public transport lines, which are however vital for the lifestyle of certain demographic groups. Finally, it should be noted that the effects of policy measures may contradictory if for different geographical areas and different time horizons. For instance, improved infrastructure may cause a shift in economic development from one region to another. In a similar vein, measures that improve mobility in the short term may lead to a decrease in accessibility in the long run as a result of congestion.

Given the diversity of policy objectives the question can be raised how policy measures should be evaluated with respect to their effectiveness and feasibility. Certainly, effects with respect to different policy objectives should be assessed objectively. The question which objective should then prevail can be answered according to the subjective preferences of policy makers. Consequently, if model studies are used for the assessment of policy measures, the outcomes should reflect economic, financial, social and environmental consequences. In this paper we propose the activity based approach in transportation modelling as a promising starting point for development of an integral evaluation tool. Activity based models typically describe which activities people pursue, at what locations, at what times, given the locations of home, work, shops and facilities and given the state of the transportation network. The outcomes of model predictions can therefore be used to assess various effects of policy measures. Activity participation can be regarded a representative of social implications of transportation. As the models also predict trips by mode and time of day, information is also gained about car mobility and the associated congestion and pollution in time and space. Furthermore, if passenger flows by public transport are predicted, revenues of passenger fees can be assessed. Thus, also environmental and financial impacts can be predicted. Finally, activity based models predict performance of economic activities (consumer behaviour) and the most likely locations, so that information on economic development in retailing and recreation is also obtained. Consequently, activity based models can be used for describing complex travel behaviour in response to various policy measures and offer possibilities for policy evaluation with respect to different policy objectives.

A crucial conditional for meaningful application of activity based models, however, is the availability of sufficient data, describing both the behaviour and the spatio-temporal conditions on a detailed level. The exact data required will depend on the kind of policy measure to be evaluated. Therefore, we plead for an integrated approach of model development, data collection and policy evaluation.

This paper makes an inventory of different types of activity based models with respect to the policy measures they can possibly evaluate and their data requirements. Activity based are defined as models that describe the choice, duration, timing or sequencing of activities. The models are classified according to the behavioural principles they describe and the point in time at which decision making is modelled. Within classes, models vary strongly with respect to the model structure. For detailed information on the applied modelling techniques the reader is referred to the publications on the various models. The emphasis in this paper however, is on similarities with respect to behavioural issues and data requirements.

The following classes of models are distinguished and described in subsequent sections:

- Trip chaining/activity chaining models, describing the choice of the next activity/destination in an activity chain.
- Choice models describing the choice or planning of a complete activity pattern before it is executed.
- Models describing adaptations to a planned activity schedule while it is executed.
- Dynamic models describing adaptations to existing activity patterns in response to policy measures.

Section six addresses data requirements stemming from the different modelling approaches and conceptual frameworks. A number of data collection techniques is reviewed with respect to their feasibility to collect the data needed for different modelling approaches. In section seven, finally, conclusions are drawn with respect to the capabilities of the model to forecast the consequences of policy measures of different kinds and their data requirements. Furthermore, recommendations for future development of models and data collection procedures will be given.

2. TRIP CHAINING/ACTIVITY CHAINING MODELS

Trip chaining/activity chaining models typically describe the consecutive choice of activities/trips in an activity chain. The model structure is such that principally the consecutive choices are made independently. Axhausen (1990) presents the so called German approach, in which activity choice, destination choice, route choice and mode choice are modelled independently, i.e. no influence of possible latter choices on previous choices is assumed. The model is not calibrated as such, but composed from existing calibrated models for the separate choices. Consequently, no data requirements stem from this approach, that can be used to simulate activity chains based on existing activity programmes. However, the effect of changes in scheduling constraints cannot be assessed by these models.

The approaches taken by Van der Hoorn (1983) and Kitamura and Kermanshah (1983, 1984) depict trip chaining as a repeated activity/destination choice. This choice is modeled by a nested logit model, where destination choice is nested under the activity choice. No influence is however assumed of later activity choices on the present activity choice. Explanatory variables include socio-demographics, time of day, travel times, the history of the activity pattern and characteristics of the destination. Van der Hoorn's (1983) model also incorporates time budgets for different activity classes.

Trip chaining models with prospective elements incorporated in the model structure are presented by Arentze, Borgers and Timmermans (1993), Kitamura (1984) and Timmermans and Van der Waerden (1992). In these models, the choice of the next activity/destination is affected by possibilities to perform other activities afterwards. E.g., preferably destinations are chosen such that travel times to following destinations are minimized. Kitamura (1984) and Arentze, Borgers and Timmermans (1993) used a recursive model structure for this purpose. Timmermans and Van der Waerden (1992) used a nested logit approach for the choice of two subsequent activities.

With exception of the Arentze, Borgers and Timmermans (1993) and Timmermans and Van der Waerden (1992) models, most trip chaining models are estimated based on activity diary data, in which activity and trip chains are recorded. From activity diaries attributes such as time of day and history of the present and previous activity chains can easily be derived. Furthermore, background variables such as time budgets for different activities can be derived.

The main problem however with activity diary data is how travel times are determined. Kitamura and Kermanshah (1984) and Kitamura (1984) used a division of the study area into zones to calculate travel times to alternative destinations. This approach however leads to an important loss of information if trips within zones are considered. Moreover, only a study area of a limited size can be treated in this way. Yet another approach was taken by Van der Hoorn (1983) who used average travel times within socio-demographic groups for different activity types as an approximation. This however seems to be a very bold simplification. Principally, the problem with data collection for trip chaining models is that at any stage a large number, spatially dispersed alternatives are available, on which data is hard to collect.

An approach which is different in nature was taken by Timmermans and Van der Waerden (1992) who used an experimental stated preference approach to control for explanatory variables such as selection of goods, parking facilities and travel times. This study however is confined to only two links in a shopping trip chain.

With respect to policy evaluation, trip chaining models could be applied for various purposes. First the effect of locational decisions on trip chains can be assessed. For instance, offering shopping facilities on attractive locations may cause inclusion of shopping in the trip from work to home, which will have an effect on the timing and size of traffic flows. Similarly, as travel time is one of the main explanatory variables in trip chaining models, the effect of changes in the transportation networks can be evaluated. These can include short term changes (e.g. congestion, roadblocks) or more permanent changes (e.g. construction of new roads, offering new public transport connections). If travel time is regarded as an subjective individual perception, the models can principally assess the effect of information systems by replacing the original travel time by adjusted travel times that can given by an information system. In this way the effect of real time information can be simulated.

The major lack of trip chaining models however is the absence of temporal constraints as explanatory variables. This prohibits evaluation of temporal policy measures such as changing the opening hours of shops, work schedules and school hours.

3. Activity Scheduling Models

Models of this class describe how a schedule for a certain period of time is made. This schedule typically entails activities to be performed, locations of activities, activity durations, start and end times of activities, sequence of activities and mode choice. The modelling techniques differ widely, ranging from utility based approaches (Adler and Ben-Akiva, 1979; Recker, McNally and Root, 1986a, 1986b) to production system models (Hayes-Roth and Hayes-Roth, 1979).

With respect to the way in which data is collected, two approaches have been followed. One is constrained to gathering data on performed activity schedules and their attributes only (Adler and Ben-Akiva, 1979; Recker, McNally and Root, 1986; Golledge, Kwan and Gärling, 1992). This approach thus assumes that the planned schedule will be performed without adaptations, which is in many instances a bold assumption. Activity diaries are typically used to collect data on revealed patterns. However, the identification of alternatives is problematic as the number of alternative patterns is usually huge, due to combinatorial explosion. Adler and Ben-Akiva (1979) constructed choice sets consisting of patterns that were recorded for individuals with similar socio-demographic characteristics. Recker, McNally and Root (1986a, 1986b) used classification techniques to narrow down the set of all feasible patterns to a set of limited size. Moreover, spatio-temporal data such as opening hours and travel times are also required. Temporal constraints are mostly obtained from activity programs which are derived from the revealed pattern for each individual or from institutional regulations such as opening hours of shops. Travel times are usually derived from a coded road network of the study area. A GIS can be very helpful in this respect to calculate travel times on the road network, applying some shortest path algorithm. A GIS can also be used to select the locations most likely to visit by a buffer function.

It can be argued that the activity scheduling process is a very complex process entailing decisions of various kinds on various levels and the use of heuristic suboptimal decision mechanisms. It is questionable whether a model describing such a complex process can be tested only by comparing model outputs and revealed patterns. Another approach (e.g. Hayes-Roth and Hayes-Roth, 1979; Ettema, Borgers and Timmermans, 1993a) aims at tracing the activity scheduling process to find out what trade offs are made and what decision rules are applied. Consequently, the scheduling process is the subject of study rather then revealed activity patterns. Hayes-Roth and Hayes-Roth (1979) used a think aloud protocol to calibrate a production system model of activity scheduling. IF...THEN... rules were derived from a verbal description given by a subject who reported all considerations and decisions made while planning a number of errands in a fictitious environment. Ettema, Borgers and Timmermans (1993b) used an interactive computer procedure (MAGIC) in which subjects constructed an activity schedule for the day after the interview by performing a limited number of predefined operation on a working schedule. All operations applied are recorded. The operations correspond to the model structure, so that activity scheduling can be readily modeled as a sequential choice process. Gärling (1993a, 1993b, 1993c) conducted a series of laboratory experiments in which subjects were requested to perform an errand planning task consisting of 2 or 3 shopping trips in a simplified, fictitious environment. Spatio-temporal characteristics were varied systematically to investigate the effects of time pressure, distance and waiting time in different scheduling stages. For the evaluation of policy measures, the question can be raised whether data collected in simplified laboratory conditions relates to real world behaviour in a straightforward way. However, it may be principally impossible to collect equivalent data on activity scheduling in real life settings. A related question if travel behaviour is to be predicted is how planned schedules relate to performed schedules.

As the input of most activity scheduling models encompasses activity programmes, perceived travel times, possible locations, travel times and temporal constraints a large range of policy measures could possibly be assessed. First, the effects of location policies can be evaluated. For instance, the effect of concentrating employment in town centres or moving employment out of town on mobility on mobility and congestions levels could be simulated. Another example would be to test whether certain socio-demographic groups can still execute their habitual activity patterns if facilities are removed or transit services become less frequent. Also the effects of technological developments, such as telecommuting, which relax the spatial fixity of activities, could be evaluated with activity scheduling models.

The models could also be used to evaluate the effect of temporal policy measures. As opening hours of stores, banks and governmental offices, work hours and school hours are input to the model, the effect of changes in the time schedules on activity and travel patterns can be assessed. A related issue in this respect are the spatio-temporal constraints stemming from public transport time tables.

A third major factor influencing activity patterns is the transportation system. Activity scheduling models are able to simulate the effects of changes in travel times and accessibility caused by the construction of new infrastructure, increased congestion or improvements in public transport. In a similar vein, the travel times that are input to the model can be interpreted as subjective perceptions of real travel times. Therefore, the effect of information systems such as ATIS and IVHS, affecting perceived travel times can be evaluated as well. E.g., if an individual would be informed that congestion on a planned route might cause considerable delay, this might lead to a rescheduling of the activity pattern. The estimated travel time on the congested route can then be used as input for the model which predicts the new activity pattern. Consequently, adaptive behaviour is an emerging issue that can be addressed by activity scheduling models.

4. Models of the Execution of Planned Schedules

Models of this type typically describe how a schedule which is made up for some period is executed and how adaptations to the schedule are made during execution. Schedules vary from simple (departure time choice, destination choice) to complex (a full activity schedule for a day). Diversion from the planned schedule thus is the main behavioural variable addressed by these models.

Poisson models of the number of route and departure time diversions for the commute trip are described by Hatcher and Mahmassani (1992), Mannering (1989) and Mannering and Hamed (1990). The schedule from which people divert is in this case the usual timing and route of the daily commute trip. These models describe the number of route or departure time diversions per month. Explanatory variables in the route diversion model are socio-demographics, travel time of the commute trip and characteristics of the alternative route and number of stops in the usual trip. Explanatory variables in the departure time switching model are flexibility of work hours, work end time, trip chaining behaviour, variation in travel times and socio-demographics.

The above models can for instance provide insight in the effect of changed work hours on congestion levels at different routes during peak hours. Also the effect of congestion, affecting travel times on different routes, and information provided to travellers about these issues can be assessed. Changes in the transportation network can be evaluated in similar vein. The data needed for the estimation of poisson switching models can be obtained by surveys in which subjects indicate their usual commute travel pattern, the number of switches per month and the length of delay along with other explanatory variables. Another option is to derive the number of switches and length of delay from trip/activity diaries which are kept for a longer period.

A different approach was taken by Khattak, Koppelman and Schofer (1992) and Abdel-Aty, Kitamura and Jovanis (1995) who used stated preference data to calibrate a model of departure time and mode diversion. Explanatory variables in their models were whether or not a freeway was used, ATIS pre trip information about length of delay, type of congestion, age, travel time, commute distance, familiarity with the route and habitual travel patterns. These models can principally be used to assess the same factors as the poisson models. However, the response in a specific case is modelled, so that these models are more useful for simulation purposes. E.g., it is more interesting to know whether or not a commuter will divert in a particular situation than it is to know the number of diversions per month.

Another class of models describing diversions of planned schedules are route choice models. These models describe how diversions from a planned route take place if during the trip new situations with respect to congestion levels and travel times are experienced. En route information is an important factor in this respect. Laboratory experiments using interactive computer experiments were performed by Adler, Recker and McNally (1992, 1993) and Vaughn et al. (1993). In these experiments subjects plan a route in an artificial road network. The planned trip is then simulated, during which subjects acquire information about congestion levels and travel times on alternative routes. Traffic flows and possibly congestion and the occurrence of incidents are also simulated. In response to this information subjects can decide to divert from the planned route. During the simulation, all actions taken by the subject (information acquisition, lane switches, left and right turns) are recorded. Models can then be estimated for the decision whether or not to divert at each decision point or for the sequential route choices over a number of trips. The models can be used to evaluate the effect of information provision in the pre trip planning phase and during the trip on route choice. More specifically, route changes and departure time changes resulting from information provision can be predicted. Consequently it can be assessed whether information technologies such as IVHS and ATIS can help to avoid congestion problems and increase the traffic flow capacity of the road network, if real time dynamic assignment methods are used.

A more complex approach which has been advocated by Axhausen, Jones and Polak (1991) addresses the execution of a full activity schedule. It is assumed that the activity schedule that is planned before travelling is subject to continuous rescheduling, due to changes in travel conditions and changed behavioural intentions, so that he realised schedule may look very different from the planned schedule. This distinction has been noted also by Root and Recker (1983), Axhausen and Gärling (1992) and Ettema, Borgers and Timmermans (1993a). Models that describe this continuing rescheduling are not readily available, although some existing models (Ettema, Borgers and Timmermans, 1993a; Gärling et al., 1993) could principally be used for this purpose. A model of execution and rescheduling of activity schedules could be very helpful in assessing the effect of information on the rescheduling of activities and trips. The effect of information could be easily modelled by manipulating the input variables regarding travel time and reliability of the model. In a similar vein, structural changes in the transportation system which influence travel times and congestion levels could be implemented. Data requirements of such an approach are however problematic. Principally, at each decision point perceptions of travel conditions such as travel times, probabilities of delay and available time windows for activities should be known. Also changes in attributes of activities should be recorded (e.g. changes in priorities or expected durations). Furthermore, the subject should mention revisions to the activity schedule due to the new conditions. Clearly, to collect these data without interfering with the behaviour itself is a cumbersome issue. Probably time sampling techniques could be used to record activity patterns and plans during the observation period. Another option is to record data in interactive simulations of execution of schedules that were planned before. Development of operational models and data collection techniques however seems to lay way ahead.

5. Dynamic Travel Choice Models

Dynamic travel models are particularly suitable to describe repetitive behaviour, such as daily commuting trip making. It can then for instance be assumed that a decision that is made at some point in time, is influenced by the outcome of previous choices as well as the expectations for future decisions. Dynamic models capture such dependencies in the model structure, e.g. by allowing for correlations in the error terms or by using lagged variables.

Mahmassani (1990) describes a dynamic model of commuters' travel time and route switching behaviour. The explanatory variables in the model are the number of available routes and the amount of information that is provided to subjects about their previous behaviour and the behaviour of the transportation system. In a later study by Hu and Mahmassani (1995), both exogenous information, provided by traffic control centres and endogenous information from personal experience are explicitly modelled. Furthermore, driver characteristics are included as explanatory variables in the model. The behaviour of the system is modelled by aggregating individual departure time and route choices. The above factors were found to influence the time it takes before the system converges and the performance level at which convergence takes place. Also the turbulence of the system is affected by the way information is presented. Dynamic models can be used to assess the effect of providing feedback information about the system performance and individual behaviour to travellers on the network. For instance, different ways of providing information by IVHS and ATIS can be evaluated to determine the accuracy level and amount of information provided to travellers such that congestion is minimised and reliability of the system is optimised. The data used for the studies was derived from different sources. First experimental laboratory data was used, in which subjects' choices were input to a assignment procedure, the output of which was presented as information to subjects which could influence their later choices. On the other hand, dynamic route and departure time choice was recorded by a longitudinal panel data approach.

Van Berkum and Van der Mede (1994) used a real life longitudinal panel study to obtain data for estimation of a dynamic route choice model. More specifically, the study consisted of one wave before and three waves after the introduction of the installation of a variable message sign. Explanatory variables in their model of adaptation of route choice are habit strength and stability, expected travel time, expected standard deviation of travel time, expected queue length and learning capacity. The model was developed to evaluate the effects of pre trip ATIS information on consecutive route choices. By aggregating the individual choices, the effect of the contents of the information on congestion and travel times can be estimated. However, the model could also be used to assess the effect of structural changes in the transportation system affecting travel time and deviation in travel time. A limitation of the model lies in the fact that route diversion is the only way to respond on information about system performance. Departure time shifts, which may severely affect congestion effects and reliability are not included in the model.

A more comprehensive approach was taken by Hirsch, Prashker and Ben-Akiva (1986), who developed a dynamic model of weekly activity patterns. The model distinguishes between several periods within a week. It is assumed that a full week activity pattern, that is planned before the first period, is updated in subsequent periods, based on experiences and information acquired in previous periods. Interdependencies between days of the week are explicitly modelled. Explanatory variables in the model are characteristics of the activity patterns, such as the time spent on various activities per week or day, and the timing of these activities. Also variables representing temporal constraints (no. of working days, whether a specific day is a work day, available time for shopping) and accessibility measures (time from home to C.B.D., time from home to nearest food store) are incorporated in the model. Finally, socio-economics are incorporated in the model. The model was applied to assess the effect of changes in working hours on weekly activity patterns. However, also the effect of changed opening hours of shops can be predicted. Other possible applications include the estimation the effect of changes in socio-demographics and accessibility patterns.

Another dynamic model of activity patterns, although of a very different kind, is the AMOS model (Kitamura, Lula, Pas, 1993). The model uses dynamic microsimulation techniques to describe how individuals adapt their current activity pattern to a changed situation. For this purpose neural network and production system modelling techniques are applied. Conceptually, the model is able to predict a variety of behavioural responses to a variety of policy measures. Behaviours that can be predicted are changes to activity patterns, including activity choice, mode choice, activity timing destination choice, route choice etc. Also land use developments can be modeled. Policy measures that can possibly be assessed are level-of-service and capacity of public transport, travel demand management tools, fuel efficiency requirements, taxes, quotas and growth management toward land use.

6. DATA ISSUES

6.1. The Issues

The modelling of activity scheduling relies to a large extent on travel diaries to provide it with the basic data required. Brief inspection of the current instruments shows, that they do not deliver all that is required. Further inspection shows, that even what it delivered is often problematic (Axhausen, 1994). This section will try to discuss the items, which are required from an activity scheduling perspective and the survey approaches which should be tried.

It should be emphasized that activity scheduling covers a whole range of time horizons, each having its own requirements in terms of information. Each is constantly on-going. They form together a machine of interacting wheels of different sizes. One should distinguish at least the following:

- *Within-day rescheduling*: the changes to an activity schedule while one has started its execution. Examples would be dropping or inserting activities because of unforeseen constraints (e.g. delays during travel) or opportunities (e.g. meeting an old friend on the street)
- *Daily scheduling*: the planning of a whole day's set of activities, including choices about mode, location and other participants
- *Multiday (Weekly) scheduling*: the indicative planning of the major activities, major in the sense of subjective importance, but not necessarily duration or cost.

The longer term horizons of yearly planning (e.g. holidays, visits to relatives, exam preparations etc.) or even life-planning falls outside the scope of this paper. However, seasonal effects should be acknowledged where required.

These activity scheduling time frames are set against the different time frames of resource commitments by households. Examples of these are the intervals, which a household uses to consider or reconsider items such as a monthly travel card, a season ticket for the theatre, the purchase of a car or moving house. The decisions constrain the choice of the scheduling process, but the scheduling process also constrains the decisions, especially those which require substantial amounts of time in themselves; the search for a new house is a prime example, which is born out by the seasonality of house purchasing (spring and fall, before and after the summer holidays and the Christmas break).

The interlocking of these cycles makes the design of the travel diary and of transport decision modelling so difficult. The design must match one or more of these cycles by requesting the information which is relevant for the time horizon. For example, today's weather is rather irrelevant for the purchase of a yearly season ticket, but it is crucial for today's mode choice.

6.2. Items

This subsection will first discuss some problems of today's travel diaries and will then highlight future data needs.

The lack of match between the time frames of the items included in today's diaries and of the modelling planned is a main source for problems with today's diaries. Mode choice is the best example for this. Mode choice models will relate today's mode choice to the long-term average conditions of the transport systems as reflected in the results of an equilibrium assignment and of its cost structures. Against the different scheduling horizons discussed above this seems peculiar. Today's decision is driven by the constraints of today in terms of resources and situation: Is there a car outside I can use for the whole duration of my journey ? Do I have a season ticket ? Do I have to carry heavy luggage now or later during the journey ? Does it rain or is it forecast to rain ? Is the car/bicycle roadworthy ? When do I have to be there ? None of these items are normally collected by travel diaries. Longer-term mode decision of using the car, bicycle or public transport to work or school, in contrast, is driven by consideration of average conditions, tempered probably by consideration of extreme conditions: overall household budgets, distance to public transport, availability of parking at work, need to bring children to school, car availability on average, relative speed of public transport to private transport on average etc. Again items, which are normally not collected.

A similar discussion would be possible for destination choice, but the stability of the home, school and work destination makes the argument less powerful.

Next to this mismatch of time frames in today's travel diaries, there are items, which are deeply ambiguous, such as "car ownership" and "car availability". The "car availability"-question is especially problematic, as availability is potentially a situation specific variable. It depends on how long the planned activity is going to be, where it is going to be, who else is going to travel in the car, how long the negotiations for the access will last, what returns in terms of other services are required by the person seeking access. None of these questions are asked in the current travel diary.

Still, it is clear, that even within the scope of today's travel diary there is a need to rethink the items collected and to match them to the modelling aims of the study.

The requirements of full activity scheduling models are wider then those of the traditional transport demand models. First, the time-space regime of the activity needs further detailing and second, the position of each activity in the different time frames needs to be identified.

The time-space regime of the activity can be described by the opening hours for the activity or by the time slot allocated to it by the service provider or person, who is being met. While, it should be possible to establish these times (earliest possible time of arrival and latest possible time of departure) for the currently intended location, this becomes difficult, when alternative locations are possible. Consider, for example, the case of a movie playing at different times in different cinemas, or the case of shopping, where different types of stores have different opening hours.

The personal assessment of an activity is more complex then the description of the time-space regime, as it has more dimensions. One can think of:

- *Ease of rescheduling*: Could the activity be shifted? and how easily?
- *Planning horizon*: What is the latest time the activity must be undertaken?
- *Ease of cancellation*: Could the activity be dropped all together?
- *Ease of replacement:* Could the activity be replaced by a different one? and how easily?
- *Length of commitment*: How long was the activity planned ?
- *Cost of the activity*: How expensive is the participation ? (entrance and parking fees, cost of food and drink etc.)
- *Interval since last activity*: When did the person engage in it the last time ?
- *Frequency*: How often is the activity undertaken by the respondent per week/month/year?
- *Regularity*: Is this an activity which the traveller undertakes at fixed intervals or fixed sequences of intervals ?
- *Importance of the activity:* How important is the activity for the respondent in comparison with other activities

Generally, the need to investigate the above characteristics of activities is invoked by an increasing complexity of both travel behaviour and policy measures, which often imply a rescheduling of activities within the context of the daily activity schedule. This rescheduling will be significantly influenced by the specific space-time regime of the activity and personal assessment constraints. Although, it is easy to formulate these concepts, it will be very difficult to translate these into questions, to which the respondents can give useful answers. First experiments on the length of commitment were carried out by Cullen and Godson (1975), but not repeated until recently (Ettema, Borgers and Timmermans, 1993b). Further experimental work needs to be carried out, before we can be sure, that these items could be included in standard mail-back, telephone interview questionnaires.

6.3. Survey Approaches and Technologies

The discussion above highlights the need for further and more complex travel diaries, but it is clear that such an increase in complexity will further reduce the response rates to such interviews or questionnaires. It will be necessary to split the data collection task between different instruments and to make those instruments, as simple and as reliable as possible, while maintaining the same conceptual basis in terms of definitions and categories. Four categories of surveys come to mind:

- *Intensive retrospective diaries.* In the context of a in-home/hall interview, where the respondents have committed themselves to a lengthy interview, it should be possible to reconstruct a day fully. Ettema's (1994) work is a good example. The data can be used to calibrate models that describe the execution of full one day activity patterns, such as STARCHILD (Recker, McNally and Root, 1986) and the work by Adler and Ben-Akiva (1979). Also the trip chaining and activity chaining models as described by Van der Hoorn (1983) and Kitamura and Kermanshah (1983, 1984) could be tested based on this type of data. To date a variety of methods for recording activity patterns retrospectively has been developed, varying from pen and paper interviews and computer aided telephone interviews to computer aided self interviews (Kalfs, 1995).

- *Stated preference experiments.* Stated preference experiments in the context of activity scheduling may be more or less structured. For instance, a limited number of well defined alternative patterns or travel options may be defined (e.g. Jones, Bradley, Ampt, 1989) or, on the other hand, the choice task may consist of a scenario description under which subjects have to construct their activity patterns (e.g. Hayes-Roth and Hayes-Roth, 1979; Jones, 1979). More structured experiments have been used to estimate a variety of models, such as trip chaining models (Timmermans and Van der Waerden, 1992), activity scheduling models (Hayes-Roth and Hayes-Roth, 1979), route and departure time diversion models (Khattak, Koppelman and Schofer, 1992; Abdel-Aty, Kitamura and Jovanis, 1995).

- *Extensive prospective diaries over short periods.* Well-designed modular diaries, maybe on palm-top computers, should be able to record some, but not all, details about the activities of one or two days. The experiences of the time-use research indicates that this level of willingness to answer is still there. A prospective approach is especially suitable if one is interested in the pre trip scheduling phase, which is strongly influenced by the issues mentioned in section 6.2. In fact, the approach is rather similar to a stated preference approach, with the restriction that the choice task is not hypothetical but refers to a real situation. A prospective diary approach was taken by Ettema, Borgers and Timmermans (1993b), who used an interactive computer procedure to acquire exact information on spatio-temporal and personal assessment constraints and disentangle the activity scheduling process.

- *Repetitive, extensive diaries over varying periods*. By interrogating subjects a number of times, insight can be gained in how subjects revise their previous schedules or adapt their behaviour to changed situations. The period within which subjects are revisited can range from a day (Axhausen, Jones, Polak, 1991) to a week (Hirsch, Prashker, Ben-Akiva, 1986). Reducing the level of detail, it should be possible to extend the survey period to two or three weeks. This seems to be the only way to obtain reliable data about the frequency and regularity of activities. These data will be required in the future for the dynamic modelling of travel demand.

7 CONCLUSIONS AND RECOMMENDATIONS

The increasing complexity of societal networks, individualisation and technological development have, in the past decades caused more complex travel and activity patterns. To regulate travel and avoid undesired side effects of mobility, new policy measures are proposed or have been introduced. Telematics, information systems and pricing mechanisms play a key role in this respect. At the same time the insight has grown that transport policy is strongly interwoven with other policy areas such as economic, financial, social and environmental policy. Consequently, models that are used to assess the effects of policy measures, should be able to predict economic, financial, social and environmental consequences of these measures. We consider activity based models as a promising starting point for further development of such models.

In this paper an inventory was made of activity based models, the policy measures they can evaluate and their data requirements. As activity based models we regarded all models that describe the choice and/or timing of activities and trips. It can be concluded that the various models can be used to predict the effects of location policy, temporal policy, telematics, information systems and pricing mechanisms.

Regarding the data requirements of activity based models, the conclusion is that there is a general need for more detailed and specific data, i.e. not general conditions should be input to the model but conditions that are specific for a particular trip or activity. Moreover, not only the behaviour should be observed, but also the circumstances that constrain travel behaviour and activity participation. For instance, possession of vehicles, season tickets for public transport and facilities may determine travel decisions and should therefore be collected. Also the time-space regime of an activity should be examined more carefully to gain a better insight in activity scheduling behaviour. Items of interest include ease of rescheduling, planning horizon, commitment etc. However, such data have only seldom been examined in large scale surveys.

To improve the empirical basis of travel models several categories of surveys can provide useful data. Retrospective diaries can provide data for estimation of trip chaining and some activity scheduling models. Stated preference experiments, which can be more or less structured, can provide data on behavioural responses to well defined policy measures and in hypothetical settings. Prospective diaries yield especially insight in pre trip scheduling processes and can be used to collect data on the specific space-time frame of particular activities. Repetitive diaries, finally, can be used to obtain insights in regularities and frequencies of activity performance.

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