Transportation Planning: Activity-Based Approach

The role of travel is as the means of enabling people to engage in spatially and temporally distinct activities. Activities and travel are, therefore, interlinked components in the overall pattern of daily behavior. It follows that the characteristics of a single trip such as its timing, destination, mode and route can only be fully understood in relation to the activities in which the traveller participates during the day. The "activity approach" (AA) acknowledges this insight as the starting point for its analysis. The main questions addressed by the approach are the description and modelling of the daily and weekly activity and travel patterns as a function of the socioeconomic situation of the travellers and of the characteristics of the transport system.

1. Characteristics of the Approach

1.1 Definition

The AA to transport modelling originated during the 1970s as a response to the widely perceived shortcomings of the prevailing four-stage, trip-based transport modelling framework. The AA challenged the fundamental assumptions of this framework by focusing on the role of travel as a means of enabling people to engage in spatially and temporally distinct activities. It argued that observed patterns of trip making should be seen as a consequence of an individual's desire to participate in activities and that the analysis of travel behavior should, therefore, be based on an understanding of the linked sequence of activities in which people engage during a day. This formulation was heavily influenced by the work of geographers such as Hägerstrand (1970) and Chapin (1974) and by work carried out on the use of time budgets during the 1960s (Szalai 1972).

Thus, within the AA, the basic focus is on the activity pattern, and the associated, contingent travel behavior to which it gives rise. The activity patterns of individuals are considered to be formed on the basis of their role within the household, as a result of the joint allocation and scheduling of tasks (e.g., working, shopping, child care) and resources (e.g., cars) and taking account of the short run time–space constraints of the current situation. Although time–space constraints have an important effect in the short term, over the longer term the AA acknowledges that they are open to conscious change by the household (e.g., by means of residential relocation, vehicle acquisition, etc.). Activity patterns are also influenced by the activity space of the household which is formed through the personal experiences of its members and of their information gathering exercises.

1.2 Frameworks of Analysis: Time–Space Geography

The time–space path of an individual provides the natural representation of travel behavior for the AA. The three-dimensional view (see Fig. 1) and its two-dimensional simplification were introduced by Hägerstrand (1970) and the Lund School of Time–Space Geography. Figure 2 shows examples of two-dimensional space–time paths and of the three constraints that shape them. Hägerstrand classified these constraints into three categories. Capability constraints reflect those constraints that are imposed on individuals because of the limits of their physical abilities or because of the limits of the available technology. The first group of limits is typified by the need for regular sleep and food, that create the basic rhythms of daily life. The second may be related to, for example, the maximum speed or maximum carrying capacity provided by a vehicle. The capability constraints define a time–space prism of locations and times which the traveller can reach. Coupling constraints are created by both the rules that govern the time–space accessibility of the environment and the agreements into which a person enters for the purpose of meeting with other persons. For example, a bank or post office is only open for certain times; a bus or train arrives only at certain times at certain places; and a family meets at certain times and places for a joint lunch or shopping journey. Coupling constraints bundle the time–space paths of many people in one location. Authority constraints describe the temporal and spatial authority individuals have over a specific domain, such as their own homes, their places in a cinema or their places in a queue.

1.3 Frameworks of Analysis: Activity Choice

The time–space paths do not identify the reason why individuals choose to participate in a given activity at given time and location. The economic and econometric modelling of time used in the tradition of Becker (1965) and his colleagues at the American National Bureau of Economic Research provide a utility-maximization framework for this analysis. Winston (1987) extends this activity choice framework by considering the problems of goal- and process-related utility and by including activity-duration-related effects in the formulation.

1.4 Dynamic Frameworks of Analysis

Time–space geography identifies the constraints on activity behavior; the activity choice framework identifies the choices open to the traveller; however, neither enables the interactions between the activities over time to be identified. The interactions between the plan of a traveller, the execution of this plan and the need to modify the plan in the light of unexpected changes in circumstances are captured in a dynamic framework of daily behavior (e.g., Hayes-Roth and Hayes-Roth 1979, Root and Recker 1983). The dynamic framework has been expanded to cover longer-term decision making (see Fig. 3), which feeds back to daily behavior through changes in the experience (mental maps) of travellers and through changes in the longer-term constraints (e.g., home location, work location, car ownership).

2. Describing Activity Patterns and Traveller Groups

2.1 Activity Patterns

Activity patterns are generally described in terms of a number of dimensions including: purpose, location, mode used to reach the location, sequence of activity, number of other persons participating, timing, duration and importance to name only the most relevant ones. The most frequently used descriptors are participation rates (activities/period), activity time budgets (duration/period) and the sequence of activities (e.g., home to work to shop to home). For an overview of the empirical studies see Hanson (1979), Golob and Golob (1982), Damm (1983), Kitamura (1988) and Jones *et al.* (1990). Techniques to describe the distribution of activity patterns in a population were developed by Küchler (1985) and Mazurkiewicz (1985). Advanced pattern recognition techniques have been applied to the analysis of daily and weekly activity patterns by a number of researchers including Recker *et al.* (1983), Hanson and Huff (1986) and Pas (1988). The measurement of the variability of activity behavior and its implications for understanding travel behavior have been discussed by Herz (1983), Hanson and Huff (1988) and Jones and Clarke (1988).

2.2 Traveller Groups

The work of the Lund School identified the importance of constraints on the nature of activity participation. This finding has encouraged researchers to attempt to classify persons and households on the basis of similarities in their activity patterns and constraints. Two main approaches have been used. The first takes an *a priori* classification of households or persons (e.g., based on socioeconomic criteria) and examines the similarities in the activity patterns carried out by members of each class. The second approach classifies units according to the similarities in their activity patterns and then examines how these similarities relate to underlying socioeconomic, demographic and other factors.

An example of the first approach is the study of Jones *et al.* (1983). This study showed the fundamental importance of the life-cycle status of a household on its travel behavior. Eight life-cycle stages were identified dependent on the presence or absence of children in the age categories: preschool children, young school children or older school children. Jones *et al.* derived typical patterns of time use from theoretical considerations, which they were able to verify empirically. Figure 4 compares the prototypical patterns for group B (families with preschool children) with the measured patterns for households in Banbury belonging to group B.

In Germany, a similar set of studies was performed by Kutter (1972), Holzapfel (1980) and Schmiedel (1984), which used the socioeconomic characteristics of individuals, and not the life-cycle status of the household as an *a priori* classification. Kutter and Schmiedel showed that a small number of classes is sufficient to

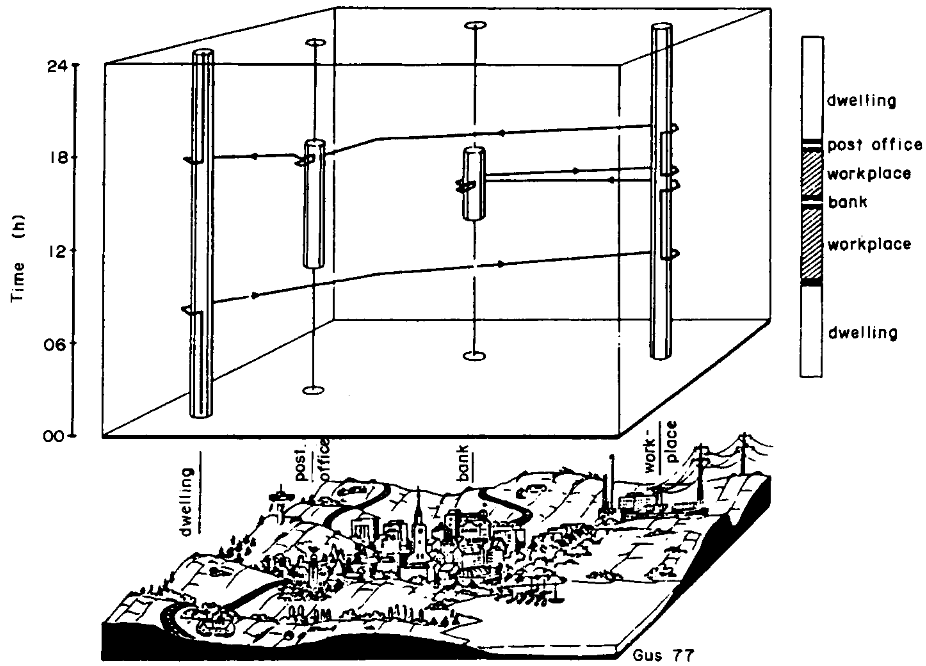

Figure 1
Three-dimensional view of a time–space path (courtesy of B. Lenntorp)

group the population into broadly similar, or homogeneous groups. The term homogeneous group does not imply that the members are homogeneous individually, but that the groups are, on average, homogeneous relative to each other.

Two American studies are examples of the second strand of research in this field. Root and Recker (1983) and Pas (1988) employ their pattern recognition techniques to classify the activity patterns of their samples. These reduced descriptions are then analyzed with clustering techniques to establish behaviorally similar groups of respondents.

3. *Household and Person Scheduling*

The AA has developed numerous approaches to predict where, when and why persons and households participate in activities. The simplest models were based on Markov chains and have been developed to incorporate the history dependency obvious in daily behavior (e.g., Marble 1964, Burnett 1978, Lerman 1979, Kitamura and Lam 1981). Choice models of activity participation during the whole day, based on simplified descriptions of location and time, were estimated (e.g., van der Hoorn 1979, Damm and Lerman 1981, Kitamura and Kermanshah 1984, Hirsh *et al.* 1986). Mentz (1984) estimated a series of sequential models of activity participation incorporating the generalized costs of the whole household. The allocation of resources and tasks within the household has been analyzed (e.g., Pas 1987, Koppelman and Townsend 1988).

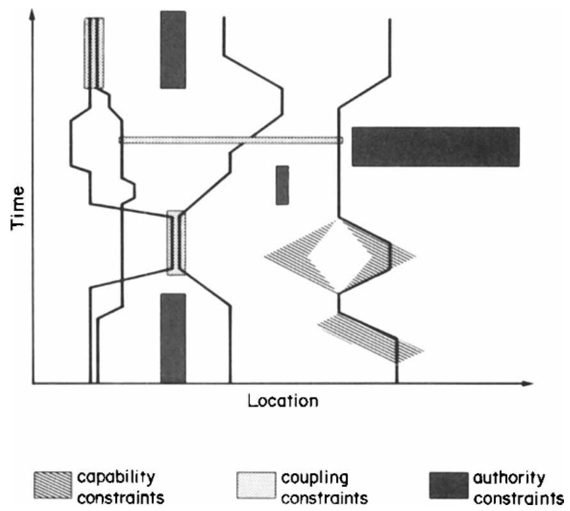

Figure 2
Two-dimensional view of the coupling, capability and authority constraints

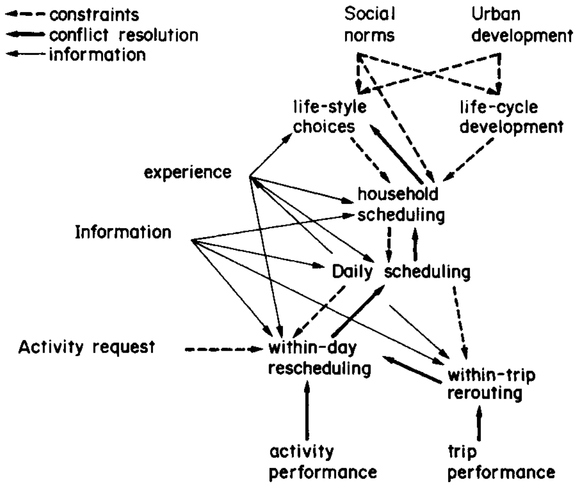

Figure 3
Dynamic framework of activity behavior (after EUROTOPP 1989)

A number of approaches to the question of scheduling have been proposed. Lenntorp's PESASP model (1978) generates all possible time–space paths for a given activity program and given time–space environment. The STARCHILD model developed by Recker *et al.* (1986) expands this approach by first generating all possible activity patterns, then classifying them and then using a choice modelling approach to select the optimal pattern. Both PESASP and STARCHILD are concerned with the synthesis of activity patterns. In contrast, Clarke's model CARLA (Jones *et al.* 1983) calculates the possible modifications to existing activity patterns given certain changes in the time–space environment, such as a change in school hours or the introduction of flexible working hours.

Gärling *et al.* (1989) propose a dynamic model of household scheduling, where the household members continuously update their plans in reaction to the mental or real execution of their plans.

4. *Using the Approach*

4.1 Improving Data Collection

The need for more accurate information about the activity participation of persons and households has led to numerous improvements in survey instruments, sampling techniques and in understanding the response biases involved in such surveys (Ampt *et al.* 1985).

Survey instruments developed to collect activity data include the household activity travel simulator (HATS) (Jones *et al.* 1983) and the situational approach (Brög and Erl 1983). The HATS interview process starts with recording the activity pattern of a person on a map and on a diary. This map and diary are the basis for observing how the interviewee's schedule is changed in reaction to a stimulus. The interviewee thinks aloud and the other household members are invited to comment and discuss. The HATS process has been transferred onto the computer (Jones *et al.* 1989) for increased accuracy of recording and for better customization of the stimuli. The situational approach is an attempt to identify the constraints in the decision making process of an individual. The constraints can be external or internal to the interviewee (physical, emotional or cognitive).

4.2 Simulating Activity Chains

German activity chain simulation models (Kutter 1984, Axhausen and Herz 1989, Zumkeller 1989) have used microsimulation techniques to develop operational models based on the AA. A particular feature of these models is that they attempt to use the implicit constraints within an activity chain in order to reduce the number of degrees of freedom within the modelling process. For example, if a car has to be used throughout a journey, no further mode choice is necessary. Models of this type have been successfully applied to urban and interurban transportation planning problems.

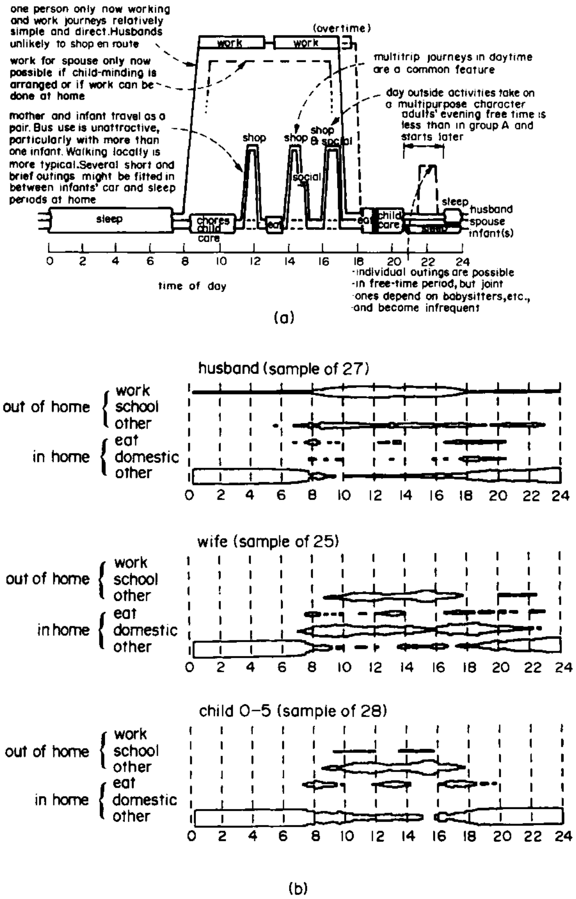

Figure 4
Comparing prototypical and empirical activity patterns: (a) group B, prototypical pattern; and (b) group B, measured activity pattern (after Jones *et al.* 1983)

5. Critique and Future Developments

The AA has been successful in four main areas. First, it has led to an increased understanding of human travel behavior and led to a greater appreciation of the true complexity of travel phenomena. Second, it has helped substantially to improve the methods and technologies for the collection of behavioral travel data. Third, it has called into question many of the underlying assumptions of conventional transport modelling that had, hitherto, been uncritically accepted. Finally, it has forced the pace of development of conventional transport modelling techniques. This has been most apparent in the addition of a large number of activity-related variables into choice modelling, in the development of models of departure-time choice for the morning commuter in the assignment process, in the introduction of dynamic frameworks and in the inclusion of journey-based models.

However, for all its success there are a number of important problems that the AA has still to address (EUROTOPP 1989).

(a) *Measurement issues.* There is still debate as to which activity and travel quantities should be measured, what techniques and protocols should be used and the relationship between measurement practice and the detection of variation and change in behavior.

(b) *Variability of behavior.* The increasing use and availability of multiday or multiperiod data requires better methods to distinguish between change in behavior and variability in behavior. Such methods are a precondition to modelling change, to establish sampling procedures and data-collection exercises.

(c) *Complexity.* A number of authors have recently warned that the AA risks being overwhelmed by the complexity of the behaviors it addresses (Mahmassani 1988, Pas 1990). These observations point to the tendency of much work in the AA to proceed inductively and not deductively from a stated hypothesis or theory. The inductive approach tends to describe and discover the complexities of human behavior, without providing general and transferable theoretical results.

(d) *Predictive ability.* The AA has not succeeded in producing a widely accepted replacement for conventional transport modelling, the German activity-chain modelling not withstanding. This failure has led to a situation where the credibility of traditional approaches is undermined without providing a credible replacement, leaving the nonacademic users of transportation planning models in a very uneasy position.

(e) *Demand–supply interactions.* The literature of the AA has mostly neglected the interactions between activity demand and supply, both in the short term on the transport networks and in the long term in the development of the urban structure and the preferences of the travellers.

(f) *Aggregation issues.* The focus of the AA on the individual or the household made it unnecessary to look at the question of how to derive aggregate results. Sample enumeration extensively used in the choice modelling area should be transferred into this area.

These points of criticism should not obscure the fact that the challenges facing transport planning require more complex and more comprehensive modelling approaches than before. The introduction of road transport informatics (RTI) weakens three central assumptions of the trip-based methodologies: the assumption of a perfectly informed driver, the assumption of an equilibrium as anything other than a theoretical construct and the assumption that it is feasible to separate trips from their journey or activity context. The multitude of interventions now possible during the trip and during the activities makes it necessary to adopt an approach that acknowledges this complexity. Models based on the concepts of the AA should be able to respond to this challenge and to provide support to the decision makers.

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K. W. Axhausen and J. W. Polak
[University of Oxford, Oxford, UK]

Transportation Planning: Microscopic Approach

Transportation plays a growing role in modern societies. The transportation system itself consists of a large number of components and has to face a number of different, sometimes opposing, goals and purposes. Therefore, a well-designed transportation system (including network, traffic management and user behavior) is crucial. The process of designing (and running) such a system cannot be carried out properly without suitable planning models and tools.

Transportation planning processes can be based on several main approaches. In recent years, the focus of attention has shifted towards activity-based and dynamic methods. To model more detailed processes, "microscopic" approaches are gaining popularity, usually implemented as microsimulation models. Since about 1970, transportation planning methodology has increasingly focused its efforts on the individual and on individual decision making.

1. General Considerations

Microscopic transportation planning models concentrate on an individual decision-making unit such as single vehicles, individual persons or households. The travel behavior of these individuals is then modelled within the approaches. Therefore, a more comprehensive definition could speak of "microanalytical models of human behavior in transportation, using *simulation* and/or mathematical tools."

Assumptions on human behavior are fundamental to models of this type. Any assumptions on travel behavior are based on rules of how people experience and memorize the transportation system, how they make, change and realize their decisions and how all their decisions interact and influence each other. It is suggested that approaches explicitly dealing with cause–effect relations at the individual level are superior to aggregate methods when dealing with changes in individual decision-making or individual travel behavior. This is due to the fact that these methods are able to:

(a) represent interactions among several individuals more closely;
(b) consider dynamic changes in behavior; and
(c) address many different points at the same time.

Thus, all approaches described in this article are characterized by the following common key features:

(a) reference and decision unit are at the level of individuals;
(b) rules determining the behavior of the individuals are explicitly incorporated into the model;
(c) conditions, restrictions and interactions influencing the behavior of the individuals are incorporated into the model; and
(d) simulation approaches are employed in order to model the behavior of many different individuals.

In Sect. 2, definitions of key expressions and important terms are given. Selected examples of this type of models are described in Sect. 3. Results and conclusions are discussed in Sect. 4.